

ДИАЛОГ ПОКОЛЕНИЙ: ИЗУЧАЕМ, ОБУЧАЕМ, УЧИМСЯ

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LEARN. TEACH. STUDY**

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THE TRANSFORMATION OF THE INSECT IMAGE IN MODERN AND CONTEMPORARY ART

Abstract. The article examines the evolution of the insect image in European and Russian art of the Modern and Contemporary periods. Using the works of Clara Peeters, Orest Kiprensky, Odilon Redon, Salvador Dalí, Ilya Kabakov, and Louise Bourgeois as examples, the author traces how the semantic significance of this image has changed over five centuries. From a symbol of mortality in 17th-century still lifes, through a romantic detail in portrait painting, an image of the subconscious in Symbolist and Surrealist graphics, a social metaphor in Conceptualism, and finally, an embodiment of maternal protection in contemporary sculpture – each period offers its own interpretation. Special attention is paid to how artists employ insects to convey philosophical, psychological, and social ideas. The article concludes that the use of this motif allows artists to address the most significant themes of their respective eras.

Keywords: insects in art, iconography, Clara Peeters, Orest Kiprensky, Odilon Redon, Salvador Dalí, Ilya Kabakov, Louise Bourgeois.

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ТРАНСФОРМАЦИЯ ОБРАЗА НАСЕКОМОГО В ИСКУССТВЕ НОВОГО И НОВЕЙШЕГО ВРЕМЕНИ

Аннотация. В статье рассматривается эволюция образа насекомого в европейском и русском искусстве Нового и Новейшего времени. На примере произведений Клары Петерс, Ореста Кипренского, Одиллона Редона, Сальвадора Дали, Ильи Кабакова и Луизы Буржуа прослеживается, как менялась смысловая нагрузка этого образа на протяжении пяти веков. От символа бренности в натюрмортах XVII века через романтическую деталь в портретной живописи, образ подсознания в графике символизма и сюрреализма к социальной метафоре в концептуализме и, наконец, к воплощению материнской защиты в современной скульптуре – каждый период предлагает собственное прочтение. Особое

внимание уделяется тому, как художники используют насекомых для передачи философских, психологических и социальных идей. Делается вывод о том, что обращение к этому мотиву позволяет художникам говорить о наиболее значимых для своей эпохи темах.

Ключевые слова: насекомые в искусстве, иконография, Клара Петерс, Орест Кипренский, Одилон Редон, Сальвадор Дали, Илья Кабаков, Луиза Буржуа.

For centuries, artists have closely observed the world around them, and their attention was sometimes drawn not only to grand subjects or formal portraits, but also to creatures we usually do not notice – or try not to notice. Flies, beetles, spiders, dragonflies – casual guests on canvases or full-fledged participants in the scene – often turn out to be the key to understanding the artist’s intention. In different eras, insects were endowed with different meanings: from a symbol of mortality to an image of the subconscious, from a lyrical detail to a social metaphor. This article attempts to trace how the significance of the insect image in Modern and Contemporary art has changed, and to identify the factors that determined the semantic content of this image at different stages of the artistic process.

Among the masters of 17th-century Flemish still life, the work of the artist Clara Peeters (1589–1658) holds a worthy place. Her works are distinguished by a high degree of realism, elegant composition, and particular meticulousness in conveying various textures [1, p. 16]. Her favorite themes were “breakfast pieces” and “set tables”.

17th-century still lifes contained deep allegorical meaning, often incomprehensible to the modern viewer. Even for professional art historians, it is not always obvious. An example is one of Clara Peeters’ early works, “Still Life with a Venetian Glass Goblet, a Cup, and a Burning Candle” (1607). For the purposes of this paper, we are interested in the fly depicted by the artist on the table.

There are two interpretations of this still life. The first refers to philosophical reflections on life and the tradition of Vanitas still lifes. The burning candle, the fly, and the gold ring were often interpreted as symbols of the transience of time and the frailty of life. The candle symbolized the passage of time, the fly – death, the ring – the uselessness of wealth after death. In this context, the glass of red wine and the sugar cross are symbols of Christ, who, according to Christian belief, shed his blood on the cross to atone for the sins of humanity. The sprig of rosemary can be seen as a symbol of eternity.

Another point of view connects this still life with a wedding. In the 17th century, gold rings with a stylized strawberry-shaped stone were often used as a gift to the bride, since strawberries symbolized fertility and marriage. Rosemary symbolized marital fidelity. The sweets on the dish are typical wedding treats, one of them in the shape of a heart. The lit candle represented the presence of the Holy Spirit sanctifying the sacrament of marriage, and finally, the two glasses symbolized husband and wife [2]. It is noteworthy that in this context, the fly no longer represents death, but rather fertility and abundance. Thus, even a single image – a fly on a table – can radically

change its meaning depending on the context of interpretation: from a grim reminder of death to a life-affirming symbol of fertility and marital happiness.

A different meaning is acquired by the dragonfly in the painting by the 19th-century Russian artist Orest Kiprensky (1782–1836). This artist went down in history as one of the first Russian masters to receive genuine European recognition: in 1820, the Florentine Academy invited him to paint a self-portrait for the famous Uffizi Gallery, which houses images of the greatest masters of art. In Russia, he became a true “favorite of the aristocracy” of the early 19th century, creating an entire gallery of images of his contemporaries. His brush also belongs to the most famous lifetime portrait of Alexander Pushkin – the very one, looking at which the poet wrote the famous lines: “I see myself as in a mirror, but this mirror flatters me” [3].

In 1826, he painted a portrait of Afanasy Shishmarev, a connoisseur of theatrical art and an amateur gardener. The portrait is elegant and somewhat theatrical. The young man posed at his estate in Novaya Derevnja near St. Petersburg, where Kiprensky spent the summer. The traditions of Russian Romanticism allowed him to depict the hero “in the bosom of nature”, where a wooden fence and daisies emphasize the “ruralness” of the landscape. The theatrically posing Shishmarev is depicted in a “Russian shirt”, as the artist himself called this attire [4]. The ornateness of the portrait’s semi-circular top, the evening sky, and the touching flowers – everything is perceived as a theatrical set for some pastoral production.

The dragonfly in the portrait, although located at the edge, invariably catches the eye. Its role in the work is to introduce a certain mood, adding an additional layer of interpretation to the image of the model. This device – introducing a detail that refers the viewer to a specific cultural context – the artist uses in a number of his other portraits (in the portrait of A. S. Pushkin, it is a statuette of a muse; in the portrait of E. S. Avdulina, it is a white hyacinth flower). The dragonfly in Shishmarev’s portrait is intended to reflect his connection with nature (in the form of his noble hobby of gardening) and theater (for an educated viewer of the Pushkin era, the dragonfly is not just an insect, but an easily recognizable image from I. A. Krylov’s fable, embodying artistry, carefree-ness, and the “theatricality” of existence).

The French artist Odilon Redon (1840–1916) turns to the theme of insects as a product of fantasies, fears, and dreams. His famous “black” works (*les noirs*) – series of graphic sheets, including “The Crying Spider” and “The Smiling Spider” (both 1881) – are built on a bizarre combination of reality and hallucination: the more precisely a detail is rendered, the more absurd the whole appears. It is characteristic that contemporaries perceived these images as a revelation about the dark sides of the human psyche. Writer Joris-Karl Huysmans, author of the famous novel “*À rebours*” (Against Nature), wrote about Redon: “These images were unlike anything else. They did not fit within the framework of fine art; they created a completely new fantastic reality – a world of fever and delirium” [5]. The artist himself explained his work differently: he believed that “we must reckon with the invisible, moving, and trembling world that surrounds us and forces us to submit to obscure and still unknown forces” [5]. Thus, Redon’s spiders become guides to this invisible world – disturbing, mysterious, but not devoid of a strange poetry.

In the painting “The Persistence of Memory” (1931) by the surrealist Salvador Dalí (1904–1989), ants appear as symbols of the subconscious, decay, and time. Salvador Dalí is a Spanish artist whose name became synonymous with Surrealism. A brilliant draftsman and painter, he created images reminiscent of nightmare visions and called them “hand-painted dream photographs” [6]. Following the Surrealist manifesto, Dalí sought to liberate the unconscious, to give visible form to the most hidden fears and desires. To this end, he developed his own method – the “paranoiac-critical” method, which, in his words, allowed him to “systematize confusion and the irrational” and turn delirium into reality [7]. Hence his famous soft watches, melting under the sun’s rays – an image that became the artist’s hallmark. In “The Persistence of Memory”, Dalí’s Surrealist method is fully revealed: the irrational coexists with the extremely credible, and the ants swarming on the watch face become a visible embodiment of anxiety, decay, and time devouring itself. It is significant that the ants have swarmed precisely the solid watch – the only mechanism in the painting that retains a rigid form [8]. The soft watches, fluid and pliable, have escaped this fate, as if the time of dreams and the subconscious is not subject to decay. Linear, real time, according to Dalí’s logic, is doomed to decompose like flesh.

The world of insects is revealed differently in the work of the non-conformist artist Ilya Kabakov (1933–2023). Kabakov was one of the founders of Moscow Conceptualism and a key figure in unofficial Soviet art. During the Soviet period, his works could not be exhibited officially, and he earned his living illustrating children’s books and magazines (“Murzilka”, “Veselye Kartinki”). This experience later paradoxically was reflected in his conceptual works: the artist constantly balanced between the “permitted” craft and free creativity, between the external simplicity of form and the depth of content.

A characteristic example is the work “The Beetle” (1982). Beneath the image of a beetle, reminiscent of a photo from the magazine “Young Naturalist”, Kabakov placed a poem taken from a children’s book he had once illustrated – a technique typical of him, combining an image with a textual commentary:

Я в траве нашел жука;	<i>I found a beetle in the grass;</i>
Черный жук, блестящий.	<i>A black beetle, shiny.</i>
Для коллекции моей	<i>For my collection</i>
Самый подходящий.	<i>It is most suitable.</i>
Вырывается мой жук,	<i>My beetle breaks free,</i>
Прыгает, стрекочет.	<i>Jumps, chirps.</i>
Он в коллекцию мою	<i>It into my collection</i>
Попадать не хочет [9].	<i>Does not want to get.</i>

It is symbolic that the “shining” beetle does not want to end up in the collection: the artist ironically makes it clear that he is defending the right to remain free from any frameworks – including those imposed by the art market, which is greedy for spectacular sensations.

In conclusion, I would like to mention Louise Bourgeois (1911–2010) – a French-American artist whose work became a bridge between Surrealism and

contemporary art. Her monumental sculpture “Maman” (1999) is perhaps the most radical reinterpretation of the insect (spider) image in the art of the 20th and 21st centuries. The nine-meter bronze spider with marble eggs in a steel sac under her abdomen is one of the most recognizable sculptures of our time. It has been installed in many cities around the world: at the Tate Modern in London, the Guggenheim Museum in Bilbao, and the Hermitage. But its significance lies not so much in its grandeur as in its message. For Bourgeois, the spider is not a symbol of horror or a product of nightmares. The spider “Maman” is an ode to the mother. Bourgeois’ mother died when Louise was 21 years old. Decades later, the artist created this monument – not a mournful one, but one full of life and protection. Art historians note the duality of this image: the spider is both protector and predator; her thin legs resemble Gothic arches, creating both a cage and a shelter [10]. The viewer experiences awe, yet finds themselves safe under the feet of the giant spider. The sculpture evokes fear and immediately disarms it.

Having traced the evolution of the insect image in Modern and Contemporary art, we see how its meaning has changed over five centuries. Clara Peeters’ fly in the 17th century is a polysemous symbol, balancing between a reminder of death and a wish for fertility. In Kiprensky’s Romantic portrait, the dragonfly becomes a lyrical detail characterizing the inner world of the hero. In Redon’s work at the turn of the 19th–20th centuries, spiders turn into products of nightmares and guides to the invisible world of the subconscious. In the 20th century, Dalí intensifies this psychologism, turning ants into an image of time devouring itself. Kabakov shifts the theme into a social realm: his beetle asserts the right to freedom from any systems and collections. And finally, at the end of the 20th and beginning of the 21st century, Louise Bourgeois offers a different interpretation: her giant spider is not so much a monster as a mother-protector, a tribute to the memory of her own mother. The history of insects in art is, in many ways, the history of ourselves: our fears, hopes, memories, and attempts to understand ourselves.

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MUSEUM INFOGRAPHICS: HISTORY AND CULTURE IN THE VISUAL REPRESENTATIONS

Abstract. The article examines the concept of museum infographics as a specific type of communication design. The focus of the research is on its potential for both permanent and temporary exhibitions. An attempt to construct a typology of museum infographics as well as the descriptions of its major formats is undertaken. Successful cases of using infographics in the design of temporary exhibitions at the Russian museums are considered. The research concludes that infographics have become essential tools for simplifying information understanding and visualization of cultural, historical, and scientific data in the museums. It also plays a key role in strengthening cultural identity and dialogue with audiences.

Keywords: infographics, museum, design, data visualization, exhibition, audience, information, communication.

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МУЗЕЙНАЯ ИНФОГРАФИКА: ВИЗУАЛИЗАЦИЯ ИСТОРИИ И КУЛЬТУРЫ

Аннотация. В статье рассматривается понятие музейной инфографики как особого вида коммуникационного дизайна. Особый акцент сделан на ее потенциальных возможностях в проектировании выставок и экспозиций. Предпринята попытка выстроить типологизацию музейной инфографики и описания ее основных форматов. В статье рассмотрены успешные примеры использования инфографики в дизайне временных выставок музеев РФ. Исследование позволяет сделать вывод, что инфографика стала важнейшим инструментом для упрощения восприятия информации, визуализации культурных, исторических и научных данных в музеях, а также играет ключевую роль в укреплении культурной идентичности и диалога с аудиторией.

Ключевые слова: инфографика, музей, дизайн, визуализация данных, выставка, аудитория, информация, коммуникация.

Graphic presentation of information in the era of visual communication is one of the dominating trends today. According to the human perception characteristics, humans perceive up to 90 % of information visually, while aurally, only 8–9 % [1]. That is why modern methods of information transfer cannot exist without its graphical presentation.

Infographics represent a system of visual tools united by the goal of conveying information or knowledge through graphic, semi-graphic, and symbolic means. According to P. Lewi, the Belgian author of the well-known essay “Speaking of Graphics. An Essay on Graphicacy in Science, Technology, and Business,” infographics “can be defined as translations of numbers in the form of a drawing, design or plan to explain or illustrate something” [2]. The term “infographics” has begun to be used relatively recently. “The concept was formed in the second half of the 20th century, combining several fields of design activities. Previously, for quantitative charts and structural schemes or graphs, the term ‘illustrative statistics’, ‘business graphics’, ‘scientific-technical graphics’ were used” [3].

In museums, infographics are a phenomenon which develops in parallel with the technologies and exhibition progress and, more importantly, alongside changing attitudes of the visitors to culture: from passive use of information to active participation and dialogue.

Today a museum is an active participator in cultural communication. Infographics serve as an effective tool for this. It provides easier understanding of artifacts, relics, historical events, and scientific concepts through visual explanations. It helps to make exhibition projects more understandable, attractive, and accessible. Infographics help to visualize complex historical, cultural, and scientific data, easing perception and stimulating audience interest.

For example, interactive maps of exhibitions allow visitors to “travel” across historical territories, and visual schemes of eras help structure knowledge about the history of art, science, and technology. Infographics enable the creation of extensive cultural narratives, linking disparate elements into a unified story. As a result, infographics become an important part of exhibition strategies, making it possible not only to present collections but also to tell stories that connect generations, cultures, and ideas.

Both Russian and foreign museums successfully adapt infographics elements in their exhibition activities. This may lead to increasing visitor attendance and more active communication with it. It raises the informational and educational value of exhibitions to an upper level, which increases interest and engagement.

A special aspect of museum infographics is its adaptation to various audience segments. Museums usually host visitors of different ages and backgrounds. Therefore, infographic materials should be universal, accessible, understandable with minimal prior preparation on one hand, and interesting to experts on the other. A museum might manage this through different levels of complexity, multi-tiered schemes, various visual codes, and symbols. And what is more important is the purpose of the message: “Infographics help you better convey your message from a sender to a recipient, enabling communication. Any communication has three components: sender, recipient, and message. The message has a goal, and the recipient needs to understand

your message and respond correctly. The format of infographics depends on the goals they want to achieve” [4].

One more important characteristic of museum infographics is its close interaction with the exhibition environment. In museum halls it connects exhibits and viewers and enables the interpretation of exhibits through visual narratives. From this point of view, infographics become a part of the exhibition design. They upgrade the visual series of exhibits, create contextual connections, and help form a holistic perception of an exhibition.

Museum infographics include schemas, diagrams, and maps, museum annotations, introductory texts, navigation, etc. They help to structure the possible typology of museum infographics based on its function and form the following groups:

- Introduction museum infographics (main texts, annotations) which provide first information about the exhibition, exhibit, or collection;
- Navigation museum infographics, represented both by elements of the museum’s navigation system (signs, informational tablets, symbolic icons) and organizational-technical documentation (museum floor plans);
- Historical museum infographics, usually presented on tablets, feature the history of the museum and the museum building as well. A wide range of data visualization techniques are used here – timelines, schemes, diagrams, graphs, etc.;
- Exhibition infographics discovers themes and motives, which curators inset at a new level. In most cases, they are integrated into the exhibition space directly.

Regarding exhibition infographics, it should be noted that this form in the museum space becomes particularly interesting. Its elements form the basis for promoting the exhibition, appearing in posters, banners, museum publics on social media, and online services. Attractively visualized infographic elements often lead to collaborations between a museum and other organizations.

For example, the extraordinary exhibition “Object Talk about Transformations” at the Yaroslavl Museum-Reserve in 2015 featured a concept where 10 selected objects told their stories by themselves. The exhibition was designed as a total infographic. The objects’ texts “entered” the exhibition, becoming a full part of a thematic group. The designer integrated the text into visual images, combining them with graphic and museum objects. Those elements were also used in posters for the exhibition and cultural activities (meetings, talks, mediations), as well as in the project social media public. It was managed by the exhibition’s author and curator, Ekaterina Zmeeva. Thanks to the engaging presentation and recognizable infographic elements, she built a comprehensive online community around the exhibition.

Another good case is the multimedia interactive exhibition “Walk the Path of Evolution” at the State Darwin Museum in Moscow. The entrance area was transformed into a timeline taking visitors back hundreds of millions of years. Opened in 2011, the exhibition is still popular among the various audience segments today. The entrance stand combines infographic elements, historical dates, texts, and original fossils from the Carboniferous period. Despite being over 15 years old, the image of this stand is the open illustrative element of the official website page about the exhibition.

In some cases, text itself can serve as a vivid, memorable visual image. An example is the specially designed installation in the first hall of the “Language of Revolution – Revolution of Language” exhibition at the Yaroslavl Museum-Reserve, opened in 2017 for the 100th anniversary of the October Revolution. Infographics are also actively used to visualize other types of information – summaries of projects, strategies, databases – presented in a logical form. Sometimes they become the main theme or hero of the exhibition. The Russian Museum of Decorative and Applied Arts in Moscow held an exhibition in 2016 titled “Infographics in Russia. From Hagiographic Icons to Postmodernism.” Its aim was to feature the history of infographics in Russia, current trends in information design, and the scientific basis for infographics as a universal meta-language.

In conclusion, infographics have become vital tools in simplifying perception, visualizing cultural, historical, and scientific data in museums, and strengthening cultural identity and dialogue with audiences.

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INFORMATIONAL EXPRESSIVENESS IN THE DESIGN OF PROFESSIONAL CLOTHING

Abstract. The article is devoted to the study of the informational expressiveness of professional clothing design as an important factor of visual communication. The purpose is to consider professional clothing as a medium of information, to identify the main means of its expression. In addition, the main means of expression (color schemes, iconic expressiveness, silhouette-volumetric shape) and their influence on the perception of professional clothing are analyzed.

Keywords: professional clothing, informational expressiveness, aesthetics, symbolism of clothing.

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ИНФОРМАЦИОННАЯ ВЫРАЗИТЕЛЬНОСТЬ В ДИЗАЙНЕ ПРОФЕССИОНАЛЬНОЙ ОДЕЖДЫ

Аннотация. Статья посвящена исследованию информационной выразительности дизайна профессиональной одежды как важного фактора визуальной коммуникации. Цель – рассмотрение профессиональной одежды как носителя информации, выявление основных средств ее выразительности. Кроме того, анализируются основные средства выразительности (цветографические решения, знаковая выразительность, силуэтно-объемная форма) и их влияние на восприятие профессиональной одежды.

Ключевые слова: профессиональная одежда, информационная выразительность, эстетика, символика одежды.

Clothing in the modern professional environment performs not only a utilitarian, but also a communicative function. Work clothes act as a carrier of information and allow you to visually convey information about a person's professional background, responsibilities, and status. Professional clothing forms the first impression of a

specialist and affects the level of trust in him. Depending on the profession, work clothes vary in the degree of aesthetic and informational impact, as well as in the level of visual accessibility (to what extent the appearance of the employee is significant in visual and social perception).

Informational expressiveness is the ability of a product to reflect in its form the cultural norms and aesthetic ideas that have developed in society [1]. Informational expressiveness determines the properties that distinguish this product from similar ones, it is characterized by such indicators as signification, originality, conformity to fashion and style [1]. The degree of informational expressiveness of clothing depends on how consistently and meaningfully the design elements are used. Insufficient expressiveness or vagueness of visual characteristics can lead to difficulties in identification and reduce the effectiveness of interaction.

It is worth noting that interest in the visual component of work clothes has increased in the process of its evolution, while remaining a utilitarian subject, it has gradually turned into an important component of professional identity, where functionality is combined with aesthetic and informational expressiveness.

The purpose is to consider professional clothing as a medium of information, to identify the main means of its expression.

Professional clothing is a system of visual signs used to convey information. Its expressiveness is formed due to a set of elements, each of which performs a specific communicative function. The main elements of informational expressiveness include: color schemes, silhouette-volumetric form, iconic expressiveness, as well as the properties of the materials used.

One of the most effective ways to convey information is through color solutions due to their quick perception. Using color, you can encode professional affiliation, functional differences, and level of responsibility. With the help of a color scheme, you can both enhance the recognition of an image and reduce it.

Symbolic expressiveness performs a significant concretizing function. These include: emblems, logos, inscriptions, designations of positions and surnames that identify the wearer of clothing.

The silhouette-volume shape of the costume significantly affects the identification of the image and enhances its overall perception. This form of workwear expressively reflects the specifics of professional activity, operational requirements for convenience, and also forms stable associations with a specific field of activity.

The materials used for sewing indicate the functional features of clothing and the level of protection, operating conditions. They also affect visual perception, creating a sense of rigor, lightness, and adaptability.

Let us consider the features of the implementation of informational expressiveness using the example of medical clothing.

Medical clothing in the USSR was characterized by a high degree of unification. The white coat was the main element that symbolized cleanliness, sterility and professional affiliation [2]. There was practically no color diversity, graphic elements were used minimally, and differences between categories of staff were poorly expressed. This unification provided an unambiguous identification of the medical worker, but at the same time did not make it possible to quickly distinguish his or her professional role.

Modern medical clothing demonstrates a more complex and individual approach to the formation of informational expressiveness. In addition to the traditional white color, other color solutions are actively used to distinguish functional areas and categories of personnel. The use of graphic elements has expanded: badges, logos and inscriptions have become an obligatory part of the professional image (Figure 1).

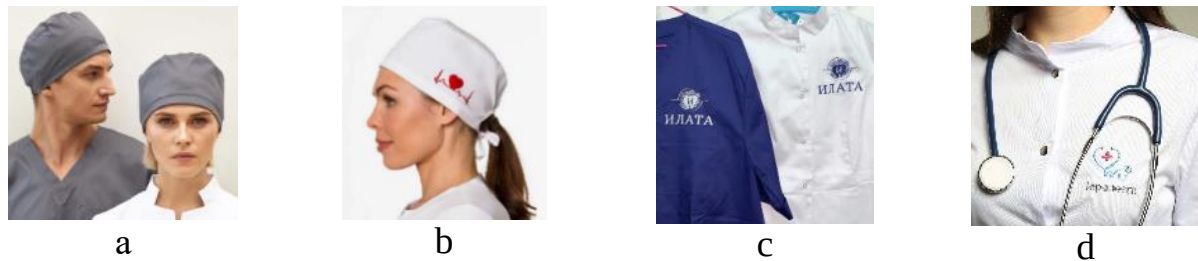


Figure 1. Visual means of identifying a profession: a, b – modern medical headdresses; c, d – examples of personalized embroidery on medical gowns

Changes in operating conditions affected the materials used and design solutions. The use of modern fabrics ensures comfort, hygiene and ease of use [2].

In the USSR, the emphasis was on standardization and depersonalization, but now there is a desire for personalization and increased visual recognition. Medical clothing is becoming more patient-oriented, its design takes into account the psychological aspect of perception, reduces anxiety and promotes trust.

The Russian Ministry of Health has provided recommendations on the colour of uniforms for medical staff, depending on their position (Figure 2) [3]. The proposed hierarchy has not yet been adopted at the legislative level and is advisory in nature.

Thus, the evolution of medical clothing reflects the transition from a strictly unified system to a more flexible and information-rich model in which the role of visual communication is enhanced. But this transition can also be seen in the design of clothing in other professions. The attitude has changed, now professional clothing is an important information carrier, and its expressiveness is determined by a system of visual and constructive elements. The most significant elements are: color, shape, graphics, and materials that convey information at different levels of perception.



Figure 2. Recommendations on the color of uniforms for medical staff, depending on their position

The modern approach to professional clothing design requires consideration of not only functional, constructive, aesthetic, but also communicative aspects. This opens up opportunities for further development of workwear design through the introduction of new technologies and materials. When designing modern professional clothing, a designer needs to take into account the identifying features of professions and use them competently in forming a visual image.

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DER EINFLUSS DER “ORGELBEWEGUNG” AUF DIE ORGELKULTUR DER UDSSR

Zusammenfassung. Der Artikel behandelt die Geschichte des Einflusses der Orgelbewegung auf die sowjetische Orgeltradition. Das Ziel des Artikels ist es, die Entwicklungswege der Orgelkultur in Russland und Deutschland aufzuzeigen sowie die Schnittpunkte zwischen ihnen zu ermitteln. Es werden die Besonderheiten der Entwicklung der Orgeltradition in beiden Ländern und ihre Wechselwirkung untersucht, die mit dem Auftreten von Orgeln in der Ästhetik des Neobarock in der UdSSR zusammenhängt. In der Arbeit wird ein historisch-vergleichender Ansatz angewendet, der es ermöglicht, die Transformation der Aufführungsprinzipien und orgelbaulichen Prinzipien im Zeitraum des 19. und 20. Jahrhunderts nachzuverfolgen.

Schlüsselwörter: die Orgel, der Orgelbau, die Orgelbewegung, das Neobarock.

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THE INFLUENCE OF THE “ORGAN REFORM MOVEMENT” ON THE ORGAN CULTURE OF THE USSR

Abstract. This article explores the history of the organ reform movement’s influence on the Soviet organ tradition. It aims to trace the development of organ culture in Russia and Germany and identify points of intersection. The article examines the evolution of organ traditions in both countries and their interactions, linked to the emergence of neo-Baroque organs in the USSR. A historical and comparative approach is employed to trace the transformation of performance and organ-building principles during the 19th and 20th centuries.

Keywords: organ, organ construction, organ reform movement, neo-baroque.

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ВЛИЯНИЕ «ОРГАННОГО ДВИЖЕНИЯ» НА ОРГАННУЮ КУЛЬТУРУ СССР

Аннотация. В статье освещается история влияния органного движения на советскую органную традицию. Целью статьи является выявление путей формирования органной культуры в России и Германии, а также определение точек их пересечения. Рассматриваются особенности развития органной традиции в обеих странах и их взаимодействие, связанное с появлением в СССР органов, выполненных в необарочной эстетике. В работе применяется историко-сравнительный подход, позволяющий проследить трансформацию исполнительских и органостроительных принципов в период XIX-XX вв.

Ключевые слова: орган, органостроение, органное движение, необарокко.

„*Kein Instrument übt einen solchen Einfluss auf die Künstler aus*“ [1], – schrieb Albert Schweitzer 1906 in seinem Artikel „*Deutsche und Französische Orgelbaukunst und Orgelkunst*“ über die Orgel. Diesen Gedanken habe ich als Epigraph für meine Arbeit gewählt, da er sich vor allem mit dem Einfluss des Instruments auf den Interpreten befasst.

Wir können die Geschichte der „Orgelbewegung“ mit dem Artikel von A. Schweitzer beginnen, da darin zum ersten Mal das Problem des Orgelbaus und der Aufführungspraxis angesprochen wird, das sich zu Beginn des 20. Jahrhunderts stellte. Technologische Fortschritte und die Erweiterung der Möglichkeiten der Orgel in der zweiten Hälfte des 19. Jahrhunderts eröffneten dem Instrument eine neue symphonische Seite. Die Orgeln der Romantik, mit ihren neuen Registern, die die Klänge verschiedener Orchesterinstrumentengruppen imitierten, und die Einführung der pneumatischen Traktur, die den Kraftaufwand beim Spielen reduzierte, eröffneten Komponisten und Interpreten neue Ausdrucksmittel. Der französische Orgelbauer Aristide Cavaillé-Coll leistete einen bedeutenden Beitrag zur Entwicklung und Modernisierung der Orgel. A. Schweitzer selbst schrieb: „Die besten Orgeln wurden etwa zwischen 1850 und 1880 erbaut, als Orgelbauer, die Künstler waren, sich die Errungenschaften der Technik zunutze machten, um das Orgelideal Silbermanns und der anderen großen Orgelbauer des 18. Jahrhunderts in höchstmöglicher Vollendung zu verwirklichen. Der bedeutendste von ihnen ist Aristide Cavaillé-Coll“ [2]. Unterschiede im technischen Aufbau und Klang zwischen barocken und romantischen Orgeln führten jedoch bald zu Schwierigkeiten bei der Aufführung des Orgelrepertoires des 17. und 18. Jahrhunderts auf Instrumenten aus A. Schweitzers Zeit. A. Schweitzer beschrieb seinen Eindruck vom Klang der neuen Stuttgarter Orgel und schrieb, dass die klangliche Wirkung des vielgelobten Instruments ihn tief enttäuscht habe. Bei der Interpretation einer Fuge von Johann Sebastian Bach habe er festgestellt, dass die polyphone Struktur völlig im Klangchaos untergehe und die Fugenstimmen nicht mehr differenzierbar seien. Dies bestärkte Schweitzer in seiner Überzeugung, dass ältere Instrumente, trotz ihrer technischen Mängel, eine größere Klangklarheit besaßen und besser für die Aufführung barocker Musik geeignet waren [2]. Ein weiteres Problem, das A. Schweitzer anmerkt, waren die erheblichen Unterschiede zwischen den nationalen Orgelbauschulen. Die Divergenz französischer

und deutscher Orgeln, die sich unter anderem in ihren verschiedenen Registern und dynamischen Techniken zeigte, veranlasste die Komponisten, nicht für die gesamte Orgel zu schreiben, sondern für ein bestimmtes Instrument, auf dem sie spielen konnten. Daher erwies sich die Aufführung von Werken, die für einen Orgeltyp geschrieben wurden, auf einem anderen oft als schwierig. Deshalb schlug A. Schweitzer die Idee einer neuen, „universellen Orgel“ vor – einer Synthese französischer und deutscher Orgeln, die die besten Eigenschaften alter und moderner Instrumente in sich vereinte – als notwendiges Ideal [1]. Das von Schweitzer angesprochene Problem fand bald die Aufmerksamkeit vieler Musiker und anderer Künstler. Der weitere Verlauf der Geschichte entsprach jedoch nicht ganz Schweitzers ursprünglicher Vision.

Im Gegensatz zu Westeuropa waren Orgeln in Russland kein weit verbreitetes Phänomen, da sie kein Bestandteil des traditionellen geistlichen Lebens waren. Das Interesse an der Orgel blieb lange Zeit eher eine private Initiative in aristokratischen Kreisen (ein Beispiel dafür ist die Hausorgel des Grafen W. F. Odojewski). Der Klang der Orgel war auch in Palästen zu hören – in Uhren integrierte Orgelmechaniken waren weit verbreitet. Die Tradition der Orgelkonzerte nahm Ende des 18. Jahrhunderts ihren Anfang. Die lutherischen und katholischen Kirchen dienten als Hauptorte für Orgelmusik.

Gleichzeitig entstand eine akademische Tradition, die mit der Eröffnung von Konservatorien in St. Petersburg (1862) und Moskau (1866) einherging, in denen Orgelklassen eingerichtet wurden. Die Orgelklasse des St. Petersburger Konservatoriums wurde von dem Musiker Heinrich Stiehl aus Lübeck geleitet, der die Stelle des Organisten an der St.-Petri-Kirche innehatte. Neben Gottesdiensten trat Stiehl auch als Organist und Dirigent in Konzerten auf. Anfangs hatte die Orgelklasse eine minimale Anzahl von Schülern, jedoch studierten bei H. Stiehl unter anderem der Musiktheoretiker und Komponist Herman Augustowitsch Laroche sowie der Komponist Pjotr Iljitsch Tschaikowski, der später den Klang der Orgel in seiner „Manfred-Sinfonie“ und der Oper „Die Jungfrau von Orléans“ verwendete. Im Jahr 1874, nachdem H. Stiehl nach Belfast und später nach Reval gegangen war, wurde Louis Homilius – ein herausragender Musiker, der am Konservatorium in der Klavierklasse von A. G. Rubinstein und in der Celloklasse von K. J. Dawydow ausgebildet worden war und auch Orgel bei H. Stiehl studiert hatte – in der Klasse zu unterrichten. Von 1870 bis 1909 war L. Homilius Organist der St.-Petri-Kirche. Die Schüler von L. Homilius traten in den 1880er und 1890er Jahren in St. Petersburg mit Programmen auf, in denen die deutsche Musik des 19. Jahrhunderts einen bedeutenden Platz einnahm. Dazu gehörten vor allem Werke von F. Mendelssohn und J. Rheinberger [3].

Von besonderem Interesse ist auch die Tätigkeit des Organisten Jacques Samuel Handschin, der 1909 nach dem Tod von L. Homilius eingeladen wurde, die Orgelklasse zu übernehmen. J. S. Handschin wurde in Moskau geboren und erhielt seinen ersten Orgelunterricht beim Organisten der reformierten Kirche, F. Brüsche. Später studierte er in München bei Max Reger und in Paris bei Charles-Marie Widor [3]. Wie auch A. Schweitzer hatte J. S. Handschin Gelegenheit, sowohl französische als auch deutsche romantische Orgeln zu spielen. Wie auch A. Schweitzer bemerkte J. S. Handschin die Schwierigkeiten, die sich für Musiker ergeben, wenn er auf einem

einzigem Orgeltyp ein stilistisch vielfältiges Repertoire aufführen müsse, wenn das Werk besondere technische Anforderungen an die Konstruktion des Instruments stellt. Im Vorwort zur Ausgabe von „Präludium und Fuge Nr.1 D-Dur“ von Alexander Konstantinowitsch Glasunow (1913) schreibt J.S. Handschin: „Für den Zustand, in dem sich die Orgel im Vergleich zu anderen Instrumenten unserer Zeit befindet, ist es ein trauriges Charakteristikum, dass Orgel-kompositionen mit zweifacher Registerbezeichnung - einer für die deutsche und einer für die französische Orgel - herausgegeben werden müssen. Wann werden wir endlich die Orgel haben, wann nicht mehr auf Schritt und Tritt durch die Verschiedenheit der Instrumente behindert werden? Offenbar erst dann, wenn die beste Orgel gefunden sein wird und man von allen Seiten bereit ist, die zur Verwirklichung des hohen Ziels nötigen Opfer zu bringen“ [4]. Dieses Konzept weist Ähnlichkeiten mit Schweitzers Vorstellung von der Notwendigkeit auf, eine neue, „universelle Orgel“ zu schaffen, die die Qualitäten verschiedener bestehender Typen vereint und gleichermaßen für die Aufführung von Musik verschiedener Stilrichtungen und Gattungen geeignet ist. Darüber hinaus wurden auf Initiative von J.S. Handschin während der Rekonstruktion der Orgel in der Klinik von Dr. Ott der romantischen Orgel Register hinzugefügt, die auf die Aufführung barocker Musik ausgerichtet waren und der aufkommenden Ästhetik der Orgelbewegung entsprachen [3].

Bei der Auswahl einer Orgel für den großen Saal des Moskauer Konservatoriums entschied sich Direktor Wassili Iljitsch Safonow für die Cavallé-Koll-Orgel, die 1901 installiert wurde. Frankreichs Organist und Komponist Charles-Marie Widor fungierte als fachkundiger Berater bei der Installation des Instruments und präsentierte die neue Orgel bei ihrer Eröffnung. C.-M. Widor lud auch russische Organisten ein, bei ihm zu studieren, um das neue Instrument und die Feinheiten der Aufführung französischer Musik zu beherrschen. Das Erscheinen der Cavallé-Coll-Orgel am Moskauer Konservatorium löste eine Welle des Interesses russischer Organisten an der französischen romantischen Ästhetik aus.

Im Jahr 1923 wurde die Orgelklasse des Moskauer Konservatoriums von Alexander Fjodorowitsch Gödicke geleitet, der einen starken Einfluss auf die Orgelkunst der Moskauer Schule hatte. A.F. Gödickes erste Ausbildung zum Orgelspieler erfolgte unter der Anleitung seines Vaters an der Orgel der französischen katholischen Kirche. Nach A.F. Gödickes Erinnerungen hatte der Klang der Kirchenorgel eine leuchtend romantische Klangfarbenpalette. Bei seiner Konzerttätigkeit war A.F. Gödicke offensichtlich bestrebt, alle Möglichkeiten der Orgel auszuschöpfen und ihren Klang dem Orchesterklang anzunähern. Eine Analyse der erhaltenen Notizen von A.F. Gödickes zeigt seine romantische Interpretation von Bachs Werken [5].

Es kann daher davon ausgegangen werden, dass die russische Orgeltradition vom Beginn ihrer Institutionalisierung – der Entstehung einer professionellen Orgelausbildung und eines systematischen Konzertlebens – bis zu einer bestimmten Zeit vom Paradigma der romantischen Kunst geprägt war.

Das zweite und dritte Jahrzehnt des 20. Jahrhunderts waren eine schwierige Zeit für die Orgelkunst in Russland. Von der antireligiösen Politik waren auch lutherische und katholische Kirchen betroffen. Viele der darin enthaltenen Orgeln wurden aufgrund mangelnder Pflege zerstört oder unbrauchbar.

In Deutschland erfuhr die Orgelbewegung dieser Zeit zunehmend Zulauf. In den 1920er Jahren fanden in Deutschland mehrere Konferenzen statt, die sich dem Thema Orgelkunst widmeten. Besonders hervorzuheben ist die Erste Organistentagung in Hamburg und Lübeck von 1925 unter der Leitung von Hans-Henny Jahn, auf der die Prinzipien des barocken Orgelbaus formuliert wurden. Die Orgeln von Silbermann und Schnitger dienten als Maßstab und Vorbild. Grundlegend wurde die Tendenz zur Rückkehr vom orchestralen Klang des Instruments zu Transparenz und polyphonischer Klarheit, die auf dem Werkprinzip beruhen. Die Ideale der Hamburg-Lübeck-Konferenz prägten den Stil in ganz Deutschland und wirkten auch über die Landesgrenzen hinaus [6]. Die nachfolgende Freiburger Konferenz von 1926 markierte einen weiteren wichtigen Wendepunkt in der Entwicklung der Orgelbewegung und verlieh ihr einen radikaleren Charakter, als Albert Schweitzer ursprünglich vorgesehen hatte. Im Mittelpunkt stand die Diskussion über die Orgel, die im selben Jahr von der Firma Walcker nach den Prinzipien von Michael Praetorius gebaut wurde. Eine wichtige Rolle spielte dabei Christhard Mahrenholz, der die Reform des Orgelbaus mit dem wiedererwachten Interesse an Liturgie und Kirchenmusik verband [7].

In der Nachkriegszeit beginnt in der UdSSR ein neuer Aufschwung der Orgelkultur, der mit der Tätigkeit der 1958 beim sowjetischen Kulturministerium eingerichteten Kommission für Orgelbau verbunden ist. Der Professor am Moskauer Konservatorium, Leonid Isaakowitsch Roizman, leistete einen großen Beitrag zur Wiederherstellung der Orgelkultur in Russland. Dank seiner Bemühungen wurde Orgelliteratur veröffentlicht, und im Großen Saal des Moskauer Konservatoriums wurden Orgelkonzerte und Vorträge abgehalten. Während der Tätigkeit der Kommission für Orgelbau wurden neue Instrumente in Konzertsälen und Bildungseinrichtungen in den Hauptstädten der Republiken und großen regionalen Zentren installiert. Dazu wurden neue Orgeln aus Ländern mit langer Orgelbautradition geliefert, die nun im Einflussbereich der UdSSR lagen, insbesondere aus der DDR und der CSSR.

Dieser bereits sozialistischen Gebiete, in denen Orgeln für die UdSSR hergestellt wurden, gerieten jedoch in den 1950er und 1960er Jahren unter den Einfluss der Ideen der Orgelbewegung. Daher entsprachen die neuen Orgeln, die in die Sowjetrepubliken gelangten, der neobarocken Ästhetik.

Hier sind einige der führenden Orgelbaufirmen und Beispiele für ihre Werke:

DDR: W. Sauer:

- Kemerowo, Russland, 1983, die Orgel der Kusbass-Philharmonie
- Tomsk, Russland, 1981, die Orgel der Tomsker Philharmonie

H. Eule:

- Tscheljabinsk, Russland, 1987, Kirche des Heiligen Alexander Newski, 2013 wurde die Orgel in den Konzertsaal "Rodina" verlegt.

A. Schuke:

- Moskau, Russland, 1959, die Orgel im Kleinen Saal des Moskauer Konservatoriums, 1976, die Orgel im Konzertsaal des Zentralen M.I. Glinka-Museums für Musikkultur
- Tiflis, Georgien, 1963, die Orgel Staatlicher Wano-Saradschischwili-Konservatorium

CSSR: **Rieger-Kloss:** Diese Firma produzierte sowohl „Universelle Orgeln“ (ein solches Instrument wurde im Tschaikowsky-Konzertsaal (Moskau, Russland, 1959) installiert) als auch neobarocke Orgeln – die Orgel der Sophienkathedrale (Polozk, Belarus, 1985).

Eine dringende Notwendigkeit für sowjetische Organisten war es, die Spieltechnik auf einem Instrument im Stil des Neobarock zu erlernen. Diese Notwendigkeit führte zu einem Interesse der sowjetischen Musiker an den Traktaten der Orgelbewegung, insbesondere an den Werken von H. Keller, der in seinen Arbeiten Fragen der Registrierung, Dynamik und Artikulation der barocken Musik behandelt (vgl. „Die Orgelwerke Bachs“). Die Studien dieser Quellen trugen zur Entwicklung einer methodologischen Grundlage bei, um Musik der Barockzeit auf neobarocken Instrumenten zu interpretieren, und förderten die Entstehung einer Orgelschule, die auf historische Aufführung ausgerichtet war. Schallplatten mit Aufnahmen authentischer Interpreten, die in die UdSSR gelangten, ermöglichten sowjetischen Musikern, sich mit der Spielweise und den Registrierlösungen vertraut zu machen, die zu dieser Zeit in Westeuropa üblich waren. Zudem wurden Musiker, die zu Gastspielen nach UdSSR kamen (darunter Ludger Lohmann und Leo Krämer), gebeten, Meisterkurse für Orgelstudenten zu geben.

Abschließend kann man sagen, dass das Interesse an authentischer Aufführung in Russland weitgehend durch die Entstehung neuer neobarocker Instrumente diktiert wurde, anstatt zu einer Tradition zurückzukehren, wie es in Europa der Fall war. Wir sehen auch, wie sehr der Organist von den Fähigkeiten und Eigenschaften seines Instruments abhängt und wie sehr die Orgel die Richtung der darstellenden Praxis bestimmt.

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METAPHER IN DER ARCHITEKTUR DER MODERNE

Zusammenfassung. Der Artikel befasst sich mit der metaphorischen Bildsprache in der Architektur der Moderne – einem Aspekt, der lange Zeit am Rande der Kunstwissenschaft stand. Am Beispiel von neun Gebäuden, die zwischen 1921 und 2010 in Russland, Europa, den USA, Brasilien und Singapur errichtet wurden, wird die Entwicklung der architektonischen Metapher von den expressionistischen Experimenten der 1920er Jahre über den Neo-Expressionismus bis hin zu zeitgenössischen Lösungen untersucht. Analysiert werden Objekte wie der Einsteinurm (Potsdam, 1921), das Chilehaus (Hamburg, 1924), der Russakow-Klub (Moskau, 1929), das TWA-Terminal (New York, 1962), das Marina Bay Sands Hotel (Singapur, 2010) und andere. Der Artikel zeigt, dass metaphorische Lösungen (Schiff, Zahnrad, Nagel, Vogel, Wal, fliegende Untertasse, Megalith) keine Abkehr von den Prinzipien des Funktionalismus darstellten, sondern eine organische Möglichkeit zur Bereicherung der modernistischen Architektur boten, die es ermöglichte, die Verbindung zur menschlichen Wahrnehmung in einer Zeit der Abkehr von traditionellen Ornamentensystemen zu bewahren.

Schlüsselwörter: Architektur der Moderne, Metapher in der Architektur, architektonisches Bild, Expressionismus, Neo-Expressionismus, sowjetische Avantgarde.

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METAPHOR IN MODERNIST ARCHITECTURE

Abstract. The article deals with metaphorical imagery in modernist architecture, an aspect that has long remained on the periphery of art history. Using nine buildings constructed between 1921 and 2010 in Russia, Europe, the USA, Brazil and Singapore as examples, the evolution of architectural metaphor from expressionist experiments of the 1920s to neo-expressionism and contemporary solutions is examined. The study analyzes such structures as the Einstein Tower (Potsdam, 1921), Chilehaus (Hamburg, 1924), Rusakov Workers' Club (Moscow, 1929), TWA Terminal (New York, 1962), Marina Bay Sands Hotel (Singapore, 2010) and others. The article demonstrates that

metaphorical solutions (ship, gear, nail, bird, whale, flying saucer, megalith) were not a departure from the principles of functionalism, but rather represented an organic means of enriching modernist architecture, allowing it to maintain a connection with human perception in an era that rejected traditional ornamental systems.

Keywords: modernist architecture, metaphor in architecture, architectural image, expressionism, neo-expressionism, Soviet avant-garde.

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МЕТАФОРА В АРХИТЕКТУРЕ МОДЕРНИЗМА

Аннотация. Статья посвящена метафорической образности в архитектуре модернизма – аспекту, долгое время остававшемуся на периферии искусствоведения. На примере девяти зданий, созданных в период с 1921 по 2010 год в России, Европе, США, Бразилии и Сингапуре, рассматривается эволюция архитектурной метафоры от экспрессионистских опытов 1920-х годов до неоэкспрессионизма и современных решений. Анализируются такие объекты, как башня Эйфштейна (Потсдам, 1921), Чилихаус (Гамбург, 1924), клуб имени Русакова (Москва, 1929), терминал TWA (Нью-Йорк, 1962), отель Marina Bay Sands (Сингапур, 2010) и другие. В статье показано, что метафорические решения (корабль, шестерня, гвоздь, птица, кит, летающая тарелка, мегалит) не были отступлением от принципов функционализма, а представляли собой органичный способ обогащения модернистской архитектуры, позволявший сохранить связь с человеческим восприятием в эпоху отказа от традиционных орнаментальных систем.

Ключевые слова: архитектура модернизма, метафора в архитектуре, архитектурный образ, экспрессионизм, неоэкспрессионизм, советский авангард.

Die Architektur der Moderne wird gemeinhin als eine rein funktionale Erscheinung wahrgenommen, die dem Prinzip "Form follows function" folgt. Auf den ersten Blick mag es scheinen, dass dies eine Kunst der geraden Linien, des Glases und des Betons ist, die auf Dekor zugunsten der Nützlichkeit verzichtet. Eine aufmerksame Betrachtung der Meisterwerke des 20. und 21. Jahrhunderts offenbart jedoch ein anderes Bild. Viele Architekten, selbst wenn sie im Rahmen der modernistischen Tradition blieben, strebten nicht nur danach zu bauen, sondern auch Metaphern zu schaffen. Sie entwarfen Gebäude, die Lebewesen, Mechanismen und antiken Bauwerken nachempfunden waren und verwandelten so städtische Landschaften in eine Sammlung stiller monumentaler Skulpturen.

Interessanterweise blieb diese bildhafte Seite der modernistischen Architektur lange Zeit am Rande der russischen Kunstwissenschaft. In diesem Zusammenhang ist der Ansatz von B. R. Wipper (1888–1967), einem der bedeutendsten russischen

Kunstwissenschaftler des 20. Jahrhunderts, aufschlussreich. In seinem grundlegenden Werk "Einführung in das historische Studium der Kunst" vertritt er konsequent die Auffassung, dass Architektur im Gegensatz zur Malerei und Bildhauerei, die mit der "Natur" verbunden sind, Ideen vermittelt und keine Bilder aus der realen Wirklichkeit reproduziert [1].

Die vorliegende Untersuchung zielt darauf ab zu zeigen, dass die metaphorische Bildhaftigkeit für die Moderne keine marginale Abweichung, sondern eine durchaus organische, wenn auch nicht immer bewusste Richtung der Suche war. Am Beispiel von neun Gebäuden, die zwischen 1921 und 2010 in Russland, Europa, den USA, Brasilien und Singapur entstanden sind, wird nachgezeichnet, wie sich die architektonische Metapher entwickelt hat, welche Bilder in verschiedenen Epochen und kulturellen Kontexten am gefragtsten waren und warum die Form in der Moderne nie nur die "blinde Dienerin" der Funktion war.

Als Ausgangspunkt dieses Phänomens kann das Schaffen des deutschen Expressionisten Erich Mendelsohn (1887–1953) angesehen werden, der als einer der Ersten begann, der Architektur organische, fast skulpturale Formen zu verleihen. Der von ihm 1921 in Potsdam errichtete **Einsteinturm**, der für ein astrophysikalisches Observatorium bestimmt war, beeindruckt bis heute durch seine Plastizität. Mendelsohn, der engen Kontakt zu den Künstlern der Gruppe "Der Blaue Reiter" hatte, schuf ein Bauwerk, in dem sich Funktionalität mit reiner Plastizität vereint [2]. Die mit Putz bedeckten Backsteinmauern bilden wellenförmige, geschwungene Konturen, wodurch das Gebäude an einen geheimnisvollen organischen Spross erinnert, der aus der Erde hervorbricht. Selbst ein Jahrhundert später wirkt diese eigentümliche Form erstaunlich modern.

Denselben expressionistischen Hang zur Metapher, jedoch im industriellen Kontext, verwirklichte Mendelsohn in der Sowjetunion, als er 1926–1928 das **Kraftwerk der Fabrik "Rotes Banner"** in Leningrad projektierte. Der Architekt konzipierte es als Dominante des gesamten Fabrikkomplexes und metaphorisierte es als Schiff, das die gesamte Produktion hinter sich herzieht [3]. Die dynamische Komposition mit dem vorkragenden, abgerundeten Volumen des Wasserturms sollte den Geist der Bewegung in die Organisation des Betriebs einbringen. Leider stieß das innovative Projekt auf den Widerstand des konservativen Umfelds der Leningrader Architekten, und so konnte Mendelsohns Entwurf letztlich nur im Kraftwerk selbst präzise umgesetzt werden.

Etwa zur gleichen Zeit entstand in Hamburg ein weiteres Schiffsgebäude, das zum Manifest des norddeutschen Expressionismus wurde. Die Rede ist vom **Chilehaus**, einem Bürozentrum, das Fritz Höger (1877–1949) 1924 errichtete. Der Bauherr, der durch den Handel mit Chile reich geworden war, gab dem Gebäude seinen Namen, aber in die Geschichte ging es aufgrund seiner Form ein. Durch eine berühmte Fotografie, die die spitze Ecke des Baus übertrieb, erhielt das Chilehaus den Spitznamen "Schiffsschnabel" [4]. Die scharfe, in die Höhe strebende Ecke erinnert tatsächlich an den Steven eines gigantischen Schiffes, das das Stadtgefüge durchschneidet. Diese Metapher wird durch die horizontalen Gliederungen der Fassaden, die an Schiffsdecks erinnern, und den dunklen Backstein, der ein Bild monumentaler Solidität erzeugt, unterstützt.

Während die europäischen Architekten in Bildern von Schiffen und Naturformen Inspiration suchten, bot die sowjetische Avantgarde Mitte der 1920er Jahre eine eigene, eng mit der industriellen Revolution verbundene Ästhetik. Ein leuchtendes Beispiel für diesen Ansatz ist der **Russakow-Klub**, den Konstantin Melnikow (1890–1974) 1929 in Moskau errichtete [5]. Das in ein enges, dreieckiges Grundstück gezwängte Gebäude wurde selbst zur Metapher für einen Mechanismus. Die drei aus dem Hauptvolumen herausragenden Beton-"Zähne" sind in Wirklichkeit die nach außen verlegten Balkone des Zuschauersaals [6]. Durch diese kühne konstruktive Lösung wird das Gebäude auf den ersten Blick als Teil eines gigantischen Zahnrads wahrgenommen, als Fragment eben jener Maschine, die die neue Industriegesellschaft erbaute.

Ein nicht weniger ausdrucksstarkes industrielles Bild schuf Jakow Tschernichow (1889–1951), den Zeitgenossen den "sowjetischen Piranesi" nannten. In seinem **Wasserturm** für das Werk "Roter Nagelschmied", der 1931 in Leningrad errichtet wurde, entspringt die Form der Funktion, wird aber gleichzeitig zu einer eigenständigen Metapher. Das schmale, vertikale Parallelepiped der Treppe trägt den Zylinder des Reservoirs, dessen Zentrum verschoben ist und sich auf zwei dünne Stützen stützt [7]. Die Silhouette wurde so ausdrucksstark, dass man in ihr unweigerlich die Umrisse eines gigantischen Nagels erkennt – eine direkte Anspielung auf die Produktion des Werks.

Nach dem Zweiten Weltkrieg ermöglichten neue Technologien, allen voran der Stahlbeton, den Architekten, bei der Schaffung komplexer, skulpturaler Formen noch weiter zu gehen. Eero Saarinen (1910–1961), einer der Hauptvertreter des Neo-Expressionismus, nutzte diese Möglichkeiten virtuos. 1958 erbaute er an der Yale-Universität die **Eishockeyarena**, die von den Studenten den Spitznamen "Yale Whale" (Yale-Wal) erhielt [8]. Der gewaltige, über die Längsachse des Gebäudes gespannte Stahlbetonbogen erinnert tatsächlich an den Rücken eines Meerestiers, und die herunterhängenden Formen erzeugen ein Gefühl des Schwebens in der Luft.

Dieselbe Dynamik des Fliegens, nun jedoch im Kontext der Luftfahrt, entwickelte Saarinen brillant im Projekt des **TWA-Terminals** am New Yorker John-F.-Kennedy-Flughafen weiter, das 1962 fertiggestellt wurde. Der Architekt konzipierte dieses Gebäude als abstraktes Symbol des Fluges. Vier miteinander verbundene Betongewölbe, die von Y-förmigen Stützen getragen werden, bilden eine flügelartige Konstruktion, die an einen Vogel mit ausgebreiteten Schwingen erinnert [9]. Die geschwungenen Linien des Dachs ähneln einem Schnabel, und der schneeweiße Pavillon wird insgesamt als Verkörperung des Optimismus und des Technologieglaubens wahrgenommen, die in der Ära der beginnenden Eroberung des Weltraums herrschten. Heute, nachdem es seine ursprüngliche Funktion verloren hat, wurde dieses Terminal in ein Hotel umgewandelt und ist ein authentisches Denkmal der futuristischen Architektur der 1960er Jahre.

Das kosmische Thema fand auch im Schaffen des brasilianischen Architekten Oscar Niemeyer (1907–2012) seine Fortsetzung. Obwohl das **Museum für Zeitgenössische Kunst in Niterói** erst 1996 fertiggestellt wurde, formte sich seine Ästhetik genau in jener Zeit, als die Menschheit von der Raumfahrt träumte. Niemeyer selbst beschrieb sein Werk als eine fliegende Untertasse, die an einem malerischen Ort

zur Erde niedergegangen sei [10]. Das schneeweiße zylindrische Volumen des Museums scheint auf einer dünnen Stütze zu schweben, und die sich schlängelnde rote Rampe, die zu ihm führt, verstärkt das Gefühl des Fantastischen. Der moderne Blick entdeckt in diesem Gebäude jedoch nicht nur außerirdische Motive, sondern auch eine Ähnlichkeit mit einer zierlichen Blume oder sogar einer Sauciere. Und dies ist vielleicht die wichtigste Errungenschaft der Moderne: die Fähigkeit, einem Gebäude jede beliebige Form zu geben, ohne dabei seine Funktionalität zu opfern.

Die Fähigkeit der Architektur, jede Form anzunehmen, führte zu einer erstaunlichen Synthese von Altertum und hochmodernen Technologien. Im Jahr 2010 errichtete der Architekt Mosche Safdie (geb. 1938) in Singapur das **Hotel Marina Bay Sands**, dessen gigantischer Maßstab die einfachste und älteste Konstruktion reproduziert – das megalithische Portal. Drei 55-stöckige Türme, die jeweils wie in zwei Hälften gespalten wirken, tragen eine riesige horizontale Plattform – einen Dachgarten, der 65 Meter über die Gebäudekante auskragt [11]. Diese Komposition erinnert erstaunlicherweise an Stonehenge: zwei vertikale Steine und die darauf ruhende horizontale Deckplatte. Safdie gelang es, ein neues Wahrzeichen der Stadt zu schaffen, eine monumentale und einprägsame Silhouette, die heute auf allen Ansichtskarten mit Blick auf Singapur unverkennbar ist.

Die durchgeführte Analyse erlaubt eine Reihe von Schlussfolgerungen über die Natur und Entwicklung der architektonischen Metapher in der Moderne. Erstens bestätigt die Untersuchung, dass das bildhafte Denken der Architekten auch im Rahmen des strengen funktionalen Paradigmas der Moderne eine wesentliche Rolle spielte. Von Mendelsohns expressionistischen Experimenten (Einsteinturm, 1921), bei denen die organische Plastizität zur Grundlage der Raumkomposition wurde, bis hin zu den industriellen Metaphern der sowjetischen Avantgarde (Russakow-Klub, 1929; Turm des Werks "Roter Nagelschmied", 1931), bei denen die mechanistischen Bilder unmittelbar aus den konstruktiven Lösungen erwuchsen, lässt sich ein konsequentes Bestreben der Autoren beobachten, zweckmäßige Bauten mit einer zusätzlichen symbolischen Bedeutung zu versehen.

Zweitens zeigen die Untersuchungsmaterialien, dass die Wahl der Metapher eng mit den technologischen Möglichkeiten ihrer Zeit verbunden war. Wenn in den 1920er Jahren Plastizität hauptsächlich durch Putzschichten auf Backsteinmauerwerk erreicht wurde (Einsteinturm, Chilehaus), so nutzte Saarinen's Nachkriegs-Neo-Expressionismus bereits die grundlegend anderen Möglichkeiten des Stahlbetons, die die Schaffung von weitgespannten Konstruktionen mit komplexer, krummliniger Form erlaubten (Eishalle in Yale, 1958; TWA-Terminal, 1962).

Schließlich zeigen die betrachteten Beispiele, dass sich metaphorische Architektur gerade in den Fällen als besonders lebensfähig erwies, in denen das Bild nicht von außen hinzugefügt, sondern aus der konstruktiven Logik des Gebäudes heraus entwickelt wurde. Aus architektonischer Sicht am überzeugendsten wirken jene Objekte, bei denen der funktionale Zweck und die plastische Lösung eine untrennbare Einheit bilden: Die Gewölbe des TWA-Terminals fungieren tatsächlich als tragende Konstruktionen, und die Zähne des Russakow-Klubs sind kein dekoratives Element, sondern die nach außen verlegten Balkone des Zuschauersaals.

Somit lässt sich behaupten, dass die metaphorische Bildhaftigkeit für die Architekten der Moderne keinen Abfall von den Prinzipien des Funktionalismus darstellte, sondern im Gegenteil eine der Möglichkeiten zu dessen Bereicherung und Weiterentwicklung war. Die Hinwendung zu wiedererkennbaren Formen der realen Welt ermöglichte es, die Verbindung der Architektur mit der menschlichen Wahrnehmung in einer Epoche zu bewahren, in der traditionelle ornamentale Systeme verworfen wurden. Und in diesem Sinne stellen die betrachteten Gebäude keine periphere, sondern eine durchaus zentrale Richtung der Architekturentwicklung des 20. Jahrhunderts dar.

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EINFLUSS DER TRADITIONEN DES DEUTSCHEN PORZELLANS AUF DIE PRODUKTE DER KAISERLICHE PORZELLANMANUFAKTUR ST. PETERSBURG

Zusammenfassung. Der Artikel geht es um die Entwicklungsgeschichte der russischen Porzellanproduktion im ältesten Porzellanunternehmen Russlands, der kaiserlichen Porzellanmanufaktur in St. Petersburg im Zeitraum von der zweiten Hälfte des 18. bis zur ersten Hälfte des 19. Jahrhunderts. Der Schwerpunkt liegt darin, den Einfluss der deutschen Porzellanherstellungstraditionen auf die Organisation der Arbeit in der Manufaktur und auf die Arbeit der Künstler des Unternehmens zu untersuchen. Der Artikel beschreibt sowohl die Arbeit deutscher Meister, die nach Russland eingeladen wurden, als auch die Tätigkeit russischer Meister, die Traditionen des deutschen Kunstporzellans, insbesondere die Manufaktur Meißen, angeeignet und weiterentwickelt haben.

Schlüsselwörter: Porzellan, Kaiserliche Porzellanmanufaktur, Dekoration, Porzellanmalerei, Meißner Porzellan.

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INFLUENCE OF THE TRADITIONS OF GERMAN PORCELAIN ON THE PRODUCTS OF THE IMPERIAL PORCELAIN MANUFACTORY IN ST. PETERSBURG

Abstract. The article focuses on the history of the development of Russian porcelain production at Russia's oldest porcelain factory, the Imperial Porcelain Factory in St. Petersburg. The period of interest is the second half of the XVIII and the first half of the XIX century. The focus is on the influence of German porcelain production traditions on the organization of work at the manufactory and on the work of the company's artists. The article describes both the activities of German craftsmen invited to Russia and the activities of Russian craftsmen who were influenced by German artistic porcelain, especially the Meissen manufactory.

Keywords: porcelain, Imperial Porcelain Manufactory, decoration, porcelain painting, Meissen porcelain.

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ВЛИЯНИЕ ТРАДИЦИЙ НЕМЕЦКОГО ФАРФОРА НА ИЗДЕЛИЯ ИМПЕРАТОРСКОГО ФАРФОРОВОГО ЗАВОДА В САНКТ-ПЕТЕРБУРГЕ

Аннотация. Статья посвящена истории развития производства русского фарфора на старейшем фарфоровом предприятии России – Императорском фарфоровом заводе в Санкт-Петербурге во второй половине XVIII и первой половине XIX века. В фокусе внимания находится влияние немецких традиций производства фарфора на организацию работы на мануфактуре и на творчество художников предприятия. В статье рассматривается как деятельность приглашенных в Россию немецких мастеров, так и деятельность русских мастеров, испытывавших влияние немецкого художественного фарфора, в особенности Мейсенской мануфактуры.

Ключевые слова: фарфор, Императорская фарфоровая мануфактура, декорирование, роспись по фарфору, мейсенский фарфор.

Traditionelles Porzellan wird aus einer Mischung aus Kaolin, Quarz und Feldspat hergestellt. Je nach der Art der benutzten Zusammensetzungen wird die Mischung unter unterschiedlichen Temperaturen gebrannt. Dabei bekommt man hartes Porzellan bei ca. 1400 Grad und Weichporzellan bei 1300 Grad. Im Laufe der Zeit änderte man die Zusammensetzung der Mischung, um andere Sorten von Porzellan zu erzeugen.

In China wurde das oben erwähnte Porzellanrezept, laut den Legenden, im dritten Jahrtausend vor Christus erfunden. Aber die ersten dokumentarischen Erwähnungen von "glasähnlicher Keramik" stammen aus dem sechsten Jahrhundert nach Christus [1]. Seit dieser Zeit wird Porzellan oft von europäischen und arabischen Reisenden beschrieben und von Händlern in verschiedene Länder geliefert. Die Europäer versuchten lange Zeit, das Geheimnis von Porzellan zu erfahren, aber auch mit detaillierter Beschreibung des Prozesses, konnten sie ihn nicht wiederholen. Das Problem war eine unzureichende Kenntnis der chemischen Zusammensetzung des Gemisches. Erst im Jahr 1708 haben der Apotheker Johann Friedrich Böttger und der Naturforscher Ehrenfried Walther von Tschirnhaus die richtige Mischung erfunden [1].

Später gründete Böttger mit Hilfe der sächsischen Herrscher die erste Porzellanmanufaktur Europas, Meißen. In den folgenden Jahrzehnten blühte die Porzellanproduktion in Deutschland weiter auf. Weitere Porzellanmanufakturen wurden gegründet, darunter die Königliche Porzellanmanufaktur Berlin, die Porzellanmanufaktur Nymphenburg in München und viele bekannte und auch kleinere Manufakturen und Fabriken zum Beispiel in Thüringen [1]. Im Jahre 1718 wurde die

Wiener Porzellanmanufaktur gegründet. In der ersten Hälfte des 18. Jahrhunderts wurden viele Porzellanmanufakturen fast in ganz Europa gegründet.

Im Jahr 1747 entwickelte Dmitri Iwanowitsch Winogradow eine Zusammensetzung für die Porzellanherstellung. Winogradow war ein russischer Bergbau-Ingenieur und ein Freund und Kommilitone des russischen Universalgelehrten Michail Lomonossow. Winogradow passte die Formel so an, dass in Russland verfügbare Rohstoffe verwendet werden konnten. Seit 1748 funktioniert in Sankt Petersburg dank Bemühungen von Dmitri Iwanowitsch Winogradow die Kaiserliche Porzellanmanufaktur [2].

Es gab bereits früher Versuche, eine Manufaktur zu gründen: Im Jahr 1744 wurde der Schwede J. C. Hunger, der an der Gründung von Fabriken in Wien und Venedig teilnahm, von Kaiserin Elisabeth nach Russland eingeladen. Hunger arbeitete auch für Meissen. Zwar hatte sein Unternehmen keinen Erfolg [1], aber Hungers ehemaliger Assistent, Winogradow, organisierte erfolgreich das Unternehmen zur Herstellung von russischem Porzellan.

Winogradow hat einige Zeit in Deutschland zusammen mit M. W. Lomonossow studiert. Winogradow hat Chemie, Physik, Mineralogie und Bergbau studiert. Die wichtigste Errungenschaft von Winogradow besteht darin, eine geeignete Zusammensetzung der Porzellanmischung auf der Grundlage von russischem Ton zu finden. Durch zahlreiche Experimente, die er in seinem Laboratorium durchführte, bestimmte er eine Zusammensetzung, aus der man erfolgreich hochwertige Porzellanprodukte herstellen konnte.

Schon während der Führung der Manufaktur von Winogradow wurden deutsche Spezialisten zum Unternehmen eingeladen, später wurde J. G. Müller aus Sachsen zum Direktor ernannt. Zuvor arbeitete er auch in der Manufaktur Meissen [1]. Die Traditionen des deutschen Porzellans bestimmten weitgehend die Stilmerkmale der Produkte der Manufaktur.

In den ersten Jahrzehnten ihres Bestehens, die als die Jahre der Gründung der Manufaktur und ihrer Kunstschule bezeichnet werden können, wurden die Künstler des Werkes oft von den Werken deutscher Meister inspiriert, unter denen sicherlich Bildhauer und Maler der Meißener Manufaktur die führenden waren. Unter anderen Statuetten der Manufaktur Meissen, die in Russland kopiert wurden, kann man die bis heute erhaltene Bachusfigur hervorheben. Diese Plastik ist eine transformierte Version des Modells der Meißener Manufaktur von Johann Joachim Kändler.

Die Orientierung auf Vorbild Meissens war nicht nur Merkmal des russischen Porzellans. Die meisten deutschen Fabriken wurden, wenn sie nicht direkt kopiert haben, eindeutig von den Produkten der Meißener Manufaktur inspiriert. In vielerlei Hinsicht hat sich die Situation für europäisches Porzellan auch in unserer Zeit nicht geändert. Trotz der Entstehung einer großen Anzahl lokaler Kunstschulen in den letzten drei Jahrhunderten gibt es eine große Anzahl von Kopien von Meißener Geschirr und Plastiken. In einigen Fällen gibt es eine Fälschung mit einem gefälschten Markenzeichen der Manufaktur. Aber viel häufiger produzieren Porzellanfabriken unter ihrer eigenen Marke Porzellan, indem sie Formen oder Malereien der Manufaktur Meissen verwenden. Insbesondere nutzten viele Porzellanfabriken der sozialistischen Staaten (Bernadotte in der Tschechischen Republik, Kahla in der DDR, viele Fabriken

in Polen) das Erbe von Meißen. Viele dieser Fabriken sind erhalten geblieben und produzieren weiterhin identische Produkte wie früher.

Während der Regierungszeit von Kaiserin Katharina II wurden jedoch mehr Meister aus Frankreich in die Fabrik eingeladen [2]. Der berühmteste von ihnen war Antoine-Jacques-Jean-Dominique Rachette, Autor der Figurenreihe "Die Völker des russischen Staates". Von anderen bekannten Werken sollte man "Arabesken-Service" nennen.

Im Jahre 1780 kam Franz Gattenberger, ein ehemaliger Professor an der Universität Geneve für Porzellanproduktionstechnologie, aus der Schweiz nach Russland [3]. Zunächst arbeitete Gattenberger in der Porzellanmanufaktur Gardner im Dorf Verbilki: Diese Fabrik ist für die Geschichte des russischen Porzellans nicht weniger wichtig als die kaiserliche Porzellanfabrik. 1803 wurde Gattenberger vom Grafen Alexander Dmitrijewitsch Gurjew, der stellvertretender («товарищ») Finanzminister war, eingeladen, den Posten des Betriebsdirektors zu übernehmen [3]. Im Jahr 1806 wird Graf Gurjew Gattenberger selbst als Direktor ersetzen, wenn auch nicht für lange: 1810 wird Gurjew dank dem Patronat des Grafen Michail Michailowitsch Speransky zum Finanzminister.

Gattenberger führte große administrative Reformen durch: er hat das Gymnasium bei der Manufaktur zu einer Realschule umgestaltet und mehrere Abteilungen der Manufaktur abgeschafft. Eine solche Reorganisation war erforderlich, um die finanzielle Lage der Fabrik zu verbessern, was Graf Gurjew ebenfalls wollte. Die Sozialhilfe für die Arbeiter der Manufaktur wurde erheblich verbessert, sie durften in der Nähe der Fabrik Wohnhäuser bauen [3].

Im Unternehmen wurde daran gearbeitet, die Porzellanmasse zu verbessern und neue Glasuren herzustellen. Die Brenntechnik hat erhebliche Fortschritte gemacht dank des deutschen Meisters Seiffert, der die dreistöckigen Drehberge in Betrieb genommen hat. Gattenberger entwickelte auch technische Hilfsmittel für die Porzellanherstellung, wie die Tonmühle [3].

Gattenberger selbst schuf auch verschiedene Designs für die Malerei und die Form von Porzellangegenständen: Er hinterließ mehrere Alben mit Zeichnungen von Milchkännchen, Vasen, Teeservice und anderen Kunstwerken. Nach diesen Zeichnungen konnten die Künstler der Manufaktur schon nach dem Abgang von Gattenberger als Direktor Geschirr herstellen.

Stilistisch neigten die Produkte der Manufaktur dieser Zeit zum Klassizismus. In diesem Zusammenhang sind viele Kunstgegenstände mit antiken Motiven auf den Markt gekommen. Die Produkte der Fabrik verwendeten jedoch häufig Rokokoelemente und pseudo-ägyptische Elemente. Die Künstler der Fabrik wählten oft bunte Farben, die offenbar auf die Wünsche potenzieller Käufer zurückzuführen sind.

Seit Anfang des 19. Jahrhunderts gibt es viele private Porzellanmanufakturen in Russland. In vielerlei Hinsicht wurde das rasante Wachstum der privaten Porzellanproduktion durch hohe Einfuhrzölle auf ausländisches Porzellan gefördert. Der Wettbewerb nahm zu, und die kaiserliche Porzellanmanufaktur war im Vergleich zu großen privaten Fabriken nicht immer führend in der Produktion. Die meisten Produkte der Manufaktur aus dem frühen 19. Jahrhundert wurden nach privaten

Aufträgen von wohlhabenden Menschen, hauptsächlich Mitgliedern des Kaiserlichen Hofes, hergestellt [2].

Seit den 1850er Jahren kopierte die kaiserliche Porzellanmanufaktur immer seltener Werke europäischer Meister. Zur Arbeit an künstlerischem Porzellan lud die Betriebsleitung berühmte Künstler ein, nicht nur leibeigene Meister. Die Nachfrage nach den Produkten der Manufaktur ist durch die allmähliche Vergrößerung des angebotenen Produktsortiments deutlich gestiegen. Die künstlerischen Produkte der Fabrik wurden für den Käufer der Mittelschicht zugänglicher, nicht nur für die reichsten Menschen des Landes.

Zum Schluss kann man sagen, dass das Hauptzentrum des russischen Porzellans im 18. und frühen 19. Jahrhundert, die Kaiserliche Porzellanmanufaktur in St. Petersburg, von der deutschen Tradition der Porzellanproduktion stark beeinflusst wurde. Dieser Einfluss wurde sowohl in der Erforschung der künstlerischen Merkmale des Meißener-Porzellans als auch in der Erforschung neuer technischer Aspekte der Herstellung von Porzellanobjekten ausgedrückt. Die Werke der Künstler der kaiserlichen Porzellanmanufaktur wurden jedoch allmählich mehr und mehr unabhängig. Schließlich ermöglichten die Synthese europäischer Traditionen und die Arbeit führender russischer Künstler dem Unternehmen, eine eigene, einzigartige Kunstschule zu bilden.

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SEMIOTICS OF A GASTRONOMIC BRAND: MECHANISMS OF CONSTRUCTING SYMBOLIC VALUE IN THE CONTEXT OF CREATIVE INDUSTRIES

Abstract. This article explores the semiotic mechanisms underlying the symbolic value of gastronomic brands in contemporary creative industries. On the basis of theoretical approaches synthesised by F. de Saussure, R. Barthes, W. Eco, and P. Bourdieu, this article proposes a conceptual model of gastronomic sign semiosis, including denotative, connotative, and mythological levels of meaning. The mechanisms by which symbolic value is constructed through narrative, visual identity, bodily experience, and cultural memory are examined. The role of gastronomic brands as a medium for transmitting cultural codes in the creative economy is analyzed. It is concluded that gastronomic brands function as a polysemiotic system integrating the material and symbolic dimensions of consumer experience.

Keywords: semiotics, gastronomic brands, symbolic value, creative industries, semiosis, cultural code, narrative, branding, consumer experience.

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СЕМИОТИКА ГАСТРОНОМИЧЕСКОГО БРЕНДА: МЕХАНИЗМЫ КОНСТРУИРОВАНИЯ СИМВОЛИЧЕСКОЙ ЦЕННОСТИ В КОНТЕКСТЕ КРЕАТИВНЫХ ИНДУСТРИЙ

Аннотация. В данной статье исследуются семиотические механизмы, лежащие в основе символической ценности гастрономических брендов в современных креативных индустриях. На основе синтеза теоретических подходов Ф. де Соссюра, Р. Барта, У. Эко и П. Бурдьё в статье предлагается концептуальная модель семиозиса гастрономического знака, включающая денотативный, коннотативный и мифологический уровни значения. Исследуются механизмы, посредством которых символическая ценность конструируется через нарратив, визуальную идентичность, телесный опыт и культурную память. Анализируется роль гастрономических брендов как средства передачи культурных кодов в креативной экономике. Сделан вывод о том, что гастрономические бренды функционируют как полисемиотическая система, интегрирующая материальное и символическое измерения потребительского опыта.

Ключевые слова: семиотика, гастрономические бренды, символическая ценность, креативные индустрии, семиозис, культурный код, нарратив, брендинг, потребительский опыт.

Contemporary gastronomic culture is undergoing a radical transformation, as food is increasingly viewed less as a means of satisfying biological needs and more as a signifying system that organizes social differences, cultural identity, and symbolic consumption. In a post-Fordist economy, where the production of meanings is no less valuable than the production of material goods, the gastronomic brand is becoming a key agent of symbolic exchange.

The relevance of this study is conditioned by a number of interrelated factors. First, it is the exponential growth of the restaurant services and food retail markets, accompanied by intensifying competition and a shift in competitive advantages from price to symbolic value. According to analytical agency “Euromonitor International”, the global foodservice market reached over \$3.5 trillion by 2025, with the growth rate of the premium experience segment consistently outpacing that of the basic consumer segment. Secondly, the inclusion of gastronomy in the register of creative industries at the level of international institutions – UNESCO, the British Council* (*declared an undesirable organisation within the Russian Federation*), and national cultural agencies – signifies recognition of its value-producing function. Thirdly, it is the insufficient theoretical development of the problem at the intersection of semiotics, branding, and cultural studies: despite the active development of research in the field of nutrition as an academic discipline, the mechanisms of the semiotic construction of gastronomic brands remain the subject of fragmented rather than systematic research.

The analysis of recent publications has shown that the issue of the semiotics of gastronomic brands and the mechanisms for constructing their symbolic value lies at the intersection of several relevant scientific fields. It shows the necessity of a wide

range of related studies in the fields of marketing, creative industries, regional economics, and digital transformation.

A study by K. A. Antoshina and N. V. Kirillova, devoted to the conceptual features of marketing activities in the context of import substitution, makes a significant contribution to the understanding of the marketing mechanisms of the food market [1]. The authors demonstrate that, in the conditions of the food market shifts toward domestic producers, the importance of the symbolic component of a product's offering increases dramatically: a brand ceases to be solely an identifier of a product's origin and assumes the function of a cultural marker, conveying the values of local identity and national authenticity. This thesis directly corresponds to the semiotic approach to analyzing gastronomic brands, since under competitive pressure, a brand's symbolic system becomes the primary tool for differentiation and the formation of consumer preferences.

No less significant for this study is the work of K. A. Antoshina and I. A. Chepeleva, who examine the marketing of creative industries within the concept of the economy of impressions [2]. The authors justify that in the modern economy consumers acquire not so much a material product as a set of emotional experiences and narratives associated with its consumption. In relation to gastronomic branding, this means that a restaurant or food brand functions as a complex semiotic construct in which taste, visual image, history of origin, and the social context of consumption form a unified symbolic system. This approach fits in seamlessly with the logic of this article and allows us to consider a gastronomic brand as a fully-fledged product of the creative industry, producing symbolic values on a par with material ones.

In the context of the regional measuring of gastronomic branding, K. A. Antoshina's study on marketing trends in the socio-economic designation of regions is becoming particularly relevant [3]. The author convincingly demonstrates that regional identity is increasingly being constructed through marketing tools, with the gastronomic component occupying a special place among them as the most sensually perceived and emotionally charged element of the territorial image. Local cuisine, traditional products, and gastronomic practices act as semiotic resources through which a region broadcasts to the outside its uniqueness and competitive advantages. This thesis significantly expands our understanding of the mechanisms for constructing the symbolic value of a gastronomic brand, highlighting its inextricable link with territorial identity.

The digital dimension of contemporary branding is explored in the work of A. Yu. Deshchenko and K. A. Kravchenko, who analyze the vectors of digital development in geomarketing [4]. The authors identify fundamentally new opportunities that digital technologies offer for the spatial analysis of consumer behavior and targeting marketing communications. In relation to gastronomic branding, this means that a brand's semiotic messages are increasingly distributed and interpreted in the digital environment – through geolocated reviews, visual content on social media, and algorithmically generated recommendations – which significantly transforms the traditional mechanisms of producing and consuming brand symbols.

The theoretical and methodological basis for understanding the economic prerequisites for the symbolization of modern consumption is provided by

A. Yu. Deshchenko's research on economic globalization and technological innovation as prerequisites for the formation of the economy of knowledge [5]. The author justifies that the transition to a post-industrial economic model is accompanied by a radical shift in emphasis from the production of material goods to the generation of knowledge, meaning, and symbolic values. This conceptual shift provides a necessary context for understanding why gastronomic brands in modern conditions acquire such a pronounced semiotic dimension: in a knowledge economy, the symbolic value of a product often exceeds its utilitarian significance, and a brand's ability to produce and convey meaning becomes a key source of competitive advantage.

Finally, the philosophical and anthropological dimension of the problem is defined by the work of D. I. Izmailova, E. I. Gavrilina, and L. A. Akhkozov, who examine the relationship between transhumanist perspectives and bioethical limitations [6]. Although this work does not directly address gastronomic issues, the questions it raises about the limits of the technological transformation of human nature and corporeality acquire indirect significance for understanding how modern humans' attitudes toward food and taste are being transformed in the context of the biotechnological revolution. Changes in the perception of corporeality and sensory experience inevitably entail a rethinking of the semiotics of the gastronomic brand, as the latter appeals specifically to the sensory, embodied dimension of human existence.

Thus, the analysis of current publications indicates that the problematic of gastronomic brand semiotics is examined by contemporary researchers across several interconnected dimensions: marketing, regional, digital, economic-theoretical, and philosophical-anthropological. However, an integrative semiotic analysis of the mechanisms for constructing the symbolic value of a gastronomic brand, specifically in the context of creative industries, remains an underdeveloped area, which determines the scientific novelty of this study.

The aim of this article is to develop a conceptual model for the semiotic construction of the symbolic value of a gastronomic brand, identifying the specifics of sign operations in the creative industries. To achieve this goal, the following objectives were addressed: the theoretical foundations of semiotic branding analysis were systematized; the concept of the "gastronomic sign" and its structural levels were conceptualized; the mechanisms of narrative, visual, and sensory construction of symbolic value were described; the role of cultural capital and habitus in gastronomic brand perception was analyzed; and the place of gastronomic branding within the creative industries was determined.

Semiotics, which emerged as the science of signs in the works of F. de Saussure and C. S. Peirce, has long since transcended the boundaries of linguistics and extended its analytical apparatus to a wide range of cultural phenomena. Several theoretical sources are fundamental to this study.

The Saussurean "signifying-signified" dyad establishes the basic logic of analysis: every element of a gastronomic brand (logo, name, flavor profile, establishment interior, packaging) functions as a signifying, appealing to certain cultural signified. The arbitrariness of the sign, as documented by Saussure, opens space for conventional play: the connection between a cup of espresso and the concept

of “Italian authenticity” is not determined by the nature of things, but is historically constructed and culturally reinforced through repeated signifying practices [7].

C. S. Peirce’s concept, which distinguishes between iconic signs (signs of similarity), indexical signs (signs of contiguity), and symbolic signs (signs of convention), allows us to describe the multi-layered symbolic nature of a gastronomic brand. The visual image of a dish on packaging functions as an icon; the smoke above a cup of coffee as an index of freshness and warmth; the name “Chateau Margaux” as a symbol, the meaning of which is conventionally assigned to a complex semantic construct incorporating concepts of terroir, tradition, elitism, and French cultural identity.

R. Barthes’s fundamental contribution to the methodology of this study is his theory of myth as a secondary semiological system, outlined in “Mythologies” (1957) and systematized in “Foundations of Semiology” (1965). Barthes demonstrates that the sign of a primary semiological system becomes the signifier of a secondary, “mythological” system, at the level of which historically constructed meanings are naturalized: the ideological is presented as natural, the accidental as necessary. Applied to a gastronomic brand, this means that concepts such as “homemade taste”, “traditional recipe”, or “natural ingredients” function precisely as myths in Barthes’s sense: they claim immediacy and organicity, while concealing carefully crafted marketing strategies [8, 9].

U. Eco, developing the theory of code and hyper coding, introduces the concept of a rhetorical super code, which allows one to describe the semiotic mechanisms through which a gastronomic brand appeals to the audience’s collective cultural competencies. The concept of the “model reader” is transformed in the context of branding into the concept of the “model consumer” – an ideal addressee constructed by the brand text itself and possessing the necessary cultural capital to adequately decode its symbolic messages [10].

Referring to the sociology of P. Bourdieu is methodologically necessary, as it allows for the situating of semiotic analysis within the social context of the production and consumption of symbolic values. Central to this study are the concepts of symbolic capital, the field of cultural production, and habitus [11, 12].

At the denotative level, a gastronomic sign refers to its literal, referential content, namely, a specific dish, product, establishment, and preparation technology. This level of description and identification, at which pizza “Margherita” signifies pizza with tomato sauce, mozzarella, and basil, “Medovik” is a honey-based cake with sour cream filling, the denotation forms the stable core of the sign, ensuring its communicative function and referential potential.

Nevertheless, even at the denotative level, a gastronomic sign is not semiotically neutral. The choice of a nomination system – descriptive (“rye sourdough bread”), nominal (“Napoleon cake”), toponymic (“Parma ham”), eponymic (“beef stroganoff”) – already carries a semiotic charge, setting a horizon of expectations and primary connotative halos [13].

The connotative level, described by Barthes as the area of secondary meanings built upon the denotation, is the key space for branding operations. It is here that the denotative sign “espresso” is enriched with connotations of Italian culture, urban

rhythm, intellectual life, masculine restraint, or bohemian freedom – depending on how the brand constructs its connotative system. The connotative level of a gastronomic sign is fundamentally polycode: it is built simultaneously on verbal (name, slogan, description of dishes on the menu), visual (logo, corporate identity, interior, presentation of the dish), auditory (background music, kitchen sounds), olfactory (aromatic profile of the space or product), and tactile (texture of the packaging, tableware, furniture) codes [14].

The mythological level, in Barthes's understanding, is the level at which historically constructed, ideologically loaded meanings take on the appearance of natural and self-evident truths. At this level, the gastronomic brand ceases to be simply a food producer and becomes a guardian of tradition, the embodiment of territorial identity, and a symbol of a particular way of life.

The most illustrative example of the functioning of the gastronomic myth is the concept of "authenticity". Authenticity in gastronomic branding is a construct that presents itself as an immediate reality: a restaurant claiming to offer authentic Italian cuisine does not reproduce some objective culinary reality, but rather produces a sign of authenticity through carefully selected semiotic elements – Italian dish names, a specific color scheme, specific aromas, and service rituals. A "natural" brand, operating within the same mythological logic, conceals a complex technological, distribution, and marketing chain behind the image of immediacy, "straight from the garden" contact with nature [15].

The mythological level is the space in which a gastronomic brand most clearly functions as an ideological mechanism: it reproduces certain value systems (environmentalism, traditionalism, cosmopolitanism, local patriotism), legitimizing them through an appeal to the "nature" of things and the "essence" of culinary practices.

Narrative is the fundamental mechanism for constructing the symbolic value of a gastronomic brand. Humans, in the words of W. R. Fisher, are *homo narrans*: narrative structure is the basic way of organizing experience and imbuing it with meaning. A gastronomic brand with a compelling narrative offers consumers not just a product, but the opportunity to participate in a meaningful story. Narrative strategies in gastronomic branding can be systematized according to several typological principles. According to the type of narrative subject, a distinction is made between personal narrative (the story of the founder, chef, or family), territorial narrative (the history of place, region, *terroir*), and process narrative (the history of technology, craft, tradition). According to temporal orientation, narratives appeal to the past (tradition, heritage, history), the present (relevance, modernity, innovation), and the future (mission, sustainable development, transformation).

The visual identity and spatial organization of a gastronomic brand form a multisensory semiotic environment in which the consumer experience is realized. The fundamental theoretical foundation here is the concept of the "rhetoric of space", developed in the tradition of A. Greimas and J. Fontange in relation to architecture and design.

The restaurant space functions as a text read by the consumer in accordance with assimilated cultural codes. The height of the ceilings encodes scale and ambition;

lighting regulates the intensity of social interaction and the degree of privacy; the choice of materials appeals to specific connotations (natural wood – authenticity and warmth, polished metal – technological sophistication and precision, raw concrete – urban rigidity and avant-garde). The distance between tables encodes social hierarchy and the degree of exclusivity.

In the creative industries, a gastronomic brand functions as a cultural medium in several interconnected senses. First, it transmits cultural memory and tradition: the preservation of regional recipes, traditional technologies, and local ingredients serves as a cultural archiving function and simultaneously creates sustainable semiotic resources for branding. Second, it serves as a medium for the production of cultural differences: through positioning within the gastronomic production field, a brand constructs social identities and lifestyles. Third, it functions as a medium for intercultural dialogue: gastronomic brands are one of the most accessible channels for transmitting cultural codes across national and linguistic boundaries.

In today's environment, a gastronomic brand operates in intensive interaction with other creative industries, forming networks of cross-media signification.

Interaction with the fashion industry manifests itself both at the level of symbolic codes (the concept of a “luxury” restaurant utilizes the same semiotic operations as a luxury fashion brand: scarcity, ritualized consumption, exclusivity of access) and at the level of direct institutional collaborations (restaurant projects by fashion houses Gucci, Prada, and Armani). Interaction with the tourism industry constitutes the phenomenon of “gastronomic tourism” – a form of cultural travel in which culinary experience is the primary motivation and key medium for exploring another place and culture. Interaction with the media industry is realized in the genre of culinary television – from “Iron Chef” to “Master Chef” – and in the forms of food blogging and social media, where gastronomic visual content has acquired the status of an independent aesthetic practice.

Based on the analysis, a conceptual model of gastronomic brand semiosis is proposed, comprising four interconnected levels.

The first level, “material semiosis”, encompasses sign operations that directly appeal to the physical substrate of a gastronomic object: taste, smell, texture, shape, and color. At this level, the sign is motivated by the sensory properties of the signified and appeals to the consumer's bodily memory.

The second level, “cultural semiosis”, includes codes of cultural identification: territorial (belonging to a specific gastronomic culture), chronological (belonging to a specific historical tradition), and social (marking the consumer's social position). At this level, the sign functions within a system of conventional cultural codes.

The third level, “narrative semiosis”, organizes sign operations into a narrative structure that imbues the gastronomic object with a “biography” and integrates the consumer into the brand's history. Here, the mechanisms of authentication, nostalgia, and identification are realized.

The fourth level, “mythological semiosis”, is the level of naturalization: the sign constructions produced at the previous levels acquire the status of self-evident, “natural” values. This is the level of ideology at work in gastronomic branding.

These levels do not form a linear hierarchy, but are interdependent and cyclically determined: mythological constructs set the interpretive horizon for narrative operations, narrative operations organize cultural codes, cultural codes mediate the perception of the material substrate, and the material substrate provides the sensory “anchor” that holds the entire semiotic structure together.

The study allows us to formulate a number of significant conclusions. A gastronomic brand is a polysemiotic system integrating symbolic operations at the material, cultural, narrative, and mythological levels. Its symbolic value is constructed through the mechanisms of narrativization (producing brand history), visual-spatial coding (organizing the semiotic environment), sensory signification (appealing to bodily memory), and mythologization (naturalization of ideological constructs).

In the creative industries space, the gastronomic brand functions as a cultural medium, producing not only food products and food services, but also cultural meanings, social identities, and symbolic values with an independent economic dimension. The inclusion of gastronomy in the register of creative industries is not an administrative convention, but a theoretically grounded recognition of its value-producing function.

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SYNERGISTIC EFFECT OF INTERREGIONAL COOPERATION IN THE FRAMEWORK OF CREATING INNOVATION CLUSTERS

Abstract. The article is devoted to the analysis of synergistic effect of interregional cooperation in the creation of innovative clusters. The modern economy is in a state of constant technological change, which sets requirements for innovations; it is becoming increasingly difficult for regions to compete for investments, making it necessary to combine efforts to accelerate the creation and implementation of new products. The study reveals the main actors of cluster development in the region. The methods of regulating the innovation process available to the state are examined. Key aspects of interregional cooperation in terms of forming innovative clusters are considered. Synergy between regions is a practical tool for growth and strengthening the country's economic sovereignty. The main result is not a one-time benefit, but sustainable development of territories, where innovations act as a constant element of the regional economy.

Keywords: synergistic effect, interregional cooperation, innovation clusters, cluster.

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СИНЕРГЕТИЧЕСКИЙ ЭФФЕКТ МЕЖРЕГИОНАЛЬНОЙ КООПЕРАЦИИ В РАМКАХ СОЗДАНИЯ ИННОВАЦИОННЫХ КЛАСТЕРОВ

Аннотация. Статья посвящена анализу синергетического эффекта межрегиональной кооперации при создании инновационных кластеров. Современная экономика находится в условиях постоянных технологических изменений, которые устанавливают требования к инновациям, региону все сложнее конкурировать за инвестиции, необходимым является объединение усилий для ускорения создания и внедрения новых продуктов. Исследование раскрывает основных акторов кластерного развития региона. Изучены методы регулирования инновационного процесса, которыми располагает государство. Рассмотрены ключевые аспекты межрегиональной кооперации в разрезе формирования инновационных кластеров. Синергия между регионами является практическим инструментом роста и укрепления экономического суверенитета страны. Главным результатом становится не разовая выгода, а устойчивое развитие территорий, где инновации выступают в роли постоянного элемента региональной экономики.

Ключевые слова: синергетический эффект, межрегиональная кооперация, инновационные кластеры, кластер.

One of the current trends of modern times has become the growing global competition, requiring the integration of numerous resources and various competencies that no single region can accumulate on its own [1]. Interconnected regions or other socio-economic systems adapt more efficiently to crisis events, as they can optimally distribute the load of production capacities, supplies, and labor movements. This circumstance provides the opportunity to reduce vulnerability to local difficulties, seasonal fluctuations of the economic situation, and external shocks. Furthermore, the events of recent years have clearly highlighted the need for diversifying raw material supplies, expanding logistics routes, and reducing the dependence of regions on the activities of a large, system-forming enterprise or industry [1, 2].

In addition to the many obvious benefits for the development of the economic turnover in the context of regions, interregional cooperation contributes to the emergence of long-term positive effects for the state economy and the improvement of the quality of life of the population. For enterprises, interregional cooperation provides access to new markets and to markets beyond local demand, scaling up sales. Joint procurement and the use of shared infrastructure reduce costs for both the regions themselves and businesses, while ensuring the influx of investments and the creation of projects based on private capital and the state budget [3].

According to various scholars, interregional cooperation is an effective platform for activating and accelerating the innovation process, through the exchange of various information and practices from different areas of economic activity, reducing the time required to transform an idea into a finished product and its subsequent implementation [1, 2]. In this regard, a special role is assigned to innovation clusters, which unite

various companies, enterprises, research centers and organizations, venture funds, and government bodies around a common activity or sectoral specialization [1].

Such associations increase the intensity of knowledge exchange, enhancing the density of interactions among cluster participants and improving the speed of bringing project solutions to market. In domestic practice, there are many examples of the cluster approach in improving the innovation process – special economic zones, industrial parks and sites, business incubators, and industry consortia [4].

The effect that arises from the combination of resources, when the overall result exceeds the simple or separate sum of the contributions of the cluster participants, is called synergistic. In other words, joint efforts and interactions provide not only a summation of capabilities but also an additional result through the exchange of knowledge, skills, and competencies. In the Figure, a visual illustration of the synergistic effect in the context of interregional cooperation is presented.

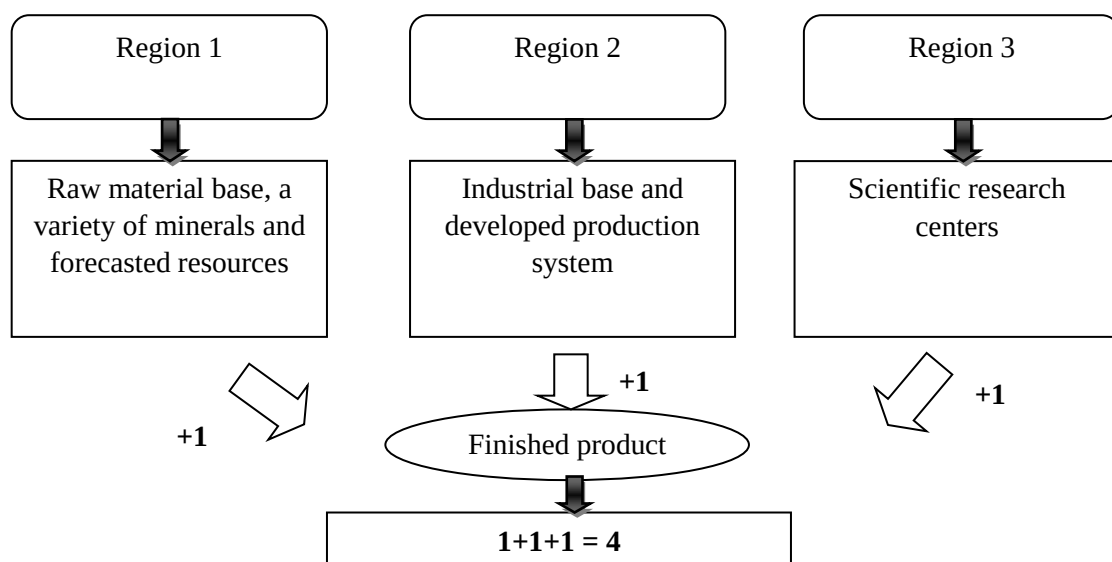


Figure. Synergistic effect under conditions of interregional cooperation

It should be noted that synergy is a complex effect that affects many different subsystems: production, financial, innovation, organizational, and social. Thus, the synergistic effect is a key mechanism for the development of cluster structures, transforming cooperation into a foundation for sustainable growth and territorial competitiveness.

A successful and effective cluster is based on the ‘three spirals’ model – the key participants of the innovation process. The interaction of business, government, and science creates the conditions that transform ideas into a finished product with a significant economic result [5].

Business and its representatives create market demand by introducing modern technologies into production, transforming scientific developments into commercial results. Commercial companies set a practical direction for cluster associations: what the market needs, which products to develop, how to increase profitability from activities.

The role of government lies in framing the interaction of economic actors and determining the rules of the game, mitigating the significance of barriers to the

emergence of cooperation, and creating a predictable environment for innovation and investment. In other words, the role of the state is to act as an arbitrator in the functioning of the cluster and create suitable conditions for the implementation of joint projects, providing various preferences. For example, tax incentives that stimulate investment in R&D, making the placement of production in the cluster attractive. The Table lists the methods of government regulation in terms of interregional cooperation and support for the innovation process.

Table. Methods of state regulation in terms of regional cooperation and support of the innovation process.

№	Methods of state regulation and support of the innovation process	Description of regulatory and support methods
1.	Tax benefits	Investment in R&D and increasing the attractiveness of locating production in the cluster
2.	Grants and subsidies	Launching applied research, pilot, and acceleration projects
3.	Infrastructure support	Technoparks, digital platforms, transport connections
4.	Organizational tools	Institutional support for projects, standardization of procedures, and simplification of access to financing

Scientific actors provide the cluster with knowledge, personnel, and solutions in the field of technology. Framing the cluster with a scientific contour turns the association into a renewing system, in which new and relevant competencies and research directions emerge. It is important to mention that the sustainability and strength of the cluster are determined not only by the strength of individual participants but also by how the connections between them are built. The mechanism of interaction between the state, business, and science is formed through joint projects, where funds from private companies, investors, and state budget resources are attracted, making the possibility of implementing large and long-term initiatives more accessible.

The balance among the three given spirals is critical for the cluster's success; if one element becomes dominant or, conversely, is insufficiently developed, cooperation loses its stability, hindering the emergence of innovation and the cluster's competitiveness.

There are many examples of domestic clusters demonstrating sustainable synergy over a long period, having formed an effective ecosystem of actors.

One of the well-known examples of innovative clusters, often considered a benchmark for urban innovation ecosystems, is the Moscow cluster. The structure of this cluster includes numerous universities, IT giants, banks, and state corporations: MSU, HSE, MIPT, Sber, Rostec, Yandex, various technoparks, and hundreds of startups, united in a single network, accelerating the process from idea to finished product. The advantage of the cluster lies in the dense concentration of research

centers, major clients, and engineering companies. Among the notable projects are the implementation of digital services in city systems, the development of artificial intelligence, fintech, and robotics [6].

Another example of a successful cluster is the Ural Industrial Cluster, which emerged around large industrial companies and the region's scientific and educational base. The core of the cluster consists of heavy industry enterprises – Uralmash Plant, Uralvagonzavod, Sinarsky Pipe Plant, and numerous metallurgical complex enterprises [2]. The activities of these enterprises are supported by the Ural Federal University and specialized technical universities, which provide the enterprises with personnel and conduct applied research. The cluster plays a key role in modernizing traditional industries through the introduction of production automation and robotics.

Apart from Moscow and the Urals, there are successful examples in Saint Petersburg, which specializes in shipbuilding and pharmaceuticals, as well as in Novosibirsk, where the scientific and educational potential of Akademgorodok supports the development of technologies [7-10]. In each of the aforementioned cases, the regional cluster relies on its strengths: a developed scientific base, a personnel reserve, industry specialization, and markets for sales.

Thus, it is possible to highlight several conditions that explain the success of cluster associations.

Firstly, the presence of anchor companies that drive demand and attract suppliers, service, and consulting organizations.

Secondly, government support reduces environmental uncertainty and is required to create infrastructure to strengthen cooperation.

Thirdly, proximity to science, which generates an influx of knowledge, personnel, and ideas.

Fourthly, cooperation that connects businesses, investors, and universities into a single structure where each participant strengthens the other.

According to various studies dedicated to the issues of cluster development in the regions, certain challenges and obstacles have emerged that hinder interregional cooperation and innovative development.

The challenges that create difficulties in interregional cooperation include administrative and regulatory barriers in terms of taxation, licensing, and the establishment of industry standards. Another difficulty is financial constraints, which are explained by the disproportion in resource distribution between regions. In addition, the problem of organizational differences in regional interests often creates competition between them and reduces their willingness to cooperate.

However, despite the aforementioned difficulties, the strengthening of interregional cooperation leads to the growth of an innovation culture: private businesses and universities are more willing to establish connections in search of partners for implementing joint pilot projects. An important tool and element of successful regional cooperation is the creation of long-term development programs, which should have a strategic planning horizon of 10-15 years, provide clear guidelines, and have measurable results.

Thus, the unification of regional efforts is not just one of the variations of the state's economic development, but a practical necessity for creating a competitive innovative economic sphere.

Adherence to a systematic approach, coordinating efforts at multiple levels – regions, industries, and federal policy – becomes important. To strengthen cooperation, it is necessary to develop common mechanisms for financing, standards for infrastructure creation, and regulatory frameworks. Strengthening the implementation of the “single window” principle and interregional agreements, which mitigate the lack of trust between actors, is also required.

Cluster growth is possible where a region can rely on its strengths, building partnerships and conditions for the interaction of science, business, and government. Success depends not on copying a perfect model, but on how accurately the local advantage is identified, turning the cluster into a full-fledged sustainable ecosystem. For this reason, interregional cooperation is a source of growth and development not only for individual companies, but also for the entire economy of the territory and the country as a whole.

In the case where cooperation is built sequentially, a multiplicative effect arises. One successful cluster gives an impulse to the development of related industries, improving the educational sector, enhancing the quality of management, and creating a development trajectory for a long-term planning horizon.

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MARKETING AT THE MACROECONOMIC AND MESOECONOMIC LEVELS

Abstract. The article considers the evolutionary concept of marketing in the context of its changes at the macro-, meso- and micro levels. The transition from researching the needs of a specific market segment to mesoeconomic marketing as a network form of partnership interaction is analyzed and discussed.

Keywords: marketing in the mesoeconomic and macroeconomic context, marketing objectives, partner equilibrium, market, product, macromarketing, mesomarketing.

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МАРКЕТИНГ НА МАКРОЭКОНОМИЧЕСКОМ И МЕЗОЭКОНОМИЧЕСКОМ УРОВНЯХ

Аннотация. В статье рассмотрена эволюционная концепция маркетинга в контексте его изменения на макро-, мезо- и микроуровнях. Анализируется переход от изучения потребностей конкретного рыночного сегмента к

мезоэкономическому маркетингу как сетевой форме партнерского взаимодействия.

Ключевые слова: маркетинг в мезоэкономическом и макроэкономическом контексте, задачи маркетинга, партнерское равновесие, рынок, товар, макромаркетинг, мезомаркетинг.

Initially, marketing was considered as a microeconomic category, as one of the tools for changing the market equilibrium. However, in modern conditions, it is increasingly common to talk about marketing in a mesoeconomic, and even macroeconomic context. In this approach, the subjects are not individual enterprises, but integrated corporations, institutional investors, and even the state that pursues an active industrial policy. To clarify the content of mesoeconomic marketing, it is advisable to consider the history of the emergence and development of this concept.

It is believed that the term “marketing” appeared in the last third of the XIX century, as a means of solving the problem of selling mass-market goods. Then, in the conditions of an unsaturated market, the production concept of entrepreneurship, focused on maximum production, dominated. Sales were given a secondary role in accordance with the prevailing classical and then neoclassical doctrine. Before the crisis of 1929-1933 and the advent of the regulated market era, according to Say’s “law of markets”, general overproduction was considered impossible. Therefore, the market price mechanism was the only effective tool for ensuring the equilibrium state of the economy. The needs of potential buyers were not analyzed and were not the subject of special (marketing) research. Until the mid-twentieth century, the market was dominated by manufacturers of mass-produced standardized goods. Market research, which we now call marketing analytics, took place only in trade, which was separated from production. However, even then A. Marshall pointed out that an industrial entrepreneur should act not only as an organizer of production, but also as a seller. “A manufacturer producing goods for the general market must, above all, act as a trader and possess a thorough understanding of all the characteristics of their industry. They must be able to anticipate general trends in production and consumption, and identify opportunities to launch a new product that meets a genuine need, or to improve the production process for an existing product” [1, p. 372].

In the second half of the twentieth century, the evolutionary concept of marketing was developed, considering it as the basis of strategic planning. The focus shifted to forward-looking market demands and reducing the shortcomings of purely market-based coordination mechanisms. As a result, marketing was considered as a strategic activity of an entrepreneur, aimed at achieving consistent development of the company and substantiating promising innovations. In contrast to the previously existing concept, it became necessary not to position a specific product, but to position the company as a whole in a specific market segment. From the point of view of strategic planning, interaction with the buyer has become more widely understood and includes such elements as:

- manufacturing and marketing of the product;
- logistics of material and information flows;
- determining the nature of interaction between sellers and buyers;
- relationships with suppliers;

- process cycle management in general, up to customer service of the final product, and much more.

At the same time, marketing tasks are not limited to determining the volume of sales. They also include the social and informational aspects of market exchange and the adaptation of products to the needs of each category of customers.

In today's market, consumers prefer to deal with companies that are able to quickly rebuild production in accordance with the interests of their customers. These interests are taken into account with the help of information technologies. As a result of their use, it is possible to build relationships between the buyer and seller in the form of long-term non-detailed contracts. Such contracts are based on taking into account the limited rationality of the behavior of transaction participants and external institutions. An example is so-called online marketing, which includes identifying customers, sales channels, payment methods, transport logistics, inventory and warehouse management [2].

In modern marketing activities, competitors are objectively involved in a new form of economic relations. They are forced to consider each other's interests and build a common strategy for market coverage. The increasing complexity of economic relations enhances the role of the planned beginning, introduces programming and modeling of market relations as a basic component in marketing. This means that the transition from private, purely commercial marketing to global socio-economic and environmental marketing is inevitable. It will be characterized by other forms of competition, long-term economic ties, with increased innovation activity of economic entities. As a result, we start talking about marketing management. It ensures the organization of interaction with all subjects of the marketing system in order not only to study, but also to generate demand in the relevant market segment. Effective communication policy is based on forecasting, planning and organizing relationships with partners, competitors and consumers. Relationships also include the organization of counter-marketing during contracting. In essence, this is already marketing, aimed at establishing, maintaining and developing two-way relationships between entrepreneurs and consumers and other participants in the process of creating added value, while respecting the interests of all participants. Today, marketing management is interpreted as a new marketing paradigm that forms the basis for a qualitative new type of economic management. Overcoming the simplified concepts of marketing as a category of market exchange opens up the way to the development of mesoeconomic marketing as a network form of partnership interaction.

Market analysis at the meso-level involves evaluating its main characteristics in order to achieve maximum superiority over competitors. At the same time, the following market parameters are distinguished: size and capacity, its share controlled by the company, development trends, the level of adaptability to changes in the market environment, and criteria for choosing marketing solutions. The result of the analysis is to find the best combination of the company's competitive advantages with the development of the situation in the mesosystem and in the surrounding market environment.

While classical liberal economic theory focused on the equivalence of exchanges in terms of value, modern marketing focuses on the effectiveness of exchanges in terms of the excess of total benefits over costs. Production efficiency,

taking into account the macroeconomic effect, and the equivalence of exchanged goods in value do not coincide and may conflict. In the modern economy, minimizing costs takes a back seat to maximizing the utility of a product. It will only be sold if it has more value for the buyer than the amount of money requested for it. This amount, which covers production costs and the usual rate of profit, may differ from the equilibrium price that suits both parties to the transaction if the seller or buyer has a surplus.

In the late 70s of the twentieth century, the concept of macromarketing as a form of regulation of aggregate demand and supply of goods with the participation of the state began to develop in the economic literature. At the same time, based on aggregated data, two types of marketing are distinguished: social and socio-ethical. Social marketing is associated with the development, implementation and control of social programs aimed at increasing innovation activity and society's receptivity to new social ideas. Social and ethical marketing is interpreted as a type of marketing activity aimed at making managerial decisions that align the needs of consumers, the positions of enterprises and the long-term interests of society as a whole.

Ph. Kotler linked the social, ethical and environmental aspects of entrepreneurship together by introducing the concept of socially responsible marketing, which focuses on balancing the interests of the firm and society as a whole, including ways to resolve corporate conflicts, etc. [3, p. 435]. It thus acts as an integrator and moderator of the market, listening to the voice of the buyer, orienting investment and production to predictable needs, and stimulating innovation and entrepreneurship. At the same time, the effectiveness of a marketing strategy at the macro level depends on the degree of its adaptation to the peculiarities of national entrepreneurship.

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THE CASE CHAMPIONSHIP “LOGISTIKIQ” AS A GROWTH POINT FOR STUDENTS, EDUCATORS AND PROFESSIONALS

Abstract. This article presents a systemic analysis of the multifaceted synergistic effect emerging in the educational process through the integration of students, faculty, and practicing professionals within the “LogistikIQ” case championship. The authors substantiate that this project serves not merely as a competitive platform but as a genuine “growth hub”, generating qualitative transformations across all levels of logistics education.

Special attention is given to intergenerational dialogue as the key mechanism for knowledge transfer: students contribute fresh perspectives and proficiency in modern digital tools; faculty provide methodological depth and scientific rigor to solutions; and industry professionals set the agenda of real-world business challenges and effectiveness criteria.

The article elucidates how the systemic involvement of all three parties across every stage of the championship – from case development to solution defense and post-competition reflection – triggers mutual learning (learn), enhances teaching quality (teach), and fosters super-professional competencies in students. It demonstrates that the resulting synergistic effect manifests in increased motivation, reduced theory-practice gap, and the formation of a sustainable academic-professional community.

The article is addressed to educational process organizers, faculty in logistics-related disciplines, and all those interested in effective formats for university-business interaction within the context of lifelong learning and intergenerational continuity.

Keywords: “LogistikIQ” case championship, synergistic effect, intergenerational dialogue, student-centered learning, education-business integration, growth hub, lifelong learning.

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«ЛОГИСТИКУМ» – ТОЧКА РОСТА ДЛЯ СТУДЕНТОВ, ПРЕПОДАВАТЕЛЕЙ И ПРОФЕССИОНАЛОВ

Аннотация. Статья посвящена системному анализу многогранного синергетического эффекта, возникающего в образовательном процессе в результате интеграции студентов, преподавателей и практикующих профессионалов в рамках кейс-чемпионата «ЛогистикУМ». Авторами обосновывается, что данный проект выступает не просто соревновательной площадкой, а полноценной «точкой роста», генерирующей качественные изменения на всех уровнях логистического образования. Особое внимание уделяется диалогу поколений как ключевому механизму трансфера знаний: студенты привносят свежесть взглядов и владение современными цифровыми инструментами, преподаватели обеспечивают методологическую глубину и научную обоснованность решений, а профессионалы-практики задают актуальную повестку реального бизнеса и критерии эффективности.

В статье раскрывается, как системное участие трех сторон на всех этапах чемпионата – от разработки кейсов до защиты решений и пост-соревновательной рефлексии – запускает взаимное обучение (learn), повышает качество преподавания (teach) и формирует у студентов надпрофессиональные компетенции. Показано, что возникающий синергетический эффект выражается в росте мотивации, сокращении разрыва между теорией и практикой, а также в формировании устойчивого академическо-профессионального сообщества.

Статья адресована организаторам образовательного процесса, преподавателям дисциплин логистического профиля, а также всем, кто заинтересован в поиске эффективных форматов взаимодействия университета с бизнес-средой в контексте непрерывного образования и преемственности поколений.

Ключевые слова: кейс-чемпионат «ЛогистикУМ», синергетический эффект, диалог поколений, студентоцентрированное обучение, интеграция образования и бизнеса, точка роста, непрерывное образование.

In the context of rapid digital transformation and increasingly complex supply chains, one of the most pressing challenges facing logistics education is the need to bridge the gap between academic theory and real business practice. One promising way to address this challenge is the integration of education and practice through case-based learning and competition formats, in which the formation and development of a community of students, faculty, and practitioners proceed through the logic of intergenerational dialogue. The LogistikIQ case championship, held within the framework of the Higher School of Technology and Energy of St. Petersburg State University of Industrial Technologies and Design, demonstrates how such a format can evolve from an ordinary competition into a sustainable growth hub for all participants in the educational process [1].

This article is devoted to a systemic analysis of the LogistikIQ case championship as a space for intergenerational dialogue, where academic knowledge, the practical experience of professionals, and the energy of youth converge. Special attention is given to the preparation of teams, the organization of the event, and the subsequent transfer of experience into the educational process, which makes it possible to speak of the formation of a synergistic effect extending beyond the boundaries of a single competition [2].

Let us examine in greater detail the issues that reveal LogistikIQ as a practice-oriented platform.

The LogistikIQ case championship is a youth competition format in which student teams solve real business cases proposed by partner companies under time constraints and present their solutions before a professional jury. The format has developed into several tracks, including LogistikIQ.SOFT, LogistikIQ.BACKGROUND, and other variants, which makes it possible to cover different aspects of logistics – from digital solutions to operational work in warehousing and transport [3].

Real cases from companies such as Dialog Terminal, ATI.SU, and other partners set the current agenda of logistics: customer claims management, digital platform optimization, service improvement with cost minimization, and more. This format enables students not merely to solve a textbook problem, but to model a real professional situation in which technical calculations are important, along with the ability to argue a position, communicate with the client, and take the business context into account [4].

A particularly important role is played by intergenerational dialogue in the preparation and implementation of LogistikIQ.

Of growing interest is the implementation of intergenerational dialogue precisely in the process of preparing and organizing the case championship. At the Higher School of Technology and Energy, an active role in this process is played by the university's student affairs unit, which brings together students from different fields and academic years, including those who do not study logistics as part of their core curriculum [5].

By participating in the preparation of the championship-organizing venues, communicating with partners, promoting the event, and providing technical support – students gain access to knowledge and practices that go beyond their study plans, thereby creating a cross-disciplinary dialogue.

A special role is also played by third-year students in the “Logistics and Supply Chain Management” programme (group 335). A team of five is formed from among them to participate directly in the case championship and compete with teams from other specialized universities. In this format, the three-level intergenerational dialogue is realized as follows:

- student organizers from different fields and years share experience in university-business interaction;
- student participants from the third year of logistics consolidate and process this experience into team solutions;
- faculty practitioners and professionals act as mentors, helping the team move beyond standard academic models.

This approach makes it possible not only to prepare a strong team for the championship, but also to create a reserve of ready personnel: if any participants are unable to attend, the already prepared group 335 can quickly adapt the strategy and ensure continuity of the application. This is especially important for fostering a culture of professional readiness and responsibility characteristic of future logisticians.

The results of the LogistikIQ project activities clearly demonstrate a synergistic effect for students, faculty, and professionals [6].

From the perspective of educational theory and the integration of education, science, and business, this large-scale case-based format corresponds to current trends in logistics training through practice-oriented modules and project-based learning. In the preparation and participation in LogistikIQ, the synergistic effect appears at three levels.

First, for students, it means increased motivation, a smoother transition from theory to practice, and the development of transferable skills such as analytical thinking, public communication, time management, and team-role coordination.

Second, for faculty, it provides feedback from business, helps identify blind spots in curricula, and creates opportunities to update teaching methods through live cases.

Third, for professionals, it offers an opportunity to test ideas, assess the potential of young talent, and build sustainable connections with the university, which aligns with the concepts of lifelong learning and academic-professional partnership [7].

It is also worth noting that the participation of student organizers from different academic backgrounds enhances the interdisciplinary nature of intergenerational dialogue, bringing the university closer to a “living” educational community in which the exchange of knowledge and practice takes place not only in the classroom, but also through project-based activity.

LogistikIQ can also be regarded as an important element of gamification in the educational process.

The concept of gamification in education and logistics is increasingly viewed as a tool for increasing engagement, reducing stress, and building long-term motivation

through game-like elements: goals, rules, feedback, time management, and scoring or ranking systems. The LogistikIQ format essentially implements the core principles of gamification:

- limited time for case solving, creating a timer challenge;
- final round with team rankings and defense before a jury, resembling a leaderboard;
- awards and recorded outcomes in the form of certificates and portfolios, serving as badges and recognition.

From the perspective of skills development, this format strengthens students' critical thinking, ability to work under uncertainty, decision-making under pressure, and presentation of well-argued solutions.

For faculty, it develops facilitation, case design, and scenario adaptation skills; in effect, the teacher becomes, together with professionals and organizers, a co-creator of the educational game.

For professionals, it cultivates mentoring skills and structured feedback, which is directly aligned with modern requirements for talent development and generational continuity within companies.

Therefore, LogistikIQ can rightly be described as a gamified laboratory where student-centered learning is combined with practical experience and a research-oriented approach.

Thus, at the present stage, the project has successfully moved beyond the format of “from case to curriculum: sustainable transfer of experience.”

Another important aspect that makes LogistikIQ a true growth hub is the systematic use of developed cases in the educational process. Over eight championships, with two cases in each, a case base has been formed that is actively used in specialized courses in warehousing logistics, transport logistics, and supply chain management [8]. These cases are used to:

- reinforce theoretical models through real business situations;
- broaden students' understanding and demonstrate the links between different elements of the logistics system;
- update faculty expertise through discussion and revision of cases in light of industry changes.

This practice directly corresponds to contemporary approaches to the integration of education, science, and business, where the creation and updating of a case repository is regarded as a key element in preparing logisticians capable of meeting market demands. As a result, intergenerational dialogue continues not only during the preparation and conduct of the championship, but throughout the academic year, when the same cases are discussed by different cohorts of students and faculty.

In conclusion, the LogistikIQ case championship, implemented by the Higher School of Technology and Energy of St. Petersburg State University of Industrial Technologies and Design, demonstrates how a student competition format can evolve into a systemic growth hub for the student community, faculty, and logistics professionals. Through a multi-year cycle of preparation, implementation, and subsequent case dissemination, a synergistic intergenerational dialogue is established,

in which student organizers, participating teams, and mentors from among faculty-practitioners together with the professional community form a sustainable academic-professional network.

Such a format fully corresponds to the theme of the “Intergenerational Dialogue” conference, as it demonstrates how education, the experience of previous generations, and the digital energy of the new generation can be effectively combined in practice. In the future, the expansion and scaling of the LogistikIQ format will make it possible to create a network of similar case championships in other regions and universities, thereby strengthening the integration of logistics education and business practice within the framework of lifelong learning and intergenerational continuity.

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INNOVATION ACTIVITY IN THE FIELD OF DIGITAL TECHNOLOGIES

Abstract. The article examines the issues of business transformation in industrial enterprises under the influence of digital innovations, based on the use of data analysis methods and comparative analysis. The authors pay special attention to revealing the content of the concept of “digital innovation”, selecting threshold values for assessing the state and monitoring the dynamics of innovation activity in the industrial sector, and disclosing the relationship between the level of economic security and innovation activity in the field of digital transformation.

Keywords: innovation activity, digital technologies, economic security.

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ИННОВАЦИОННАЯ ДЕЯТЕЛЬНОСТЬ В СФЕРЕ ЦИФРОВЫХ ТЕХНОЛОГИЙ

Аннотация. В статье рассматриваются вопросы трансформации бизнеса промышленных предприятий под влиянием цифровых инноваций на основе использования методов анализа данных и сравнительного анализа. Авторы уделяют особое внимание раскрытию содержания понятия «цифровые инновации», выбору пороговых значений для оценки состояния и мониторинга динамики инновационной деятельности в отрасли промышленности, а также раскрытию зависимости между уровнем экономической безопасности и инновационной деятельностью в сфере цифровой трансформации.

Ключевые слова: инновационная деятельность, цифровые технологии, экономическая безопасность.

In the context of globalization and increasing competition, Russian enterprises face the need to adapt and constantly transform their management systems. The dynamics of these changes are driven by both internal factors related to innovation and organizational development, and external factors, including technological progress, changes in legislation and consumer preferences. One of the key directions of transformation is the transition to more flexible and adaptive organizational structures. Organizational management models built on a functional basis are gradually being replaced by matrix and project-based models, which to a greater extent allow for a prompt response to changes in the external environment and facilitate coordination among the internal divisions of an enterprise.

The transition to digital technologies in order to maintain and enhance the competitiveness of an enterprise in various areas of economic activity is becoming a highly relevant and widely discussed topic in academic circles. As the analysis has shown, special attention is paid to assessing the impact of digital technologies on the operational activities of an enterprise, and above all, to tools such as ERP systems, the robotization of production business processes, and Big Data, which help reduce production costs and contribute to increased labor productivity. Achieving these goals, in our view, requires coordinated efforts from academia, business, and the state, aimed at creating conditions for the widespread implementation of innovations.

At the same time, it is necessary to consider a multitude of factors when assessing the process of investing in digital technologies, including geographic specifics, industry characteristics, and others.

Nevertheless, general trends allow us to identify key stages in the development of digitalization and the dynamics of financial investments in this area.

In the initial period of digitalization, covering the late 20th and early 21st centuries, the lion's share of investment went into the acquisition of computer equipment, the development of the Internet, and the implementation of basic software solutions. Investment growth during this period was exponential, driven by the desire of enterprises to automate routine operations and improve the efficiency of business processes. With the development of cloud technologies, mobile devices, and big data analytics, the structure of investments has undergone significant changes. These changes indicate a transition to digital business transformation.

Digital business transformation is an innovative activity based on the introduction of relevant ICT into business processes at an enterprise in order to transform the business, up to turning it into a digital form, to maintain or gain competitive advantages, as well as to increase the level of economic security of the enterprise. The internal motivating factor for digital transformation at an enterprise is the need to solve a number of problems in the sphere of production and management under the influence of external factors that create conditions for the inefficient use of traditional systems [1].

According to a number of researchers, a systematic approach to enterprise management in the context of digital transformation best ensures direct and feedback relationships between the elements of the management system, making it more flexible and ready to adjust management decisions and continuously develop the organizational system in order to achieve sustainable functioning of the enterprise [2].

Digital innovations, by facilitating business transformation, are designed to accelerate the pace of economic development of enterprises and ensure their competitiveness. Differences in approaches to formulating the concept of "innovation" as a process of applying new knowledge, technologies, materials, or as a result of their application, in our opinion, are not significant, since the process and the result are interconnected. Nevertheless, considering innovation as a positive result leading to essential changes in the enterprise's activities (updating technologies and product lines, sustainable business development, etc.) in a competitive market environment is considered more preferable. On the other hand, the concept of "innovation activity" can already be viewed as the process of creating innovations, since the result is already embedded in the concept of "innovation" [3].

A number of studies indicate a high positive correlation between GDP per capita and two indices: the Global Innovation Index and the Digital Competitiveness Index. Another important indicator is the level of innovation activity. Despite its relatively low level, the Russian Federation maintains a positive dynamics of innovative growth; as a result, according to Rosstat data, this indicator in 2024 amounted to 12.5 %, and in the manufacturing industry – 23.7 %.

According to available data, the average life cycle of high-tech IT developments is approximately 2.5 years from the date of market entry. As threshold values for assessing the state and monitoring the dynamics of innovation activity in the industrial sector, the following indicators can be proposed: the share of innovative industrial products is at least 25 %, the intensity of spending on technological innovations is at least 3 % per year, and the level of innovation activity is at least 30 % [4].

For some time, it was believed that innovation activity in the field of digital technologies was associated with significant information security threats for users. However, today the development and implementation of cyber-physical systems have had a significant impact on reducing these threats. As practice shows, the use of cyber-physical systems increases the uptime of the system array by almost 40 %. It can be concluded that there is a direct relationship between the level of economic security and innovation activity in the field of digital transformation [5].

Economic security at an enterprise consists of elements such as challenges, dangers, threats, and risks. The correlation and interrelation of these elements in the context of the economic security of an enterprise is presented in the Figure.

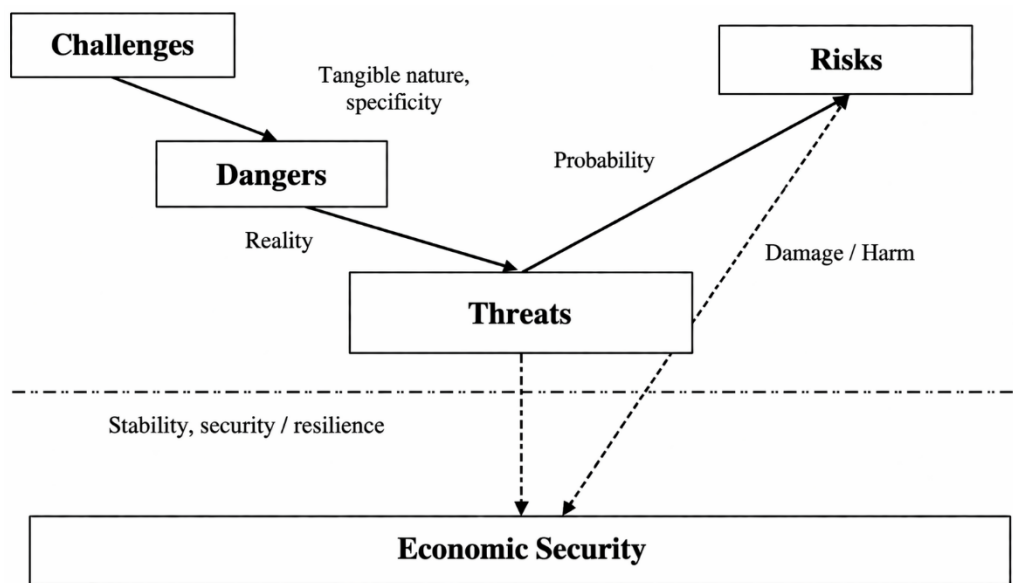


Figure. Elements of economic security at an enterprise.

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DIGITAL ECONOMY: FOR THE BENEFITS OF PROGRESS AND WELL-BEING

Abstract. The article examines the development of the digital economy in Turkmenistan, focusing on the implementation of modern technologies in various sectors. Key programs and concepts aimed at modernizing and diversifying the economy, as well as increasing efficiency and creating new services, are discussed. Special attention is given to the role of innovative technologies, such as artificial intelligence and big data, in economic growth and improving the quality of life for the population.

Keywords: digital economy, innovative technologies, economic modernization, artificial intelligence, socio-economic development programs.

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ЦИФРОВАЯ ЭКОНОМИКА: ВО БЛАГО ПРОГРЕССА И БЛАГОПОЛУЧИЯ

Аннотация. В статье рассматривается развитие цифровой экономики в Туркменистане с акцентом на внедрение современных технологий в различные отрасли. Обсуждаются ключевые программы и концепции, направленные на модернизацию и диверсификацию экономики, а также повышение эффективности и создания новых услуг. Особое внимание уделено роли инновационных технологий, таких как искусственный интеллект и большие данные, в экономическом росте и улучшении качества жизни населения.

Ключевые слова: цифровая экономика, инновационные технологии, модернизация экономики, искусственный интеллект, программы социально-экономического развития.

Introduction. In the era of the Revival of the New Epoch of the Powerful State, under the wise leadership of the Esteemed President, well-considered measures are being consistently implemented in our country to develop the digital economy, introduce scientific achievements into production, and manage trade and industry, agriculture, transport and communications, science and education, and other sectors on an innovative basis. All enterprises operating within the economic system are being equipped with the world's most advanced machinery and technologies. The implementation of innovations contributes to strengthening the national economy and qualitatively improving the living standards and quality of life of the population.

In recent years, the digital economy has become a widely discussed topic among politicians, economists, and experts. This is primarily due to the fact that many countries have managed to achieve significant progress by successfully integrating the achievements of scientific and technological development – particularly digital data and technologies – into their economies [1, 2].

Turkmenistan is consistently carrying out reforms aimed at modernizing and diversifying its economy across all sectors, as well as at a gradual transition to an industrial-innovative model of development, while putting forward initiatives of regional and global significance. At the core of the market reforms implemented in the country and the socio-economic results achieved lie the principles of state regulation and public administration pursued under the leadership of the Esteemed President. These principles find their concrete expression in carefully developed and effectively implemented development programs, strategies, and comprehensive concepts.

Among the key documents are:

- The National Program “Revival of the New Epoch of the Powerful State: Socio-Economic Development of Turkmenistan for 2022–2052”;
- The Program of the President of Turkmenistan for the Socio-Economic Development of the Country for 2022–2028;
- The National Program for Improving the Living and Social Conditions of the Population of Villages, Settlements, Cities within Etraps, and Etrap Centers until 2028.

In Turkmenistan, which has chosen the path of comprehensive renewal and digital development, particular importance in the successful implementation of these objectives is attached to the Concept for the Development of the Digital Economy in Turkmenistan for 2019–2025. This Concept provides for comprehensive support and development of private entrepreneurship, enhancement of investment activity, transition of the public administration system to a modern digital foundation, creation of additional jobs for the population, as well as effective attraction and utilization of large-scale investments on a comprehensive basis. One of the key objectives of the document is to attract investment in the development of information and communication technologies and the Internet network.

Purpose and functions of the work. The objectives set for the wide attraction of foreign investment into priority sectors of Turkmenistan’s economy and for stimulating the investment activity of private enterprises create favorable conditions for national producers – primarily individuals and legal entities operating in the private sector – to adopt advanced and highly productive innovations in production and marketing [3, 4].

The digital economy is a complex and multifaceted system in which various technological solutions influence the development of business, public administration, the social sphere, and other areas. The most important directions of digitalization include the implementation of innovative technologies such as artificial intelligence, big data, the Internet of Things, and cloud computing, which open up new opportunities for data processing, efficiency enhancement, and the creation of new products and services. These areas are not limited to transforming existing processes but also contribute to significant changes in the structure of the economy and society as a whole.

Main part. Based on an analysis of foreign scientific literature and Internet sources, the table below presents the main directions of the digital economy, the key technologies applied within them, and their impact on the economy.

Table. Main Directions of the Digital Economy and Their Impact on the Economy

Directions of the Digital Economy	Overview	Key technologies	Impact on the economy
Digitalized Business	the use of digital technologies to optimize business processes and increase efficiency	ERP systems, CRM systems, cloud services, mobile applications	contributes to higher productivity, cost reduction, and improved customer service
Electronic Commerce (e-commerce)	offering goods (works, services) via the Internet and the development of online trade	online stores, electronic payment systems, mobile applications	leads to increased sales volumes, market expansion, and greater accessibility of goods

Digitalization of Public Administration	improving and increasing the accessibility of government processes and services through digital technologies	electronic government services, data management systems, blockchain	simplifies interaction with citizens and enhances transparency
Big Data	collection, processing, and analysis of large datasets to improve managerial decision-making	Hadoop, Spark, analytical platforms	ensures greater accuracy in decision-making, increased efficiency, and the creation of new products and services
Internet of Things (IoT)	data collection and process automation through devices and sensors connected to digital systems	smart devices, sensors, 5G networks, cloud computing	enhances convenience and safety, optimizes processes, and enables the creation of new services
Artificial Intelligence (AI)	application of algorithms and machine learning to solve complex problems and automate processes	machine learning, neural networks, deep learning	improves forecasting accuracy, increases automation, and supports the development of new products and services
Cybersecurity	protection of information and data in digital systems from external threats	antivirus systems, encryption technologies, blockchain	builds user trust, ensures data protection, and reduces the risks of data breaches
Cloud Technologies	provision of computing resources and data via the Internet for more flexible and accessible use	AWS, Microsoft Azure, Google Cloud	reduces infrastructure costs, improves accessibility of services and data, and enhances flexibility and business efficiency

This table makes it possible to systematize the main directions of the digital economy, the technologies applied within them, and their impact on the economy,

which, in turn, may be useful for scientific research devoted to the study of digital transformations in various spheres of life [4, 5].

At present, such widely implemented and universally accessible tools as electronic payments, e-commerce, and online marketing represent some of the positive outcomes of the digitalized economy. The extensive use of information technologies and Internet capabilities contributes to saving consumers' time and resources, ensuring rapid service delivery, and reducing the volume of information used in paper form, which can also be regarded as an important advantage of digital technologies.

Conclusions. In accordance with Turkmenistan's long-term strategy for socio-economic development, the further development of the digital economy will be carried out based on the subsequent stages of the industrial revolution. This will provide access to advanced digital infrastructure, a developed market for information and communication technologies, and modern digital services.

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**MANAGEMENT OF SOCIAL PARTNERSHIP BETWEEN EDUCATIONAL
ORGANIZATIONS AND BUSINESS AS A MECHANISM
FOR THE DEVELOPMENT OF REGIONAL SOCIO- ECONOMIC
SYSTEMS**

Abstract. Modern economic development is accompanied by profound transformations associated with the formation of an innovation-oriented model of socio-economic development. The management of social partnership between educational organisations and business acts as a mechanism for the development of regional socio-economic systems. In this regard, the development of social partnership becomes particularly relevant, as it makes it possible to combine the potential of educational institutions, business, and society in order to address the challenges of workforce development and sustainable economic growth. The study analyses the key factors that contribute to the successful implementation of strategic partnerships and managerial technologies. The system of managing social partnership facilitates the formation of stable human resource flows, improves the quality of educational training, and supports the development of innovative educational initiatives. As a result, it is concluded that the integration of the educational environment and the business community generates new managerial approaches to the development of human capital, which in modern conditions becomes an important factor in the socio-economic growth of regions.

Keywords: social partnership, educational organisations, business, management, socio-economic systems, human capital, regional development, interaction between education and business.

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УПРАВЛЕНИЕ СОЦИАЛЬНЫМ ПАРТНЕРСТВОМ ОБРАЗОВАТЕЛЬНЫХ ОРГАНИЗАЦИЙ И БИЗНЕСА КАК МЕХАНИЗМ РАЗВИТИЯ РЕГИОНАЛЬНЫХ СОЦИАЛЬНО-ЭКОНОМИЧЕСКИХ СИСТЕМ

Аннотация. Современное развитие экономики сопровождается глубокими преобразованиями, связанными с формированием инновационно ориентированной модели социально-экономического развития. Управление социальным партнерством образовательных организаций и бизнеса является механизмом развития региональных социально-экономических систем. В связи с этим особую актуальность приобретает развитие социального партнерства, позволяющего объединять потенциал образовательных организаций, бизнеса и общества для решения задач кадрового обеспечения и устойчивого экономического роста. В статье анализируются ключевые факторы, способствующие успешному внедрению стратегического партнерства и управленческих технологий. Система управления социальным партнерством способствует формированию стабильных кадровых потоков, повышению качества образовательной подготовки и развитию инновационных образовательных инициатив. В результате сделан вывод о том, что интеграция образовательной среды и бизнес-сообщества формирует новые управленческие подходы к развитию человеческого капитала, которые в современных условиях становятся важным фактором социально-экономического роста регионов.

Ключевые слова: социальное партнерство, образовательные организации, бизнес, управление, социально-экономические системы, человеческий капитал, региональное развитие, взаимодействие образования и бизнеса.

Modern economics develops under conditions of significant structural changes caused by the acceleration of scientific and technological progress, the spread of digital technologies, and increasing global competition. In such conditions, human capital is beginning to play an increasingly important role, being regarded as one of the key factors of sustainable socio-economic development. The training of qualified specialists becomes a critical condition for ensuring innovative growth and enhancing the competitiveness of regions. It is educational organisations that form the human resource potential on which the development of the economy and social sphere of territories largely depends [1].

At the same time, there is a growing need for closer interaction between the education system and the real sector of the economy. Traditional models of specialist training, based predominantly on academic learning, are increasingly insufficient to meet the demands of the modern labour market. Employers are interested in graduates who possess not only fundamental knowledge but also practical skills, experience in project activities, and an understanding of the specifics of the professional environment [2].

Under these circumstances, the development of mechanisms for interaction between educational organisations and business acquires particular importance. Such cooperation makes it possible to align the content of educational programmes with the current needs of the economy and to improve the efficiency of specialist training. One of the most effective tools for such interaction is social partnership.

In scientific research, social partnership is viewed as a system of stable institutional relations between various actors of socio-economic activity aimed at achieving mutual interests and the development of society as a whole [3]. Such interaction contributes to improving the quality of educational services and developing innovative educational projects [4]. In the field of education, it implies the formation of long-term cooperation between educational organisations, enterprises, public authorities and civil institutions. One of the most effective instruments of this interaction is social partnership. Social partnership between the educational environment and enterprises makes it possible to build sustainable mechanisms for specialist training oriented towards the real needs of the labour market. Collaboration of this scope has a noticeable impact on the development of regional socio-economic systems. This model of interaction improves the quality of vocational training, introduces modern technologies and practice-oriented learning. The implementation of practices into the economy has its own regional specificity. Besides, enterprises gain the opportunity to participate in shaping the professional competencies of future specialists, thus enabling the training of personnel that are in demand in various sectors of the economy [5]. The effectiveness of interaction between educational organisations and business is largely determined by the presence of a well-thought-out management system. A particular role in this process is played by the management of social partnership. The main managerial mechanisms include strategical planning of partnership programmes, coordination of the participants' activities, and evaluation of the results of implemented projects [6]. To form sustainable and long-term relations between the education system and the economic sector, appropriate institutional conditions must be created. These conditions should provide an organisational basis for the development of social partnership, facilitate the alignment of participants' interests, and ensure the stability of joint educational and personnel projects.

The methodological basis of the study comprises general scientific and special methods of analysing socio-economic processes. Both theoretical and empirical approaches were used, allowing social partnership between educational organisations and business to be considered as a complex system of interaction among various actors of the regional economy.

One of the main research tools is the systems approach, which enables the analysis of social partnership as a set of interconnected elements, including educational organisations, enterprises, and governing bodies. The application of this approach makes it possible to view the interaction between education and business not as isolated initiatives, but as an integrated mechanism for shaping the region's human resource potential [7].

The institutional approach is also applied, which allows social partnership to be examined as a stable system of relations between different social institutions. This approach helps to identify the features of the formation of cooperation mechanisms

between educational organisations and enterprises and to determine the role of various participants in the process of training qualified specialists [8].

To analyse the effectiveness of interaction between educational organisations and enterprises, methods of comparative analysis, synthesis of scientific sources, and examination of practical experience in implementing educational projects were employed. The analysis of scientific literature revealed the main trends in the development of social partnership in the educational sphere [3, 9]. In the context of economic transformation and accelerated technological development, the formation of mechanisms for integrating education, science, and industry becomes particularly important. School education is becoming the initial stage of vocational training. Basic knowledge and professional interests form the main motivation for mastering engineering and technological specialities. The high effectiveness of social partnership is confirmed by employment and admission rates to regional secondary vocational and higher education institutions. School graduates, within the framework of social partnership, demonstrate a high level of pre-professional training. The management of interaction processes becomes the key formula for success. Within regional educational policy, social partnership performs a specific function. Social partnership between education and business makes it possible to create effective mechanisms for personnel training oriented towards the real needs of the economy. An essential component of such interaction in the educational process is the participation of both the educational institution and the enterprise. This approach allows the requirements of modern production to be taken into account when developing curricula. Enterprise representatives act as mentors and experts, delivering lectures, master classes, and career guidance activities [10]. Systemic effects of social partnership for all subjects of the educational process have been identified. For educational organisations, this is expressed in increased competitiveness, development of the material and technical base, and attraction of additional resources. For students this results in a higher level of professional readiness and successful employment, for business – in reduced costs for training and adaptation of personnel, as well as the formation of a stable personnel reserve. Under social partnership, a key role is also assigned to teachers and the management team. Teachers act not only as transmitters of knowledge but also as moderators of project activities, mentors, and coordinators of interaction with business partners. The managerial leadership of educational institutions ensures strategic planning of partnership, its institutionalisation, and sustainability. In contemporary practice of interaction between education and business, there are numerous examples of successful cooperation. Today, students demonstrate the ability to harmoniously combine digital technologies and humanistic values of education, which meets the modern requirements for the development of educational systems [1, 7]. Within the framework of social partnership, enterprises actively participate in the implementation of career guidance programmes. Such interaction is possible only with a properly constructed management strategy. The implementation of integrative educational models makes it possible to improve the quality of training of future specialists. In educational institutions, the learning process is aimed at developing students' interest in professional activity and a conscious choice of future profession. Such interaction is possible through processes that include professional trials, internships, work placements, and joint educational projects [1, 5]. From a scientific perspective, the

issue of social partnership in education has been widely covered in the works of both Russian and foreign researchers. However, most studies focus on individual levels of education – mainly secondary vocational and higher education, while the issues of integrating all levels into a single system of lifelong education remain insufficiently developed. Social partnership plays a huge role, as it is on this basis that innovative educational programmes and projects are implemented. The creation of an interaction platform becomes important. Managing social partnership involves establishing a sustainable system of interaction between educational institutions and industrial enterprises. Collaboration between the education system and business contributes to improving the quality of personnel training. The development of practice-oriented learning makes it possible to acquire real professional skills in a production environment. The data obtained can be used in the design of educational programmes and regional personnel training strategies, as well as for making managerial decisions on the development of human capital. The management of social partnership between educational organisations and business is an important factor in the development of regional ecosystems. Overall, innovative management technologies combined with social partnership should be considered as a strategic development resource that ensures integration into the regional economy and the formation of competitive human capital. Prospects for further research are related to the development of new models of social partnership management, as well as to the effectiveness of various forms of interaction between educational organisations and business in the context of the digital transformation of the economy.

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CHINESE MANAGEMENT MODEL

Abstract. The article examines the Chinese management model rooted in Confucianism and Taoism. Key characteristics include paternalism, collectivism, guanxi, and a leadership style based on experience and long-term orientation. A comparison with the Western model reveals differences in structure, decision-making, and attitudes toward personnel. The Chinese model creatively adapts Western methods to national philosophy, forming a dynamic system that contributes to global management thought.

Keywords: Chinese management, Western management, comparative analysis, Confucianism, guanxi, paternalism, collectivism, leadership.

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КИТАЙСКАЯ МОДЕЛЬ МЕНЕДЖМЕНТА

Аннотация. В статье рассматривается китайская модель управления, коренящаяся в конфуцианстве и даосизме. Ключевыми характеристиками модели являются патернализм, коллективизм, гуаньси (личные связи), а также стиль лидерства, основанный на опыте и долгосрочной ориентации. Сравнение с западной моделью выявляет различия в структуре, процессе принятия решений и отношении к персоналу. Китайская модель творчески адаптирует западные методы к национальной философии, формируя динамичную систему, которая вносит вклад в мировую управленческую мысль.

Ключевые слова: китайский менеджмент, западный менеджмент, сравнительный анализ, конфуцианство, гуаньси, патернализм, коллективизм, лидерство.

In the context of deepening economic interaction between Russia and China, understanding the national features of Chinese management is becoming a necessary tool for successful cooperation. China has developed a unique management system deeply rooted in its own cultural and philosophical tradition. The Chinese management model represents a holistic ideological complex that determines the principles of building organizational relationships, leadership style, communication practices, and methods of motivating personnel.

The Chinese management model is based on millennia-old traditions and philosophical teachings, primarily Confucianism and Taoism [1]. These teachings have shaped the basic principles that continue to influence business practice.

The central element of Confucian values is the concept of hierarchy, modeled on the patriarchal family. The leader plays the role of a strict but caring father, while subordinates play the role of children. This structure implies unconditional respect for those senior in rank and age, as well as loyalty directed not at an abstract organization, but personally at the superior. A crucial role is played by the concept of “face” (面子), which requires employees to show initiative in a polite and thoughtful manner so as not to put the leader in an awkward position or “lose face” themselves [1].

From Taoism comes the principle of striving for harmony and balance. Management is viewed as the art of “adapting to change”, which implies flexibility, intuition, and the ability to adapt to the present moment, rather than blindly following formal rules and laws. Chinese thought examines all phenomena in their integrity, believing that even minor events, such as the weather or the leader’s breakfast, can influence the outcome of a matter [2].

The philosophical and cultural foundations discussed above give rise to several key characteristics of organizational structure and management specific to Chinese organizations.

Paternalism and Authoritarianism. Management is authoritarian in nature, where power is concentrated in the hands of a single leader. He distributes tasks received from above and bears full responsibility for their execution [1]. This leadership style is reinforced by the desire for total control over subordinates, which is partly explained by uncertainty about the future and the desire to minimize risks.

Collectivism and Teamwork. In contrast to Western individualism, collectivism prevails in Chinese culture [1]. Employees perceive the successes and failures of the company as their own. Management is a holistic process in which not only managers but also subordinates are equally involved [2]. The goal is the maximum return of the entire system, rather than merely achieving formal indicators.

The Role of Guanxi (关系) and Familialism. Personal connections and informal relationships (guanxi) are of great importance. Society in the Chinese understanding is divided into three spheres: family, friends and acquaintances, and everyone else [2]. This structure is projected onto business: many companies,

especially small and medium-sized ones, are family enterprises [3]. A personal appeal to a leader is often more effective than an official request. Business reputation and trust within the network of contacts are key assets.

The specific organizational structure and management practices described above naturally determine the unique leadership and decision-making style characteristic of Chinese organizations.

Experienced Leader. In China, a leader (经理, jīnglǐ) is not just a manager, but a person deeply versed in the essence of the matter and the “system of laws”. Preference is given to candidates who have worked for a long time at a given enterprise and possess solid practical experience, rather than recent university graduates. Experience is valued as the ability to respond wisely and timely to a situation, making balanced decisions with a “cool head” [2].

Long-Term Orientation and Intuition. Chinese management is focused on long-term development and unlocking the potential of employees. Decision-making is a slower and more deliberate process compared to the Western “time is money” approach. Chinese managers rely more on intuition and a holistic vision of the situation, which from the perspective of a Western observer may look like an inability to clearly formulate production tasks.

The Chinese and Western management models have fundamental differences rooted in cultural, historical, and philosophical premises.

The key characteristics of the Chinese management model are summarized in the Table.

Table. Comparison of Chinese and Western management models [3-6]

Characteristic	Chinese Model	Western Model
Foundation	Personal relationships, hierarchy, guanxi	Formal rules, laws, contracts
Focus	Long-term development, harmony, human potential	Short-term result, profit, task efficiency
Structure	Paternalistic, authoritarian, centralized	Flatter, decentralized, function-based
Decision-making	Intuitive, collective (with leader’s approval), slow	Analytical, individual, fast
Attitude towards personnel	Leader as “father”, personal loyalty	Leader as professional manager, loyalty to the company
Control	Strict, total control over the process	Control based on results, delegation of authority
Cultural metaphor	“Garden culture” (nurturing)	“Fishing culture” (harvesting)

The modern Chinese model is not a rejection of Western achievements, but rather their creative adaptation and synthesis with national philosophy. Entrepreneurs actively promote the idea of combining Chinese wisdom with advanced scientific management methods. Companies transplant Western achievements onto their own soil, which yields high results and ensures rapid economic growth [2]. At the same time, unique Chinese practices, such as flexibility, speed, and adaptability, are becoming the subject of study in the West [1].

Technological development, in particular cloud computing, is also transforming management, giving rise to the so-called “era of cloud management” (云管理时代), which requires even greater flexibility and innovativeness from companies. Thus, the Chinese management model is not a frozen dogma, but rather a dynamic and evolving system striving to make its contribution to global management thought.

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HEALTH TOURISM AS AN INTERDISCIPLINARY AREA FOR PEOPLE OF HELPING PROFESSIONS

Abstract. Currently, there is a need worldwide to develop and modernize the humanistic principles of tourism, which is focused on preventing diseases among the population, in order to achieve economic feasibility and social integration. Organized leisure activities, strengthening the body, and treatment in the early stages of disease contribute to the health of the nation, improving the demographic situation, creating specific social institutions, and introducing new specializations, as well as preparing young people for professional activities. Health tourism aims to strengthen the economy and create a favorable psychological environment for the development of each person. Creating new jobs for young people of helping professions will help to rejuvenate the population in these areas.

Keywords: health tourism, tourism potential, job creation, employment among specialists in helping professions, training for young people, and demographic growth.

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ОЗДОРОВИТЕЛЬНЫЙ ТУРИЗМ КАК МЕЖДИСЦИПЛИНАРНОЕ НАПРАВЛЕНИЕ ПОДГОТОВКИ СТУДЕНТОВ ПОМОГАЮЩИХ ПРОФЕССИЙ

Аннотация. В настоящее время во всем мире созрела необходимость развития и модернизации гуманистических принципов туризма, ориентированного на предотвращение заболеваний среди населения, в целях экономической целесообразности, интеграции общества. Организованный досуг, укрепление организма и лечение на ранних стадиях заболевания способствуют оздоровлению нации, улучшению демографической ситуации, созданию определенных социальных учреждений, появлению новых специализаций, подготовке молодежи к профессиональной деятельности. Оздоровительный туризм направлен на укрепление экономики, создание благоприятного психологического фона для развития каждой личности.

Создание новых рабочих мест для молодежи помогающих профессий поможет омолодить население данных мест.

Ключевые слова: оздоровительный туризм, туристический потенциал, создание рабочих мест, трудоустройство среди специалистов помогающих профессий, обучение молодежи, подъем демографии.

In the current situation in Russia, which is accompanied by armed conflicts in the world, recreational or health-improving tourism has become particularly relevant. The special rehabilitation of people with post-traumatic stress disorder, musculoskeletal disorders, and many young people with special health needs is seen as a necessary task not only for improving the psychological health of the nation, but also as a factor that enhances the health and productivity of individuals of all ages. This can be seen in the film *Avatar*, where a disabled person's life is replaced in a fantastic world. Working through both male and female archetypes not only contributes to therapy, but also allows one to find new images and archetypes for a new phase of your life.

Trainings with photography allow us to explore our own bodily reflections of archetypes. Philip Sokolov's training gives the readers his methodology for conducting such an author's project in his article on social service practice: "The article presents a methodology for author's training of working with female and male archetypes using dance and photography as a possible practice of working with injuries. The training aims to identify and develop the style of self-presentation of clients with the study of movements and the analysis of visual images. Using the theory of archetypes by C. G. Jung and the developments by Galina Bednenko, the author describes a number of exercises that he includes in his training" [1, p. 178].

In a situation of accelerating pace of life and inability to feel the beauty of the world around us due to information overload, the urban resident seeks to find a resource more often in a small and quiet town than in a big one. The development of recreational tourism in small towns requires the study of the tourist and medical potential of small towns and the discovery of new specializations among people of helping professions – practitioners, psychologists, social educators, teachers, psychotherapists, athletes, etc.

Climate changes, topography, altitude, the presence of healing springs, and the absence of harmful industries – all these factors create an initial great potential for both health-improving and rural tourism [2]. The presence of hills and mountains in the area makes vacationers' nervous and musculoskeletal systems more resilient [3].

During spa treatment, doctors recommend a more drastic change in climate, which trains all body systems, according to an additional resource. People in the Silver age are not recommended to undergo sudden shifts in climate. Organs that have not been sufficiently trained in one area begin to activate themselves when moving to a different location and change the lifestyle.

However, this same group of people, having received retraining and a new specialization, could be actively involved in many aspects of health promotion in their local area: conducting master classes, giving lectures, presenting their own books, organizing activities and competitions (including those for people with disabilities), and organizing psychotherapeutic and encounter groups.

Many modern resorts organize master classes for special categories of tourists, especially for children with narcissistic spectrum disorders. Drawing, dough, clay, collage crafts, mandala, coffee drawings, and needlework are becoming very popular among children with disabilities and their parents. The same techniques are used in school education in group work, performing additional psychotherapeutic functions [4].

In the post-Soviet space, in some schools of Uzbekistan, where children with health problems often study in general education classes, interactive methods proposed by Russian methodologists are used to improve the psychological climate in education. In particular, the method of working with the mandala in teaching Russian as a foreign language lessons makes it possible to work with idioms, proverbs, and the clip-based thinking of a modern child, and integrate partial fragments of the image into the whole image. “The symbol of the mandala goes back to the image of the abyss, a funnel formed as a result of a whirlpool, rotation, whirling” [5, p. 502]. Thus, the mandala collects and makes obvious those traumatic experiences that are very difficult to symbolize, and J. Lacan labeled as a sphere of the Real, associated with the terrible and practically unsymbolizable. The use of this technique is especially useful for children with disabilities to work with the development of emotional intelligence.

Currently, due to the demographic crisis in Russia, it seems advisable to revive forms of preventive medicine and sanatorium treatment, especially for the male population who were injured in battles. It is also important to organize rehabilitation centers for dependent people, people with post-traumatic syndrome outside the city on a separate territory. In the situation of a big city with a huge amount of alcohol advertising, this rehabilitation system turns into a prison system, as it requires strict rules and a complete restriction of temptations. The number of men dying from various types of addictions in Russia makes it necessary to fix the scale of the national catastrophe.

The revival of elements of sports tourism also requires rehabilitation specialists [3]. Therefore, it would be useful to introduce a similar specialization among even paramedics, followed by active practice at resorts of this type with further employment. People of the Silver Age, who currently make up the majority of the Russian population, especially in small towns, could play an educational role at the resort.

Within the framework of Russian traditional culture, the revival of bell ringing in Russia is of particular importance, which was carried out by Professor Alexandr Yareshko from the Saratov Conservatory. Bell ringing, with its specificity of perception of overtones by the whole body (not by the ear), is able to heal the human body at the cellular level. Information about bell ringing nowadays could contribute to its intensive revival and the opening of the bell-ringer specialization in music colleges and conservatoires in Russia.

In the context of the revival of the region's chronicles, it would be relevant to organize mobile photo projects, similar to the “Russian Atlantis” project, which brings together realist painters from various Russian cities under the leadership of Vitaly Vasilyev. Additionally, the tradition of creating a photo chronicle of the family ties is crumbling and there is a lack of coverage of good deeds, which is also relevant.

The organization of concerts, cultural performance, and the inclusion of music as a background in parks and on city streets, as well as the holding of fairs, are integral parts of recreational tourism. “Co-creation plays both an organizational and a

psychotherapeutic role, boosting self-esteem and enhancing social adaptation for everyone” [6, p. 461]. Additionally, any resort attracts people to its territory, where individuals with disabilities feel valued and appreciated.

Thus, wellness tourism, which is based on the country’s small towns and is surrounded by a number of projects aimed at reviving the region’s history, could serve as a center for attracting and improving the health of young people, a place of strength, cooperation, and mutual assistance.

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BESONDERHEITEN DER REGIONALEN ZUSAMMENARBEIT DER UdSSR MIT DEN STAATEN DER OSTSEEREGION

Zusammenfassung. Im 20. Jahrhundert entwickelten sich die Beziehungen zwischen der UdSSR und den europäischen Staaten von Konfrontation hin zu der Kooperation, was die Grundlage für die Intensivierung grenzüberschreitender Kontakte in den 1990er-2020er Jahren bildete. In diesem Zusammenhang ist die Untersuchung der historischen Voraussetzungen dieser Zusammenarbeit und der Kanäle der außenregionalen Kommunikation in der Sowjetzeit von besonderem wissenschaftlichem Interesse. Ziel des Artikels ist es, die Besonderheiten der regionalen Zusammenarbeit der UdSSR mit Finnland, Schweden, Norwegen und Polen zu identifizieren. Die methodologische Grundlage bilden die Prinzipien des Historismus und der Systemhaftigkeit sowie Ansätze des Realismus, Funktionalismus, liberalen Institutionalismus und der Paradiplomatie. In der Arbeit wurden historische und allgemeine wissenschaftliche Methoden angewandt. Es wurde festgestellt, dass die Zusammenarbeit außenwirtschaftliche Aktivitäten, Tourismus sowie Städtepartnerschaften umfasste und dabei unter strenger staatlicher Kontrolle stand. Ihr Charakter wurde durch den politischen Kontext bestimmt: Im Verhältnis zu Polen dominierte der ideologische Faktor, mit Finnland überwogen wirtschaftlicher Pragmatismus und gutnachbarschaftliche Beziehungen, während in den Beziehungen zu Norwegen und Schweden Fragen der Abgrenzung maritimer Räume, der Fischerei und des Grenzhandels im Vordergrund standen, was die wirtschaftlichen und geographischen Interessen der beteiligten Seiten widerspiegelte.

Schlüsselwörter: UdSSR, regionale Zusammenarbeit, grenzüberschreitende Beziehungen, Finnland, Schweden, Norwegen, Polen, außenwirtschaftliche Tätigkeit, Paradiplomatie.

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FEATURES OF REGIONAL COOPERATION BETWEEN THE USSR AND THE STATES OF THE BALTIC SEA REGION

Abstract. In the 20th century, relations between the USSR and European states evolved from confrontation to cooperation, laying the foundation for the intensification of cross-border contacts in the 1990s–2020s. In this context, it is of research interest to examine the historical preconditions for this interaction and the channels of extra-regional communication during the Soviet period. The aim of this article is to identify the characteristics of the USSR's regional cooperation with Finland, Sweden, Norway, and Poland. The methodological framework is based on the principles of historicism and systemic analysis, as well as the tenets of realism, functionalism, liberal institutionalism, and paradiplomacy. Historical and general scientific methods were employed in this study. It was established that cooperation encompassed foreign economic activity, tourism, and sister-city relations, while remaining under strict state control. The nature of the interaction was determined by the political context: with Poland, the emphasis was on ideological commonality; with Finland, on economic benefit and good-neighborliness; and with Norway and Sweden, issues of maritime delimitation, fisheries, and border trade prevailed, reflecting the economic and geographical interests of the parties.

Keywords: USSR, regional cooperation, cross-border relations, Finland, Sweden, Norway, Poland, foreign economic activity, parallel diplomacy.

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ОСОБЕННОСТИ РЕГИОНАЛЬНОГО СОТРУДНИЧЕСТВА СССР С ГОСУДАРСТВАМИ РЕГИОНА БАЛТИЙСКОГО МОРЯ

Аннотация. В XX веке отношения между СССР и европейскими государствами прошли путь от конфронтации к сотрудничеству, заложив основу для активизации межгосударственных контактов в 1990-х – 2020-х годах. В этом контексте представляет научный интерес изучение исторических предпосылок данного взаимодействия и каналов внерегиональной коммуникации в советский период. Цель данной статьи – выявить особенности регионального сотрудничества СССР с Финляндией, Швецией, Норвегией и Польшей. Методологическая основа базируется на принципах историцизма и системного анализа, а также на положениях реализма, функционализма, либерального институционализма и парадипломатии. В исследовании использовались исторические и общенаучные методы. Установлено, что сотрудничество охватывало сферу внешнеэкономической деятельности, туризм и побратимские связи, оставаясь при этом под строгим государственным контролем. Характер

взаимодействия определялся политическим контекстом: в отношениях с Польшей акцент делался на идеологической близости; с Финляндией – на экономической выгоде и добрососедстве; а с Норвегией и Швецией преобладали вопросы морского разграничения, рыболовства и приграничной торговли, что отражало экономические и географические интересы сторон.

Ключевые слова: СССР, региональное сотрудничество, трансграничные отношения, Финляндия, Швеция, Норвегия, Польша, внешнеэкономическая деятельность, параллельная дипломатия.

Einleitung

Im 20. Jahrhundert war die Entwicklung der Beziehungen zwischen der UdSSR und den europäischen Staaten durch einen Übergang von gegenseitiger Ablehnung hin zur Kooperation gekennzeichnet, was die Grundlage für die weiteren Beziehungen zwischen der EU und der Russischen Föderation bildete. Von besonderer Bedeutung ist die Analyse der Erfahrungen regionaler und grenzüberschreitender Zusammenarbeit der UdSSR mit einzelnen Staaten, insbesondere der sowjetisch-finnischen Kooperation, die sich trotz der Zugehörigkeit Finnlands zum kapitalistischen Lager aktiv entwickelte. Auch mit Norwegen und Schweden etablierten sich Kooperationsbeziehungen in Grenzregionen. Mit Polen als befreundetem Staat basierten die Beziehungen auf sozial-politischer Nähe. Gerade diese Länder – Finnland, Norwegen, Schweden, Polen sowie die ehemaligen Unionsrepubliken Estland, Litauen und Lettland – wurden Ende des 20. bis Anfang des 21. Jahrhunderts zu zentralen Partnern Russlands in der grenzüberschreitenden Zusammenarbeit, was maßgeblich auf gewachsene historische Verbindungen zurückzuführen ist.

Ziel der Studie ist es, die Besonderheiten der regionalen Zusammenarbeit der UdSSR mit Finnland, Norwegen, Schweden und Polen zu identifizieren. Untersuchungsobjekt ist die regionale Zusammenarbeit der UdSSR mit diesen Staaten, während der Forschungsgegenstand in deren spezifischen Merkmalen und historischer Entwicklung besteht.

Materialien und Methoden

Die Methodologie der Studie basiert auf den Prinzipien des Historismus und der Systemhaftigkeit sowie auf ausgewählten Ansätzen des Realismus, Funktionalismus, liberalen Institutionalismus und der Paradiplomatie [1–4]. In der Arbeit wurden sowohl historische als auch allgemeine wissenschaftliche Methoden angewandt. Die historisch-genetische Methode ermöglichte es, die Entwicklung der Kooperationsformen der UdSSR mit europäischen Staaten im Kontext der allgemeinen historischen Dynamik nachzuvollziehen. Die historisch-vergleichende Methode wurde eingesetzt, um Gemeinsamkeiten und Unterschiede in der Zusammenarbeit mit Finnland, Norwegen, Schweden und Polen herauszuarbeiten. Mithilfe des systemischen Ansatzes wurde die regionale Zusammenarbeit als komplexes Phänomen analysiert, das integraler Bestandteil der Außenpolitik und der internationalen Beziehungen ist.

Die verwendeten Materialien lassen sich in folgende Gruppen unterteilen: internationale Verträge und Abkommen, normative Rechtsakte auf regionaler Ebene sowie Veröffentlichungen in der periodischen Presse, die die Entwicklung der

regionalen Zusammenarbeit widerspiegeln. Die Vielfalt der Quellen ermöglichte eine umfassende Analyse der grenzüberschreitenden Zusammenarbeit der Regionen der UdSSR und die Identifizierung ihrer spezifischen Merkmale.

Ergebnisse

Tabelle. Kooperationsbereiche und Besonderheiten der regionalen Zusammenarbeit der UdSSR mit einzelnen Staaten der Ostseeregion

Land	Kooperationsbereiche	Besonderheiten
Finnland	1. Außenwirtschaftliche Zusammenarbeit, gekennzeichnet durch den Aufbau einer rechtlich-normativen Grundlage in den 1940–1950er Jahren [5] sowie die Entstehung des grenzüberschreitenden Handels ab 1958 (Lieferungen von Strickwaren nach Leningrad, Gründung von “Lenfintorg” und gemeinsamer sowjetisch-finnischer Unternehmen); 2. Kooperation im Bereich Bauwesen und Energie, deren Höhepunkt in den 1960–1970er Jahren lag (Bau des Wasserkraftwerks Werchne-Tulomskaja, des metallurgischen Kombinati “Rautaruukki” in Raahen, des Kernkraftwerks in Loviisa sowie einer Gaspipeline [6, S. 18]); 3. Tätigkeit gesellschaftlicher Organisationen (seit 1958 – sowjetische Freundschaftsgesellschaft “UdSSR–Finnland”, seit 1962 – deren karelische Abteilung), deren Rolle sich von politisch bedeutenden Organisationen zu gewöhnlichen nachbarschaftlichen Vereinigungen wandelte; 4. Städtepartnerschaften (seit 1953), gekennzeichnet durch rasches Wachstum, Intensivierung der Kontakte zwischen Exekutivkomitees der Stadträte der RSFSR und kommunalen Behörden anderer Länder (1970er Jahre), sowie Kooperation in Tourismus, Informationstechnologie, Sport und Kultur (1970–1980er Jahre) und zunehmende Jugendaustausche (1980er Jahre) [7, S. 71–74]; 5. Aktiver Austausch von Delegationen auf regionaler und kommunaler Ebene.	1. Zentrale Bereiche: grenzüberschreitender Handel, Bauwesen, Energie, städtische Paradiplomatie (Städtepartnerschaften), Kultur und Tourismus; 2. stabile Sonderbeziehungen zwischen der UdSSR und Finnland als Verbindungsglied zwischen der UdSSR und dem Westen, geprägt durch den pragmatischen Ansatz Moskaus und die Paasikivi-Kekkonen-Linie.
Norwegen, Schweden	1. Tätigkeit der Freundschaftsgesellschaften “UdSSR–Norwegen” und “UdSSR–Schweden” (seit 1958): in den 1950–1960er Jahren Organisation thematischer Abende und touristischer Reisen, in den 1970er Jahren Ausstellungen, Konzerte, Veröffentlichung schwedischer Autoren in der UdSSR sowie	1. Zentrale Bereiche: Grenzhandel, Ressourcennutzung, begrenzter Tourismus und Kultur; 2. spätere Entwicklung der Städtepartnerschaften

	Ausbau des Russischunterrichts an schwedischen Universitäten [9]; 2. Grenzhandel (z. B. zwischen der Oblast Murmansk und Norwegen); 3. Regelung von Fischereifragen und Abgrenzung maritimer Räume, insbesondere im Zusammenhang mit Spitzbergen [10]; 4. Aufbau von Städtepartnerschaften seit Ende der 1980er Jahre; 5. “Murmansker Initiativen” von M. S. Gorbatschow (1987) als außenpolitisches Maßnahmenpaket, das u. a. die Schaffung einer kernwaffenfreien Zone in Nordeuropa, die Begrenzung militärischer Aktivitäten in nördlichen Meeren, Kooperation bei der Ressourcennutzung und beim Umweltschutz in der Arktis sowie die Öffnung des Nördlichen Seewegs für ausländische Schiffe vorsah [11].	(seit den 1980er Jahren) im Vergleich zu anderen Ländern; 3. starke Abhängigkeit der Beziehungen von der geopolitischen Lage.
Polen	1. Austausch von Produktions-, Kultur- und Sportdelegationen sowie Konsumgütern [12, S. 140–141]; 2. Tourismus als “Instrument kommunistischer Erziehung” und zugleich Einnahmequelle [13, S. 142], mit einer Intensivierung in den späten 1980er Jahren; 3. Städtepartnerschaften (seit den 1950er Jahren) mit dem Ziel, die Einheit des sozialistischen Lagers zu demonstrieren [13, S. 141]; 4. Gemeinsame Verwaltung von Ressourcen, insbesondere von Entwässerungssystemen (Einrichtung einer gemeinsamen Kommission 1959 und rechtliche Verankerung 1967) [12, S. 142–143]; 5. Entwicklung gemeinsamer rechtlicher Grundlagen zwischen regionalen Behörden und lokalen Selbstverwaltungsorganen (Programme und Kooperationsprotokolle der 1980er Jahre) [14].	1. Zentrale Bereiche: Austausch von Delegationen, Konsumgüterhandel, Tourismus, gemeinsame Ressourcennutzung, Paradiplomatie sowie Kooperation zwischen regionalen und lokalen Behörden; 2. Annäherung auf Grundlage ideologischer und wirtschaftlicher Gemeinsamkeiten.

Diskussion

Die grenzüberschreitende Zusammenarbeit in der Sowjetzeit kann im Rahmen einer staatszentrierten Modellperspektive internationaler Interaktionen betrachtet werden, die für den realistischen Ansatz charakteristisch ist [1]. Diese Zusammenarbeit umfasste außenwirtschaftliche Aktivitäten, in gewissem Maße auch Tourismus sowie Städtepartnerschaften und stand zugleich unter strenger staatlicher Kontrolle.

Die Zusammenarbeit mit Polen folgte der Logik des sozialistischen Internationalismus auf der Grundlage ideologischer Nähe, während die Kooperation mit Finnland einen pragmatischen Charakter aufwies und sich dem Konzept des begrenzten Funktionalismus zuordnen lässt [2]. In den Beziehungen zu Norwegen und Schweden dominierten Fragen der Abgrenzung maritimer Räume, der Fischerei sowie des Grenzhandels, was Elemente des liberalen Institutionalismus widerspiegelt [3].

Hervorzuheben ist die Einbindung gesellschaftlicher Organisationen in die grenzüberschreitende Zusammenarbeit, die trotz der Kontrolle durch zentrale staatliche Organe später in der Entwicklung von Prinzipien der Mehrebenen-Governance ihren Niederschlag fand [4].

Schlussfolgerung

Zusammenfassend lässt sich feststellen, dass die regionale Zusammenarbeit der UdSSR ein begrenztes System von Interaktionen darstellte, das durch die dominante Rolle des Staates geprägt war. Inhalt und Formen der Zusammenarbeit hingen von außenpolitischen Prioritäten sowie vom Charakter der bilateralen Beziehungen zu den Nachbarstaaten ab. Gleichwohl bildeten einzelne Kooperationskanäle und -formen mit Finnland, Schweden, Norwegen und Polen die Grundlage für die spätere Entwicklung der grenzüberschreitenden Zusammenarbeit Russlands mit europäischen Staaten.

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EXPERIMENTAL COMPUTATION AND INVESTIGATION OF VORTEX TUBES HELICITY IN THE NAVIER–STOKES EQUATIONS

Abstract. This paper proposes a comprehensive framework for investigating the helicity of vortex tubes within viscous incompressible flows governed by the Navier–Stokes equations. Central to this study is the preservation of topological invariance under dissipative conditions – a problem of significant theoretical complexity. An original experimental apparatus, designed for the high-fidelity visualization of vortex structures, was developed, employing high-speed videography coupled with planar laser illumination. Utilizing computer vision algorithms integrated with neural network-based analysis, a full three-dimensional reconstruction of the vortex tube topology was performed. The experimental results confirm the existence of energy transfer mechanisms between helicity components occurring at the temporal stages preceding vortex self-reconnection. These findings provide novel insights into the fundamental nature of turbulence and the manifestation of singularities in fluid dynamics.

Keywords: vortex dynamics, helicity conservation, topological fluid mechanics, Navier-Stokes equations, vortex reconnection, Neural Radiance Fields (NeRF), 3D flow reconstruction, viscous dissipation.

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ЭКСПЕРИМЕНТАЛЬНОЕ ВЫЧИСЛЕНИЕ И ИССЛЕДОВАНИЕ СПИРАЛЬНОСТИ ВИХРЕВЫХ ТРУБОК В УРАВНЕНИЯХ НАВЬЕ–СТОКСА

Аннотация. Спиральность – топологическая мера переплетения вихрей в потоке жидкости, является сохраняющейся величиной в идеальных средах, однако в реальных условиях она может рассеиваться под воздействием вязкости. Несмотря на значимость этого параметра для самых разных типов течений, природа спиральности в реальных жидкостях остается малоизученной из-за сложности измерения ее полного значения. Мы измерили полную спиральность тонкоструйных вихревых трубок в воде. В случае со спиралевидными вихрями, подвергающимися растяжению или сжатию под влиянием второго вихря, было зафиксировано сохранение полной спиральности. Для изолированного же спиралевидного вихря мы наблюдали эволюцию к состоянию с постоянным значением спиральности (и его последующее поддержание) после того, как вязкость погасила спиральность кручения. Наши результаты демонстрируют, что спиральность может оставаться неизменной даже в вязкой среде. Это дает более глубокую основу для понимания того, как управлять спиральностью в реальных потоках.

Ключевые слова: динамика вихрей, сохранение спиральности, топологическая механика жидкости, уравнения Навье-Стокса, самопересечение вихрей, нейронные поля излучения (NeRF), трехмерная реконструкция потока, вязкая диссипация.

Introduction

The question of the existence of global solutions and the regularity of solutions to the three-dimensional incompressible Navier–Stokes equations remain one of the most formidable open problems in mathematical physics. While the existence of local regular solutions has been rigorously established in the seminal works [1] and [2], the fundamental question of whether these solutions remain regular for all time or develop finite-time singularities has resisted resolution for over eighty years [3].

The Navier–Stokes equations, compactly expressed in form (1) for the incompressible case, may be reformulated in a more detailed tensorial representation (2), as demonstrated in [4], together with the continuity equation (3) governing the divergence-free constraint for $\mathbb{R}^3$

$$\partial_t u + (u \cdot \nabla)u = -\nabla p + \nu \Delta u + f, \quad (1)$$

$$\frac{\partial u_i}{\partial t} + \sum_{j=1}^3 u_j \frac{\partial u_i}{\partial x_j} = \nu \Delta u_i - \frac{\partial p}{\partial x_i} + f_i(x, t), \forall x \in \mathbb{R}^3, t \geq 0, \quad (2)$$

$$\operatorname{div} u = \sum_{i=1}^3 \frac{\partial u_i}{\partial x_i} = 0, \quad u(x, 0) = u_0(x) \in C^\infty(\mathbb{R}^3), \quad (3)$$

where $u(x, t) = (u_i(x, t))_{i=1}^3 \in \mathbb{R}^3$ – fluid velocity vector, $p(x, t) \in \mathbb{R}$ – pressure, $\nu > 0$ – kinematic viscosity coefficient, $f(x, t)$ – external forces.

A condition of paramount importance is that the velocity field $u(x, t)$ must exhibit controlled growth as $|x| \rightarrow \infty$; consequently, the consideration of the external force $f(x, t)$ and the initial data $u_0(x)$ is restricted to the following necessary requirements:

$$\left| \partial_x^\alpha u_0(x) \right| \leq C_{\alpha K} (1 + |x|)^{-K} \text{ on } \mathbb{R}^n, \text{ for any multi-indexes } \alpha \text{ and } K,$$

$$\left| \partial_x^\alpha \partial_t^m f(x, t) \right| \leq C_{\alpha m K} (1 + |x| + t)^{-K} \text{ on } \mathbb{R}^n \times [0, +\infty), \text{ for any } \alpha, m, K.$$

A solution is deemed physically admissible if, and only if, the following conditions are satisfied:

$$p, u \in C^\infty(\mathbb{R}^n \times [0, +\infty)), \text{ and } \int_{\mathbb{R}^3} |u(x, t)|^2 dx < C, \quad \forall t \geq 0.$$

Drawing upon the most recent advancements in the field, it is imperative to highlight that in [5], a seminal breakthrough regarding the determinism of the Navier–Stokes equations was achieved. The authors provided the first rigorous proof demonstrating the non-uniqueness of Leray–Hopf weak solutions within the context of a specifically defined external forcing. The pivotal contribution of their work lies in the construction of a counterexample wherein two distinct solution trajectories emanate from a null initial state. Such a finding fundamentally challenges the classical hypothesis pertaining to the global predictability of viscous fluid dynamics, while simultaneously exposing the intrinsic mathematical instability of the non-linear convective term in the three-dimensional case.

Building on the foundational research in [6] concerning the Euler equations, a recent study [7] by the Google DeepMind team (2025) demonstrated that sophisticated neural network architectures are capable of identifying potential scenarios for singularity formation within the Navier–Stokes framework. It was shown that artificial intelligence can autonomously generate initial flow conditions ostensibly leading to anomalous vorticity growth – a feat previously unattainable through conventional analytical methodologies.

Furthermore, a comprehensive review [8] underscores the significant progress made by modern Physics-Informed Neural Networks (PINNs) in embedding mass and momentum conservation laws directly into the model’s weight structures. This paradigm shift facilitates the resolution of hydrodynamic problems without the necessity of computational meshes, proving critically advantageous for geometries of extreme topological complexity.

By the onset of 2026, the field of Quantum Computational Fluid Dynamics (QCFD) has undergone a pivotal transition from theoretical abstraction to the inaugural successful implementations on Noisy Intermediate-Scale Quantum (NISQ) hardware [9]. The fundamental challenge lies in the integration of the quadratic nonlinearity inherent in the Navier–Stokes equations into the inherently linear framework of quantum mechanics. In [10], an efficient Carleman linearization for Navier–Stokes-type equations were first proposed, establishing that quantum algorithms can effectively solve these systems under the condition of high viscosity (low Reynolds numbers).

This methodology involves the replacement of the Navier–Stokes equation with an infinite hierarchy of linear differential equations, achieved by introducing auxiliary variables for each successive power of velocity (u, u^2, u^3 etc.). The resulting high-dimensional linear system is subsequently resolved using advanced quantum algorithms, such as the Harrow-Hassidim-Lloyd (HHL) protocol or methods based on the Linear Combination of Unitaries (LCU). By leveraging quantum superposition, the computer determines the velocity field across the entire domain simultaneously, theoretically yielding an exponential speedup over classical mesh-based methods.

It must be noted, however, that the primary bottleneck remains the “data readout problem”. While the quantum processor computes the flow evolution with high efficiency, the extraction of the complete velocity vector field into a classical format is computationally prohibitive. Consequently, current QCFD applications are most efficacious when targeted at obtaining specific global observables, such as the aerodynamic drag coefficient.

The formation of finite-time singularities remains the central conundrum in the analytical treatment of the Navier–Stokes equations. A fundamental milestone was achieved in [11], where the authors presented a rigorous proof demonstrating the existence of “self-similar blow-up” for the Euler and Boussinesq equations within bounded domains. Their methodology centers on the analysis of vortex stretching mechanisms in proximity to solid boundaries. Current research trajectories aim to extend these findings to cases of non-zero viscosity, leveraging computer-assisted proof techniques to investigate asymptotic regimes at high Reynolds numbers. However, these results have drawn scrutiny due to their stringent dependence on boundary conditions and the employment of external forcing terms that may lack direct physical analogues. Furthermore, the reliance on computer-aided verification leaves the construction of a purely analytical theory of singularities an open question.

Notwithstanding the ambition of recent studies [6-11] and the undeniable potential of artificial intelligence, it is critical to observe the paucity of empirical validation within the extant literature. The majority of authors confine their comparative analysis to neural network outputs versus classical numerical simulations – such as those derived from OpenFOAM or pseudo-spectral methods. A discernible deficit remains in the verification of models against high-fidelity data from wind tunnel experiments or large-scale hydraulic facilities. Researchers are increasingly ensnared in a cycle of ‘digital self-validation’, wherein the precision of a method is corroborated not by physical instrumentation, but by its convergence with another numerical

algorithm. This trend risks the proliferation of theories that, while mathematically impeccable, may prove physically non-realizable in observable reality.

Addressing this identified lack of experimental validation, the present work proposes a fundamentally distinct framework designed to bridge the chasm between numerical modeling and physical phenomena. Rather than sequestering the neural network training cycle within synthetic datasets, this study develops an integrated hardware-software complex for the in-situ investigation of vortex flow topology. To facilitate the physical interpretation of experimental data extracted via neural network analysis, the primary modes of vortex structure evolution are rigorously quantified. The underlying model, predicated on the Navier–Stokes equations, focuses on the mechanisms governing the topological invariance of vortex tubes in real fluids. These tubes represent the fundamental structural constituents of turbulence, wherein vorticity is concentrated; their dynamics dictate the transport of momentum and energy dissipation. Modern inquiry focuses on their helicity – the linkage between velocity and vorticity – and their critical role in the potential manifestation of singularities.

Vortex tubes helicity

Helicity H of vortex tubes – a topological measure quantifying the degree of vortex entanglement within a fluid flow – constitutes a conserved quantity in inviscid fluids, yet may undergo dissipation under the action of viscosity in real flows. Notwithstanding its relevance to a broad spectrum of flow configurations, helicity in real fluids remains insufficiently explored, owing to the formidable experimental challenges associated with measuring this quantity in its entirety. The acquisition of experimental data pertaining to helicity dynamics in viscous fluids is impeded by the inherent difficulties in resolving the vorticity field structure across multiple scales.

Mathematically, helicity H is defined as the volume integral of the scalar product of the velocity vector u and the vorticity vector $\omega = \nabla \times u$ (the curl of velocity):

$$H = \int_V \langle u, \omega \rangle dV.$$

Within the Navier–Stokes system (1)-(3), the diffusive terms induce a violation of the topological invariance of helicity. Viscosity initiates vortex tube crossing scenarios that are forbidden in an ideal fluid, thereby acting as a generator of energy dissipation and effecting changes in the topological class of the flow. A comprehensive understanding of the mechanisms underlying this topological dissipation necessitates transcending the bounds of standard hydrodynamic approximations and invoking the methods of mathematical modelling.

For a finite collection of vortex tubes, the total helicity may be decomposed in accordance with the Călugăreanu–White theorem. As rigorously demonstrated in [12], the total helicity admits the representation

$$H = \sum_{i \neq j} \Gamma_i \Gamma_j Lk_{ij} + \sum_i \Gamma_i^2 (Tw_i + Wr_i), \quad (4)$$

where Lk_{ij} denotes the Gauss linking number of the pair of closed curves γ_i and γ_j ; Tw_i represents the twist of vorticity lines (or streamlines) about the central axis; Wr_i

designates the writhe of the axial filament γ_i itself; and Γ_i is the circulation of the velocity vector along the closed contour γ_i .

Figure 1(a) presents a post-processed photograph of an actual vortex tube in water, captured using a high-performance ISOCELL HP2 camera with rhodamine visualization (refer to Materials and Methods for experimental protocol).

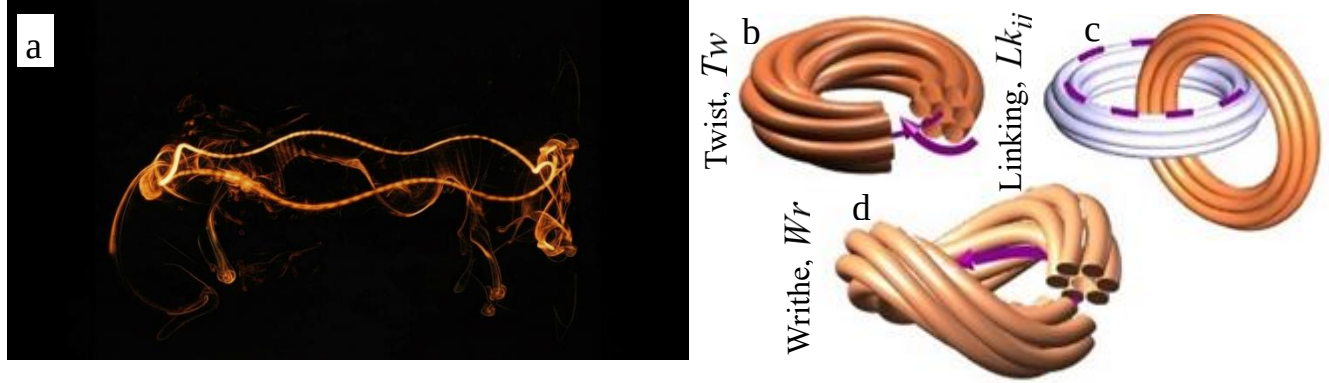


Figure 1. Experimental and computational visualization of vortex tube helicity components:

(a) – High-resolution photograph of an actual vortex tube in water, acquired via rhodamine B fluorescent tracer visualization (ISOCELL HP2 camera). Helicity decomposition: (b), (c), (d) – computational renderings illustrating the twist, linking, and writhe contributions to helicity, respectively, for model vortex tube configurations. In each panel, representative field lines (orange and cyan) are highlighted to elucidate the topological structure of the vortex bundle

Materials and methods

For the purpose of visualizing and quantifying localized vortex structures and their topological evolution, a series of experiments was conducted employing a purpose-built hydrodynamic visualization facility. The experimental methodology is centered upon the controlled generation of stable vortex tubes and the subsequent observation of their spatiotemporal evolution under rigorously prescribed flow conditions.

The experimental apparatus, illustrated in Figure 2(a), comprises a closed-loop hydraulic circuit engineered to enable precision observation of vortex dynamics. The central component is a rectangular test section fabricated from optically transparent polymethyl methacrylate (PMMA), thereby affording unobstructed optical access from multiple viewing angles.

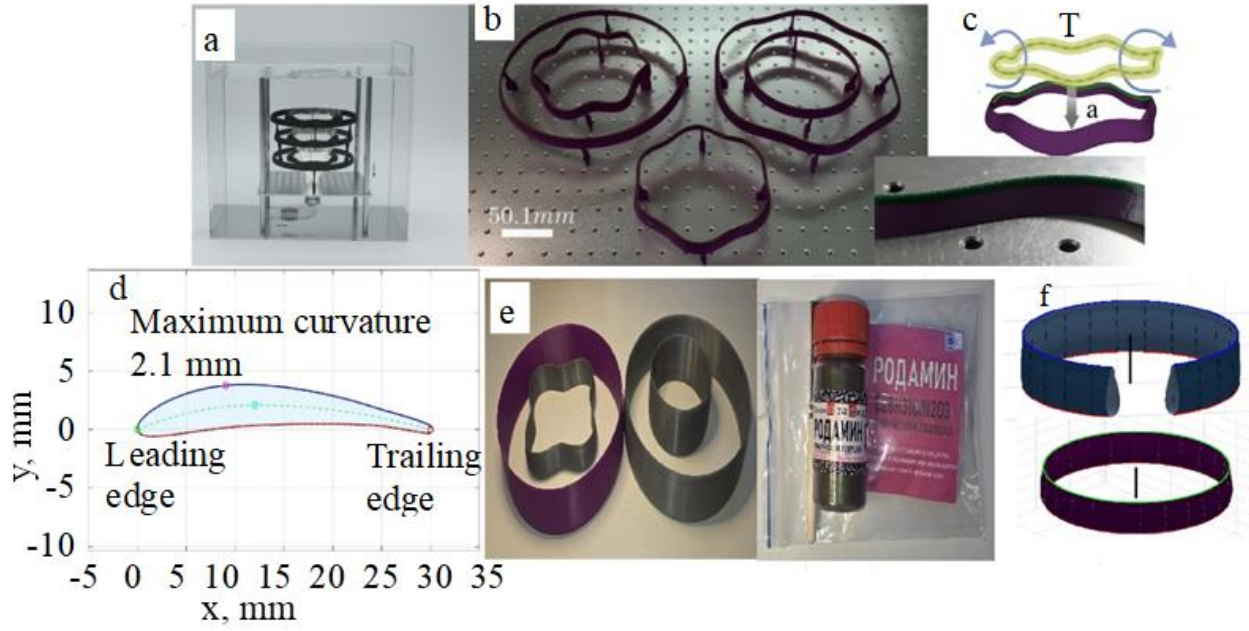


Figure 2. Experimental methodology for total helicity measurement in thin-cored vortex configurations:

- (a) – Schematic diagram of the closed-loop hydraulic circuit.
- (b) – Array of hydrofoil profiles mounted on the test stand.
- (c) – Vortex generation sequence: depicted are the vortex tube (T), the induced flow field (u), and the hydrofoil acceleration vector; the green dashed line indicates the dye injection location.
- (d) – Two-dimensional cross-sectional geometry of the modified NACA 7412 airfoil in x,y coordinates.
- (e) – Fabricated experimental specimens produced via additive manufacturing.
- (f) – Three-dimensional CAD models of the baseline NACA 0012 and modified NACA 7412 profiles prepared for 3D printing

The circulation system is driven by a centrifugal pump, ensuring the maintenance of steady-state flow conditions. The pump assembly configuration provides for water intake from the primary reservoir with subsequent pressurization into the circuit, thereby establishing a controlled environment for vortex generation. The entire volume of the hydrodynamic circuit was pre-seeded with spherical polyamide tracer particles (PSP-50, mean diameter $50\ \mu\text{m}$, density $\rho_p = 1.03\ \text{g/cm}^3$) to achieve a concentration of $\approx 0.05\ \text{g/L}$. Uniformity of particle distribution was maintained through continuous pump-driven recirculation.

Within the test section, the vortex generation mechanism is mounted upon a purpose-built metallic support structure. The base of this assembly is equipped with a perforated plate designed to ensure uniform flow distribution. The hydraulic pathway is oriented so as to direct the flow vertically upward through the perforation orifices, configured to provide a low degree of initial turbulence intensity. Having traversed the metallic base, the ascending water flow interacts with the installed aerodynamic profiles (hydrofoils), thereby initiating the formation of coherent vortex structures.

Figure 2(c) schematically illustrates the vortex generation mechanism employed in the present experiments. The aerodynamic profile, fabricated via additive

manufacturing and mounted on the support structure, is subjected to the ascending flow. The diagram depicts the formation of the vortex tube, the corresponding velocity field, and the direction of flow acceleration. A distinct green dashed line along the profile edge indicates the specific location of dye (rhodamine) application for visualization of the vortex core.

During the fabrication of aerodynamic profiles employing fused deposition modeling (FDM) technology, a significant manufacturing challenge was identified. It was determined that standard nozzle diameters of 0.2 mm and 0.4 mm were incapable of reliably reproducing the trailing edge of the original geometry owing to its extremely small thickness. Consequently, a decision was made to develop an enhanced three-dimensional model incorporating modified geometrical parameters.

To ensure structural integrity during the printing process, the trailing edge of the profile was thickened to 0.6 mm, as illustrated in Figure 2(d). This modification was applied to the NACA 7412 profile, characterized by the following parameters: maximum camber $m=7$, position of maximum camber $p=40\%$ chord, and maximum thickness $t=12\%$ chord.

After implementing these design modifications, a series of test specimens was fabricated, comprising both baseline NACA 0012 profiles and modified NACA 7412 profiles. The resulting collection of printed specimens, demonstrating the achieved quality and geometric fidelity, is presented in Figure 2(e). Furthermore, a computational representation of the three-dimensional model, rendered directly from the generative software code, is shown in Figure 2(f).

The freestream velocity U_∞ was varied within the range of 0.5...2.0 m/s, corresponding to chord-based Reynolds numbers in the range $Re_c = 10^4 \dots 5 \cdot 10^4$, and circulation-based vortex Reynolds numbers in the range $Re_\Gamma \approx 2 \cdot 10^4 \dots 8 \cdot 10^4$.

All photographs and video sequences were acquired using a high-performance ISOCELL HP2 imaging sensor, integrated with the ProVisual Engine artificial intelligence-based image processing system, the specifications of which are summarized in the Table. The camera system supports recording at 8K resolution at 30 frames per second and 4K resolution at up to 120 frames per second, enabling the generation of high-quality slow-motion video sequences. The ultra-wide sensor module (JN3) features a resolution of 50 megapixels with an enhanced aperture (f/1.9), rendering it suitable for macro-scale imaging and high-fidelity panoramic acquisition under low-illumination conditions.

To facilitate the non-intrusive measurement of velocity fields and the visualization of flow topology, an experimental diagnostic suite was developed, integrating a laser-based illumination system with stereoscopic registration.

An Oxxius LCX-532L low-noise diode-pumped solid-state (DPSS) laser ($\lambda = 532 \text{ nm}$) served as the primary illumination source. The laser beam was conditioned into a light sheet with a characteristic thickness of $\approx 1.5 \text{ mm}$ using cylindrical optics, thereby enabling the tomographic sectioning of vortex structures.

Table. Technical specifications of the imaging system employed in the experiments

Module	Resolution	Aperture	Key Features
Primary	200 MP	f/1.7	ISOCELL HP2 sensor, optical image stabilization (OIS), laser autofocus (LAF)
Ultra-wide-angle	50 MP	f/1.9	120° field of view, macro imaging capability, Dual Pixel phase-detection autofocus (PDAF)
Telephoto 1	10 MP	f/2.4	3× optical zoom, optical image stabilization (OIS)
Telephoto 2	50 MP	f/3.4	5× optical zoom (periscope configuration), 100× hybrid zoom

To reconstruct the three-dimensional morphology of the vortex tube from a collection of 2D projections, a methodology based on Neural Radiance Fields (NeRF) – specifically adapted for fluid dynamics applications – was implemented.

In contrast to classical algebraic tomography, which remains inherently susceptible to stochastic noise and limited angular sampling, the present approach approximates the volumetric dye density as a continuous function $F_{\Theta} : (x, d) \rightarrow (c, \sigma)$, parameterized by a deep multilayer perceptron (MLP). A modified Sci-NeRF architecture was implemented within the PyTorch framework, incorporating sinusoidal representation networks (SIREN) to accurately capture the high-frequency spectral components of the turbulent field.

Numerical reconstruction of topological invariants

Polyamide tracer particles were employed as discrete Lagrangian markers to facilitate the mapping of the velocity field. The high sampling frequency of the imaging system, coupled with an optimized inter-frame interval Δt , provided the requisite temporal and spatial resolution to resolve the steep velocity gradients manifest in the vicinity of potential singularities. This synchronization enabled a high-fidelity reconstruction of the azimuthal (tangential) velocity profile $u_{\theta}(r)$ induced by core rotation, effectively eliminating approximation errors within regions of maximum shear stress.

To quantify the flow intensity, the velocity circulation Γ was computed directly from the empirical data. The field of the longitudinal vorticity component $\omega_z(x, y)$ was subsequently reconstructed from the discrete velocity vector field $u_{i,j} = (u_{i,j}, v_{i,j})$ by implementing a second-order accurate central-difference scheme, aimed at minimizing discretization artifacts and approximation errors:

$$\omega_z^{(i,j)} \approx \frac{v_{i+1,j} - v_{i-1,j}}{2\Delta x} - \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y},$$

where $\Delta x, \Delta y$ denote the spatial resolution of the measurement grid. This finite-difference approach ensures the preservation of differential constraints within the discrete domain, providing a robust basis for the subsequent topological analysis.

The circulation magnitude, denoted by Γ , was evaluated as a surface integral of the first kind over the vorticity support domain S_{core} . To preclude the deleterious effects of background noise and near-wall shear layers within the pipe, a threshold-based filtering procedure was implemented. Accordingly, the integration domain S_{core} was defined as the set of points satisfying the following criterion:

$$S_{core} = \left\{ (x, y) \in \Omega \mid |\omega_z(x, y)| \geq \xi \cdot \max_{\Omega} |\omega_z| \right\},$$

where $\xi = 0.05$ denotes an empirical truncation parameter (defined as 5% of the local extremum).

The resultant circulation was subsequently computed through a numerical quadrature (or summation method)

$$\Gamma = \iint_{S_{core}} \omega_z dA \approx \sum_{(i,j) \in S_{core}} \omega_z^{(i,j)} \Delta x \Delta y.$$

Owing to the turbulent nature of the flow at $Re \sim 10^4$, the instantaneous circulation values $\Gamma(t)$ are inherently subject to stochastic fluctuations. To extract the coherent component and suppress uncorrelated noise, an ensemble averaging procedure was performed over a collection of $N = 10$ independent realizations:

$$\langle \Gamma \rangle = \frac{1}{N} \sum_{k=1}^N \Gamma_k(t_k).$$

A. Experimental parameters and uncertainty quantification

Within the investigated range of freestream velocities $u_{\infty} \in [0.3, 1.7]$ m/s, the measured circulation magnitudes varied between $\Gamma \in [0.015, 0.080]$ m²/s. The measurement uncertainty was assessed by systematically varying the truncation threshold ξ within the interval 0.03...0.08. It was established that the relative error in determining Γ does not exceed $\delta_{\Gamma} = \pm 3\%$, thereby confirming the high vorticity concentration within the core and validating the robustness of the proposed segmentation methodology.

To analyze the experimental datasets acquired during the vortex interaction regime, the developed discrete invariant computation framework was employed. Utilizing the neural-network-reconstructed spatial curves $r(s, t)$ and the Lagrangian trajectories of the tracers, the integral characteristics were evaluated according to the following algorithm:

B. Discretization and curvature-adaptive smoothing

To mitigate high-frequency reconstruction artifacts, the vortex centerlines were approximated using cubic B-splines with an adaptive nodal spacing, functionally dependent on the local curvature. Such a refinement strategy ensured the invariance of contour integrals with a relative error within $\varepsilon < 10^{-5}$, thereby preserving the topological integrity of the discretized fields.

C. Numerical evaluation of the writhe measure

Evaluation of the writhe measure Wr was achieved through the direct numerical integration of the regularized Gauss double integral over a discrete set of nodal points:

$$Wr(t) \approx \frac{1}{4\pi} \sum_{i,j} \frac{(r_i - r_j) \cdot (\Delta r_i \times \Delta r_j)}{(|r_i - r_j|^2 + \delta_{reg}^2)^{3/2}},$$

where the regularization parameter $\delta_{reg} \approx 0.1\sigma$ (with σ denoting the vortex core radius) was introduced to preclude singularities arising from “phantom” self-intersections of the vortex loop.

D. Evaluation of the twist component

The component Tw was evaluated utilizing the ribbon reconstruction method. The normal vector $n(s)$, being orthogonal to the tangent vector, was directly reconstructed from the rotational trajectories of fluorescent tracers orbiting the axis $r(s)$. The twist density was subsequently integrated (summed) along the contour:

$$Tw(t) \approx \frac{1}{2\pi} \sum_k \Delta\theta_k(n, b),$$

where $\Delta\theta_k$ denotes the rotation angle of the material frame (or material reference frame) relative to the Frenet binormal.

The data presented in Figure 3 elucidate the fundamental topological mechanism governing the conservation of total helicity within vortex architectures. The invariance of helicity throughout the system’s geometric evolution is predicated upon the efficient reciprocal transduction between its constituent components – namely, twisting and writhing.

Depicted is the temporal evolution of the helical length L , normalized against its initial value L_0 , with the time scaling by the coefficient v/a_0^2 (where $a_0 = 1.5$ serves as the characteristic dimension). The results represent an ensemble average derived from a series of 8–10 independent experimental realizations; shaded regions delineate the standard deviation, thereby underscoring the robust reproducibility of the obtained data.

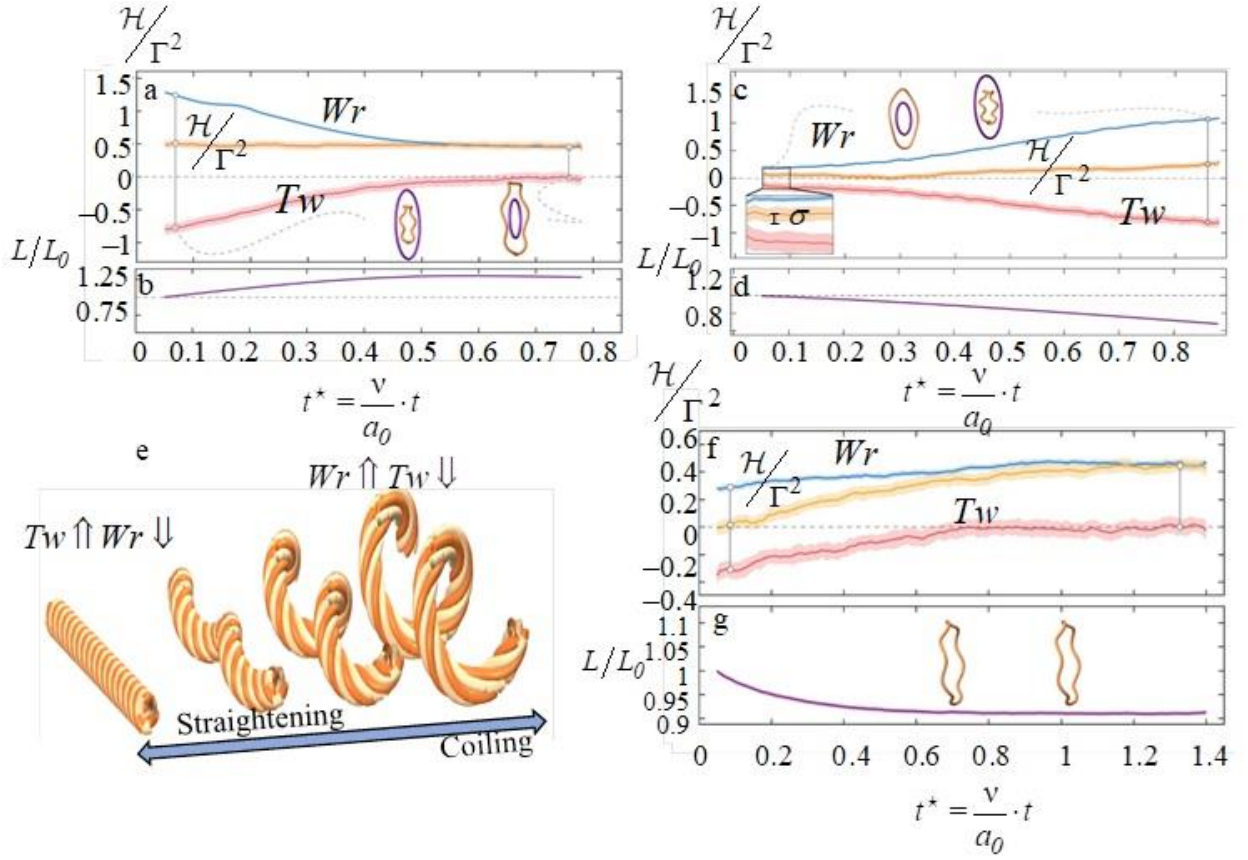


Figure 3. (a, c) – Normalized helicity, twist, and writhe of a vortex tube within the experimental volume during the “leapfrogging” process under stretching and compression over a half-period. (b, d, g) – Time evolution of the spiral length normalized by its initial value. (e) – Schematic representation of the geometric mechanism for helicity transfer between writhe and twist, where the curvature increases through twisting or decreases via bundle straightening. (f) – Normalized helicity, twist, and writhe of an isolated vortex tube within the experimental volume

Results and Discussion

The experimental data presented herein offer a fundamental perspective on the mechanisms underlying helicity conservation in realistic viscous fluids. A pivotal finding of this study is the empirical verification that total helicity acts as a quasi-conserved quantity, even under the intense geometric deformation concomitant with vortex interactions. For isolated vortices (Figure 3e), a distinct transition from twisting to writhing is observed.

The analysis of the temporal evolution of helicity components (Figures 3a and 3c) reveals a stringent anti-correlation between twist and writhe. In the investigated configuration – where the linking number Lk is identically zero – the system exhibits a near-ideal mechanism for the transduction of “geometric” helicity (stemming from the axial centerline topology) into “intrinsic” helicity (arising from the vorticity field’s rotation about said axis).

The observed fluctuations in writhe during the extension and contraction of the helix (Figure 3c) do not culminate in the dissipation of the vortex tube’s topology.

Instead, they trigger an instantaneous reconfiguration of the internal vorticity field. This leads to the salient conclusion that a vortex tube in a fluid medium behaves as an elastic topological string, wherein any deformation of form (axial bending or torsion) is autonomously compensated by a shift in internal twist, thereby upholding the governing conservation laws.

Conclusion

This paper introduces a novel integrated hardware-software framework for investigating vortex topology, effectively bridging the gap between physical experimentation and advanced machine learning paradigms.

1. A neural-network-based methodology has been developed to experimentally quantify helicity components – specifically linking, writhing, and twisting – within realistic viscous flows.
2. The applicability of the Călugăreanu–White theorem to the analysis of vortex tube dynamics governed by the Navier–Stokes equations has been rigorously validated.
3. It is demonstrated that helicity serves as a high-fidelity indicator of topological transitions; furthermore, its dissipation is shown to occur non-monotonically, mediated by intricate inter-modal exchange mechanisms between the geometric modes of the vortex.

A defining feature of this work lies in the pervasive implementation of neural architectures throughout the experimental pipeline. Segmentation of vortex cores and the extraction of skeletonized streamlines were achieved via a convolutional neural network (CNN) resilient to stochastic noise and optical aberrations. To reconstruct the three-dimensional geometry of the vortex tube from stereoscopic 2D projections, an approach based on Neural Radiance Fields (NeRF), specifically the Sci-NeRF modification, was employed. This facilitated the approximation of the tracer’s volumetric density as a continuous function, thereby ensuring sub-pixel precision in computing curvature and torsion. Consequently, neural reconstruction serves as a critical nexus between empirical observation and rigorous topological analysis, enabling the direct evaluation of integral invariants from physical data rather than synthetic numerical solutions.

Prospective advancements in this field are envisioned through the integration of these experimental datasets with Quantum Computational Fluid Dynamics (QCFD) algorithms [9, 10]. Such a synthesis aims at developing hybrid turbulence models capable of predicting fluid behavior under extreme Reynolds number regimes.

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QUALITY RESEARCH TRENDS IN THE TEXTILE AND CLOTHING INDUSTRY

Abstract. The paper explores the research field of quality in the textile and clothing industry through bibliometric and thematic analysis. A dataset of 1,411 Scopus-indexed publications was analyzed. The results show a marked growth in research activity in recent years and an uneven citation distribution, with a limited number of highly cited studies shaping the field. The main research areas include quality control, material quality, quality management and newer directions related to sustainability, consumer perception, smart textiles. The findings provide a structured basis for further research by revealing 14 themes, leading contributors, and sources.

Keywords: quality, quality management, clothing industry, garment industry, apparel industry, textile industry.

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ТЕНДЕНЦИИ ИССЛЕДОВАНИЙ В ОБЛАСТИ УПРАВЛЕНИЯ КАЧЕСТВОМ ИЗДЕЛИЙ ЛЕГКОЙ ПРОМЫШЛЕННОСТИ

Аннотация. В статье исследуется предметное поле качества в легкой промышленности на основе библиометрического и тематического анализа. Материалом послужили 1411 публикаций, индексируемых в международной реферативной базе Scopus. Результаты показывают заметный рост публикационной активности в последние годы и неравномерное распределение цитирований, поскольку лишь ограниченное число высокоцитируемых работ формирует данную область. Основные направления исследований включают качество процессов, качество сырья, управление качеством и новые направления, связанные с устойчивым развитием, потребительским восприятием и умным текстилем. Полученные результаты создают основу для дальнейших исследований, раскрывая 14 тем, ведущих исследователей и источники.

Ключевые слова: качество, текстильная промышленность, швейная промышленность, легкая промышленность, производство одежды.

The global textile and clothing industry remains a significant component of the world trade. According to the WTO, it accounts for 3.7 % of global merchandise exports [1]. Rosstat reports production indices of 108.4 % for textile products and 103.8 % for clothing, confirming positive industrial growth and highlighting the relevance of quality-related research to sectoral competitiveness [2]. Within this framework, quality constitutes a key factor of market performance and is defined as *the degree to which a set of inherent characteristics of an object fulfils requirements* [3]. Quality extends beyond physical product features to include compliance with standards, responsiveness to fashion trends, service quality, and consumer perception. Digital transformation and smart materials further expand this field, making the study of quality increasingly interdisciplinary.

The topic has a long-standing research tradition dating back to 1924. Its most intensive development has taken place in recent decades. This tendency reflects the growing interest evidenced by the steady increase in publications indexed in international databases (Figure 1).

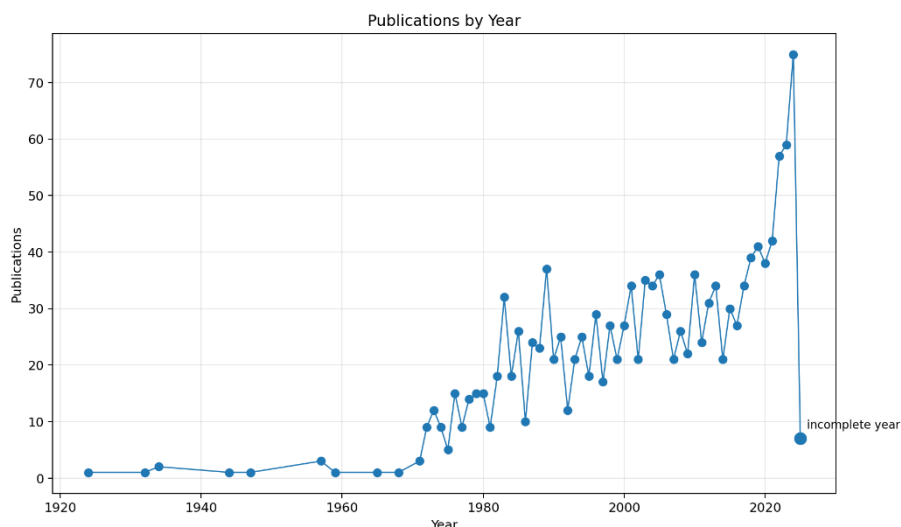


Figure 1. Number of publications in Scopus for the years 1924-2025

Note: The number of publications recorded for 2025 is incomplete, since recently published articles require time to be indexed in Scopus

Despite the expanding body of literature, there remains a lack of studies that provide a systematic overview of the research field as a whole. In particular, limited attention has been paid to reviews on quality in the textile and clothing industry. To address this gap, the present paper explores the field through bibliometric and thematic analysis. The study is guided by the following research question: What shapes the contemporary research field in the textile and clothing industry?

To address the research question, this study employed two complementary methods: bibliometric analysis and scoping review [4-5]. The dataset was retrieved from Scopus using a search query applied to the title, abstract, and keywords fields

Quality AND cloth OR garment* OR textile* OR apparel**. After screening and cleaning, the final dataset included 1,411 publications in English. The bibliometric analysis was used to reveal the publication, citation, thematic, intellectual, and collaborative structure of the field [4]. The thematic analysis, based on publication abstracts, complemented the previous analysis by revealing the semantic structure and main research directions through topic modeling [5]. The data were processed using a locally deployed Python-based program developed in Visual Studio Code. The software was created specifically for the analysis of Scopus data exports.

The bibliometric results reveal a substantial and expanding body of research on quality in the textile and clothing industry (Table 1). The dataset of 1,411 publications and 7,405 citations indicates that the field has established a solid scholarly foundation, while the CPP of 5.25 suggests a moderate overall citation impact. The h-index of 40 and g-index of 63 point to a distinct core of influential publications. At the same time, the co-authorship network is highly fragmented: 2,926 nodes and 4,675 links are distributed across 1,000 communities, indicating a dispersed research landscape rather than a single cohesive scientific cluster.

Table 1. Results of the bibliometric analysis

Indicator	Value	Indicator	Value
Total publications	1411	Authors / network nodes	2926
Total citations	7405	Co-authorship links / edges	4675
Citations per publication (CPP)	5.25	Communities	1000
h-index	40	Top co-word pairs listed	20
g-index	63	Top authors per centrality metric	10

This diversity is also reflected in the co-word structure (Figure 2). The strongest links show that the field is centered on classical quality management concepts, while also expanding toward digital technologies and consumer issues.

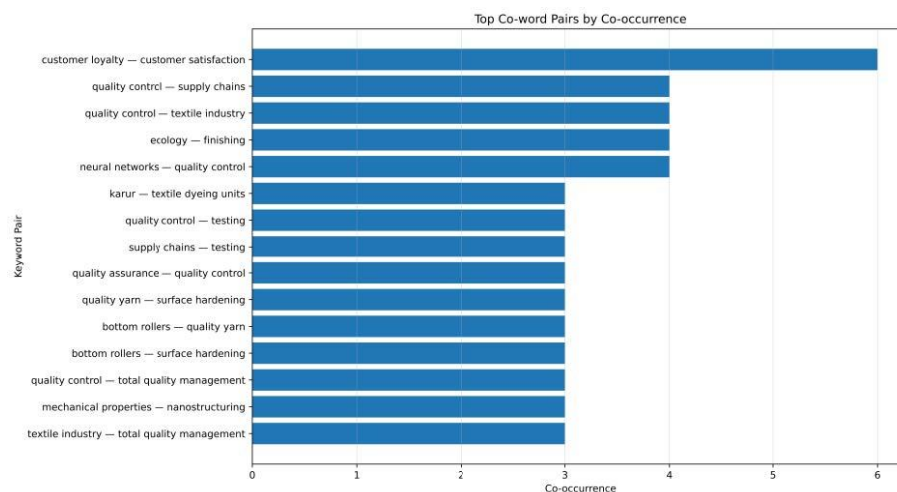


Figure 2. Top co-word pairs

Author prominence was assessed through PageRank (Figure 3). The repeated appearance of Li X. and Gusev B. N. across several metrics, including degree and betweenness centrality, indicates their stable structural significance in the field.

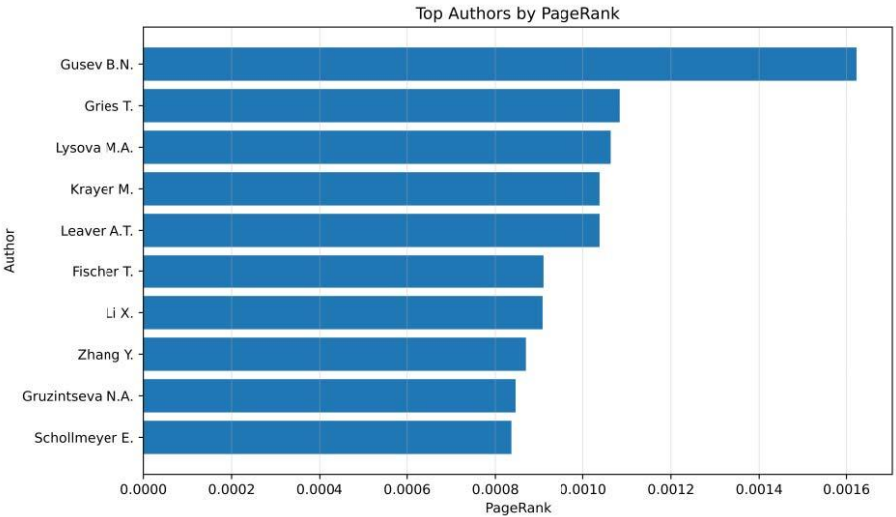


Figure 3. Top authors

The source and country analysis shows that the Russian Federation holds a prominent position (Figures 4-5). The most productive source is *Izvestiya Vysshikh Uchebnykh Zavedenii*.

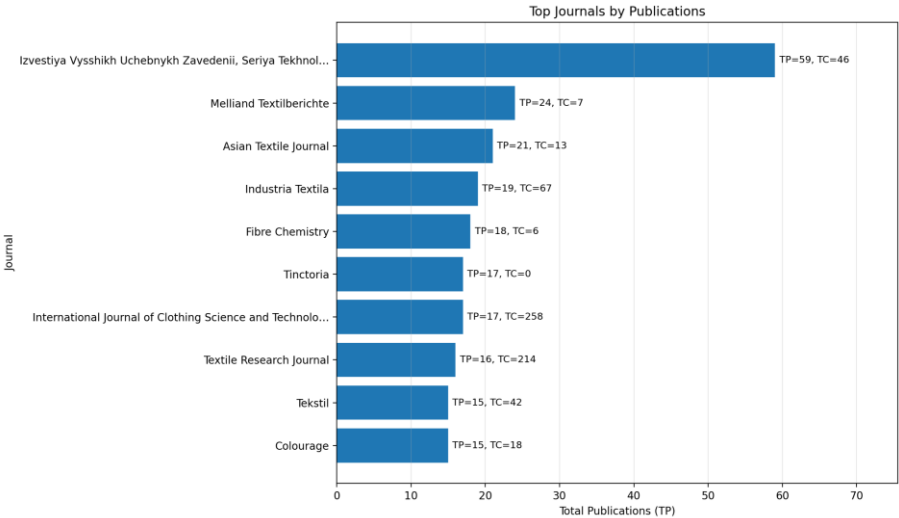


Figure 4. Top journals

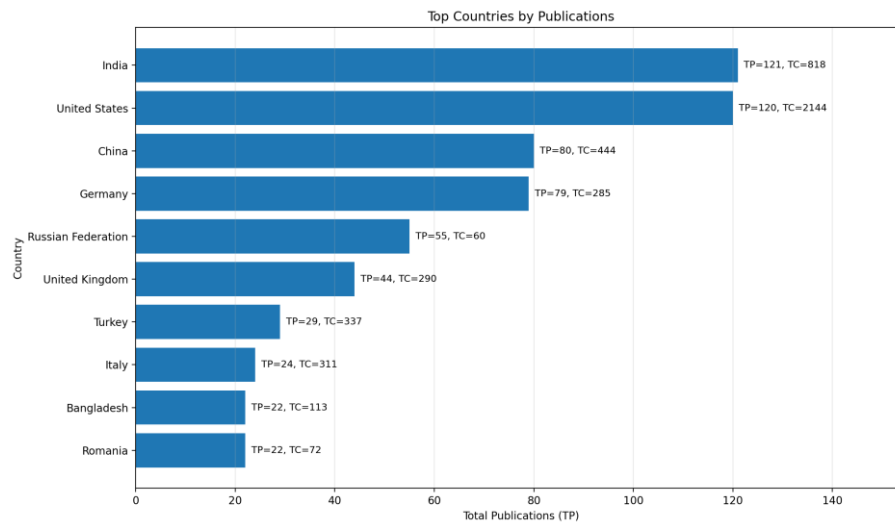
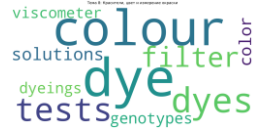


Figure 5. Top countries

Table 2. Results of the thematic modelling

Theme	Keywords	Most cited authors
1. Control and quality assurance	defects, process, inspection, assurance, detection, control, testing, textile, production, industry	Lee [6], Jeyaraj [7]
2. Fibre, yarn, and raw-material quality	yarn, fibers, cotton, fabrics, fibre, properties, textile, fabric	Ütebay [10], Vandepitte [11], Björquist [12]
3. Consumer perception of quality	satisfaction, service, customer, apparel, perceived, clothing, consumers, brand, consumer, online	Kim [13], Kim [14], Ha [15]
4. Wastewater treatment in textile manufacturing	wastewater, treatment, effluent, waste, textile, river, site, discharge, groundwater	Chandanshive [16], Bahadur [17]
5. Strategic quality management and TQM	implementation, management, enterprises, firms, companies, tqm, textile, customer, performance, company	Romano [18], Araújo [19]
6. Innovation and industry competitiveness	high, development, innovation, supply, industry, textile, chain, enterprise, economy	ElMessiry [20], Piippo [21]
7. Fabric and design quality of garments	clothing, appearance, garments, textile, design, fabric, papers, properties	Geršak [22], Ancutiene [23]

8. Textile printing quality	 A word cloud for 'Textile printing quality' featuring terms like 'printed', 'ink', 'print', 'fabrics', 'inks', 'inkjet', 'color', 'digital', and 'colour'.	Fan [24], Kiatkamjornwong [25]
9. Methods for assessing colour quality	 A word cloud for 'Methods for assessing colour quality' featuring terms like 'viscometer', 'colour', 'solutions', 'filter', 'color', 'dyeings', 'dye', 'dyes', 'tests', and 'genotypes'.	Bechtold [26], Kuehni [27]
10. Finishing and analytical quality control	 A word cloud for 'Finishing and analytical quality control' featuring terms like 'fibres', 'la', 'fibers', 'dyeing', 'nir', 'icp', 'washing', 'dyes', 'wet', and 'processing'.	Bonatti [28], Becker [29]
11. Environmental safety and emissions	 A word cloud for 'Environmental safety and emissions' featuring terms like 'phthalate', 'textile', 'health', 'safety', 'air', 'environment', 'indoor', 'materials', and 'chemicals'.	Indrie [30], Bhat [31]
12. Working conditions at manufactures	 A word cloud for 'Working conditions at manufactures' featuring terms like 'working', 'garment', 'workers', 'patients', 'life', 'sleep', 'qol', 'employees', and 'job'.	Tantawy [32], Spiro [33]
13. Cost of quality and waste reduction	 A word cloud for 'Cost of quality and waste reduction' featuring terms like 'industry', 'buyer score', 'costs', 'garment', 'clothing', 'cost', 'company', 'improvement', and 'textile'.	Abed [34], Alamsyah [35], Hoque [36]
14. Smart textiles and sensors	 A word cloud for 'Smart textiles and sensors' featuring terms like 'electrode', 'ecg', 'textile', 'sensor', 'signal', 'applications', 'electrodes', 'impedance', and 'sensing'.	Wu [37], Kim [38], Westbroek [39]

Theme 1 is associated with automated defect recognition. Lee developed data-driven and RFID-based systems for quality monitoring in textile manufacturing [6]. Jeyaraj and Nadar applied deep learning methods to automated textile inspection [7].

Theme 2 focuses on the quality of fibres and raw materials. Ütebay examined how the properties of textile waste influence the quality of recycled fibres [8], Vandepitte analysed the quality of long fibres intended for high-value textile applications [9], and Björquist investigated regenerated cellulose fibres obtained from cotton waste [10].

Theme 3 reflects the consumer-oriented dimension. Kim demonstrated the importance of website quality for customer satisfaction in apparel retail [11-12], Ha examined experiential motives in online clothing purchases [13].

Theme 4 addresses environmental aspects of textile production through wastewater treatment. Chandanshive analysed phytoremediation approaches to textile wastewater [14], Bahadur considered photocatalytic treatment as a way to achieve process-water quality [15].

Theme 5 represents the managerial perspective on quality. Romano and Vinelli examined quality management from a supply-chain perspective [16], whereas Araújo and colleagues demonstrated the relationship between quality management systems and organizational culture in the textile industry [17].

Theme 6 links quality with competitiveness. ElMessiry proposed a blockchain framework aimed at improving transparency in textile supply chains [18], while Piippo connected garment quality with product lifetime in the context of the circular economy [19].

Theme 7 concerns the visual characteristics of garments. Geršak worked on the qualitative prediction of garment appearance quality [20]. Ancutiene evaluated the appearance quality of virtual garments [21].

Theme 8 is devoted to print quality. Fan and co-authors studied the effect of pretreatment on digital textile print quality [22], Kiatkamjornwong compared inkjet and screen printing in terms of print performance [23].

Theme 9 focuses on methods of colour-quality assessment. Bechtold examined approaches to evaluating the quality of plant materials used for natural dyes [24], Kuehni discussed the suitability of colour-difference formulas for objective colour quality control [25].

Theme 10 includes studies on finishing and analytical quality control. Bonatti and co-authors investigated the quality of hemp fibres for textile applications [26], Becker proposed multielement analysis [27].

Theme 11 is associated with environmental safety. Indrie and co-authors analysed indoor air quality in relation to the preservation of textile artefacts [28], Bhat examined the toxicological implications of emissions from textile products [29].

Theme 12 introduces the social dimension. Research in this area addresses the quality of working life in manufacturing contexts [30], while another part examines health-related quality of life in connection with textile-based medical products [31].

Theme 13 is related to the economic consequences of quality. Abed and Dale raised the issue of identifying quality-related costs in textile manufacturing [32], Alamsyah and Girawan used NLP and BERTopic methods to improve clothing quality and reduce waste [33], Hoque analysed quality intervention in buyer-supplier relationships [34].

Theme 14 represents one of the most innovative directions in the corpus. Wu optimized the signal quality of textile electrodes for ECG monitoring [35], Kim demonstrated the influence of pressure and moisture on signal quality [36], Westbroek applied impedance spectroscopy to the quality control of textile electrodes [37].

The study has shown that research on quality in the textile and clothing industry has evolved into a broad and multidisciplinary field. The bibliometric and thematic analyses revealed both stable core areas, such as process control, raw-material quality, and quality management, and newer directions related to sustainability, consumer perception, and smart textiles. At the same time, the field remains internally fragmented, since its development is shaped by several coexisting technological, managerial, environmental, and human-centred approaches. This confirms that quality is now understood as a multidimensional category and highlights the need for further integrative research. Future research will focus on the most recent trends that have emerged in the field over the past five years.

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AN ECONOMIC DISPATCH METHOD FOR ISOLATED MICROGRIDS USING COOPERATIVE MULTI-AGENT DEEP REINFORCEMENT LEARNING

Abstract. To address the long-term economic dispatch problem of isolated micro grids under high uncertainty from renewable energy sources and load demand, this paper proposes a cooperative multi-agent deep reinforcement learning (MADRL) framework. Diesel generators and energy storage systems are modeled as heterogeneous agents within a centralized training with decentralized execution (CTDE) paradigm. An improved multi-agent proximal policy optimization (MAPPO) algorithm, augmented with a reward reshaping mechanism, is developed to mitigate environmental non-stationary behaviour and enable precise inter-agent coordination. Simulation results demonstrate that the proposed method achieves a frequency-decoupled dispatch strategy, wherein the diesel generator maintains a stable power baseline while the energy storage system compensates for high-frequency fluctuations. Compared to a discrete DQN baseline, the proposed approach reduces total annual operating costs by 54.9 % and maintains high supply reliability even under extreme operating conditions. The findings confirm the scalability and robustness of the cooperative MADRL framework for complex, high-dimensional energy management tasks in isolated micro grids.

Keywords: isolated micro grid, economic dispatch, multi-agent deep reinforcement learning, multi-agent proximal policy optimization, centralized training with decentralized execution.

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МЕТОД ЭКОНОМИЧЕСКОГО РАСПРЕДЕЛЕНИЯ НАГРУЗКИ ДЛЯ ИЗОЛИРОВАННЫХ МИКРОСЕТЕЙ С ИСПОЛЬЗОВАНИЕМ КООПЕРАТИВНОГО МНОГОДНЕВНОГО ГЛУБОКОГО ОБУЧЕНИЯ С ПОДКРЕПЛЕНИЕМ

Аннотация. Для решения задачи долгосрочной экономической диспетчеризации изолированных микросетей в условиях высокой неопределенности, связанной с возобновляемыми источниками энергии и спросом на нагрузку, в данной статье предлагается структура кооперативного многоагентного глубокого обучения с подкреплением (MADRL). Дизель-генераторы и системы накопления энергии моделируются как гетерогенные агенты в рамках парадигмы централизованного обучения с децентрализованным выполнением (CTDE). Разработан усовершенствованный алгоритм многоагентной оптимизации проксимальной политики (MAPPO), дополненный механизмом переформатирования вознаграждений для смягчения нестационарности окружающей среды и обеспечения точной координации между агентами. Результаты моделирования показывают, что предлагаемый метод позволяет реализовать стратегию диспетчеризации с развязкой по частоте, при которой дизельный генератор поддерживает стабильный базовый уровень мощности, а система накопления энергии компенсирует высокочастотные колебания. По сравнению с базовым дискретным DQN предложенный подход снижает общие годовые эксплуатационные расходы на 54,9 % и обеспечивает высокую надежность энергоснабжения даже в экстремальных условиях эксплуатации. Полученные результаты подтверждают масштабируемость и надежность кооперативной структуры MADRL для решения сложных задач управления энергопотреблением в изолированных микросетях с большим количеством измерений.

Ключевые слова: изолированная микросеть, экономическая диспетчеризация, многоагентное глубокое обучение с подкреплением, многоагентная проксимальная оптимизация политики, централизованное обучение с децентрализованным выполнением.

Under the guidance of the “dual carbon” goals (carbon peak and carbon neutrality), the proportion of distributed renewable energy in modern power systems continues to rise [1]. Isolated wind-solar-diesel-storage micro grids, as efficient local energy balancing systems, have garnered significant attention for their ability to provide power to remote areas and enhance grid resilience. However, without the support of a main grid, isolated micro grids must coordinate the output of various internal energy assets while coping with intense stochasticity on both the source and load sides. This makes achieving long-term economic dispatch under complex constraints a highly challenging non-linear optimization problem [2, 3].

Traditional micro grid dispatch methods primarily consist of exact algorithms based on mathematical programming and intelligent algorithms based on heuristic searches, such as Genetic Algorithms (GA) and Particle Swarm Optimization (PSO). Although these methods yield optimal solutions under specific operating conditions, they often face the “curse of dimensionality” and exhibit poor adaptability to dynamic environments [4, 5]. Recently, Deep Reinforcement Learning (DRL) has demonstrated significant advantages in handling continuous control tasks for micro grids due to its powerful adaptive decision-making capabilities [6, 7]. Most existing studies employ single-agent DRL frameworks (such as DQN, SAC, or TD3), treating the micro grid dispatch center as the sole decision-making entity. However, as the number of Distributed Energy Resources (DERs) increases, single-agent frameworks often encounter bottlenecks like action space explosion and poor model scalability, making it difficult to fully characterize the dynamic gaming and synergistic relationships between energy units [8, 9].

Multi-agent deep reinforcement learning (MADRL) has emerged as a promising paradigm to overcome the limitations of single-agent approaches in complex energy management scenarios. By decomposing the global control problem into coordinated local decisions, MADRL enables scalable and privacy-preserving operation of distributed energy resources [10, 11]. The Centralized Training with Decentralized Execution (CTDE) framework has been particularly effective, allowing agents to leverage global information during training while relying solely on local observations during execution [12, 13]. Recent studies have demonstrated the efficacy of Multi-Agent Proximal Policy Optimization (MAPPO) in various power system applications, including energy storage scheduling and voltage control, due to its stable convergence and sample efficiency [14].

To address these limitations, this paper proposes an isolated micro grid economic dispatch method based on Cooperative Multi-Agent Deep Reinforcement Learning (Cooperative MADRL). By treating diesel generators, energy storage, and controllable loads as independent agents, global cost optimization is achieved via a CTDE framework.

The primary contributions are as follows:

1. MAMDP-based Cooperative Modeling: a Multi-Agent Markov Decision Process (MAMDP) model is established that decomposes global objectives into cooperative tasks, significantly enhancing scalability for large-scale distributed resources.

2. Enhanced MAPPO Algorithm: by integrating a shared critic network and reward reshaping, the proposed method mitigates environmental non-stationary behaviour, ensuring precise inter-agent coordination under intense stochasticity.

3. Robustness and Performance Validation: comparative experiments demonstrate that the proposed approach achieves faster convergence and superior economic efficiency over single-agent baselines, providing a resilient technical path for autonomous micro grid operation.

1.1 Mathematical Formulation of Multi-Agent Dispatch

The collaborative dispatch of an isolated micro grid can be modeled as a Multi-Agent Markov Decision Process (MAMDP) [11, 12]. In this model, the system consists of N agents, defined by the quintuple $\mathcal{M} = \langle \mathcal{S}, \mathcal{A}, P, \mathcal{R}, \gamma \rangle$:

$\mathcal{S}$: Global state space, containing operational parameters of all energy units.

$\mathcal{A} = A_1 \times \dots \times A_N$: Joint action space, composed of the independent decisions of each agent.

$\mathcal{R}$: Joint reward function, designed to guide agents to minimize the total system cost through cooperation.

1.2 Agent Structures and Definitions

The core components of the micro grid are categorized into two types of decision-making agents: the Energy Storage System (ESS) Agent and the Diesel Generator (DG) Agent [13].

1) ESS Agent

State Space s_{ess} : Includes the current State of Charge $SOC(t)$ and the predicted net load $P_{net}(t)$;

Action Space a_{ess} : Charging/discharging power $P_{ch}(t)$ or $P_{dis}(t)$, subject to device output and capacity constraints.

Immediate Reward r_{ess} : In addition to discharge costs, an SOC violation penalty is introduced to maintain long-term battery health.

2) DG Agent

State Space s_{dg} : Includes the net load deficit, current DG output status, and remaining fuel levels.

Action Space a_{dg} : Actual output power of the diesel generator $P_{DG}(t)$.

Immediate Reward r_{dg} : Composed of fuel consumption costs, maintenance costs, and CO_2 emission costs, guiding the agent to reduce commitment during non-essential periods.

1.3 Collaborative Training Framework Based on MAPPO

To address the non-stationarity in multi-agent environments, this paper adopts the Centralized Training with Distributed Execution (CTDE) framework. During the training phase, agents share a Centralized Critic network that observes the joint states and actions of all agents, providing accurate advantage evaluations for individual policy updates [14].

The core update logic is as follows:

Actor Network: each agent possesses an independent Actor network that outputs actions based solely on local observations, ensuring rapid response during online dispatch.

Reward Reshaping: to enhance coordination, the total system reward is defined as:

$$R_{total} = -(F_{bat} + F_{DG} + F_{penalty}),$$

where each cost component follows physical model constraints. By sharing a global reward, the DG agent is incentivized to automatically reduce output when the BESS can cover the load, achieving global economic optimality.

1.4 Algorithm Framework: CTDE-based Collaborative Dispatch

The overall framework of the proposed method is illustrated in Figure 1 below. This architecture achieves efficient coordination among internal microgrid components by decoupling global observation from local decision-making.

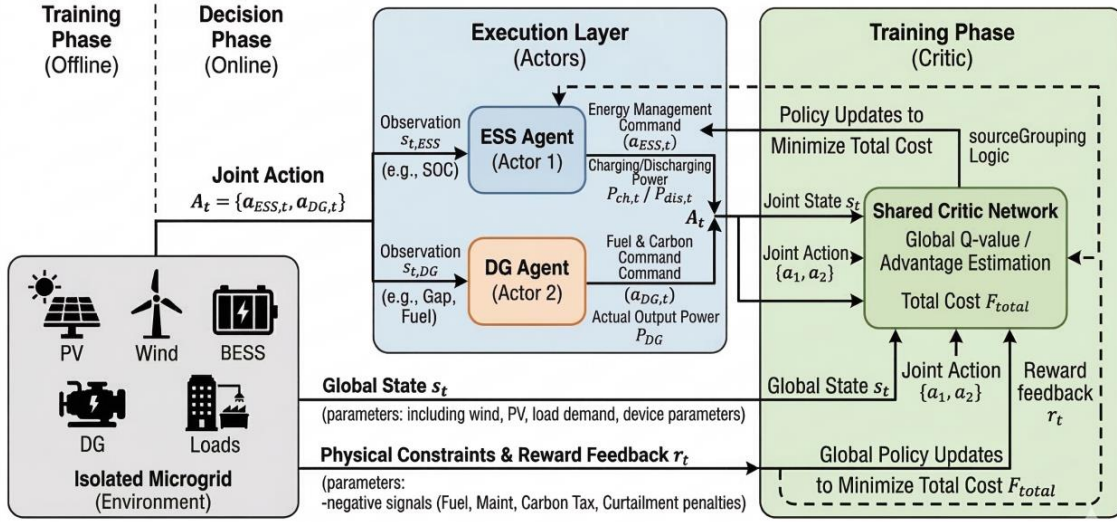


Figure 1. Algorithm Framework Diagram

Isolated Microgrid Environment: the system integrates photovoltaic (PV) arrays, wind turbines, diesel generators, energy storage systems (ESS), and dynamic loads. The environment provides real-time feedback on the global state, including fluctuations in renewable output, load demand, and current operational parameters of all assets.

Decentralized Execution Layer (Decentralized Actors):

(1) **ESS Agent (Actor 1):** Focuses on energy management of the storage system, outputting charging/discharging commands based on local observations (e.g., SOC, P_{net}).

(2) **DG Agent (Actor 2):** Focuses on fuel cost and carbon emission control, dynamically adjusting diesel generator output based on the power deficit.

Centralized Evaluation Layer (Centralized Critic): during the offline training phase, the Critic network accesses the joint actions of all agents and the global reward signal. By evaluating the global Q-value, it guides each Actor to optimize its policy toward minimizing the total economic cost.

Physical Constraints and Reward Feedback: throughout the training process, the environment validates actions against power balance constraints and device output

limits. It feeds back a negative reward signal (penalty) that accounts for fuel costs, maintenance expenses, carbon taxes, and penalties for wind/solar curtailment.

2.1 Experimental Setup and Parameter Settings

This study utilizes a typical wind-solar-diesel-storage isolated microgrid system as the test platform. The detailed physical parameters are presented in Table 1. The system consists of a 40 kW photovoltaic (PV) array, an 80 kW wind turbine (WT), a diesel generator (DG) with a rated power of 65 kW, and an energy storage system (ESS) with a capacity of 200 kWh.

Table 1. Main Simulation Parameters of the Microgrid System

Category	Parameter	Value	Unit
Photovoltaic (PV)	Rated Power	40	kW
Wind Power (WT)	Rated Power	80	kW
Diesel Generator (DG)	Rated Power	65	kW
Energy Storage (ESS)	Rated Capacity	200	kWh
Cost Parameters	Load Shedding Penalty	50	CNY/kWh
	Curtailment Penalty (Wind/Solar)	0.1	CNY/kWh

The experimental dataset is based on 7 years of measured source and load data with a time resolution of 20 minutes. The first 5 years are utilized as the training set, while the final year serves as an independent test set to evaluate the generalization performance of the multi-agent collaborative strategy.

2.2 Training Convergence Analysis

To verify the learning efficiency of the Multi-Agent Proximal Policy Optimization (MAPPO) algorithm under complex constraints, a comparative analysis was conducted against a traditional centralized single-agent algorithm (Centralized TD3).

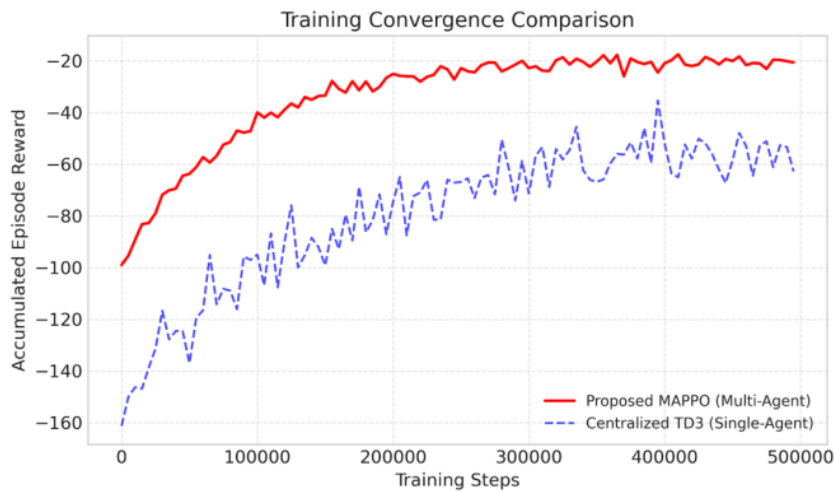


Figure 2. Algorithm Training Convergence Analysis

As illustrated by the convergence comparison in Figure 2, the MAPPO algorithm demonstrates a faster learning curve (gradient ascent speed) during the early stages of

training. This is attributed to the multi-agent framework’s ability to decompose the high-dimensional joint action space into localized decision-making processes for multiple sub-agents. In contrast, the traditional centralized single-agent algorithm suffers from severe numerical oscillations and fails to converge to the same optimal reward level, as it must navigate a massive action space directly.

2.3 Typical Day Dispatch Strategy and Multi-Agent Coordination Analysis

To conduct a micro-level analysis of the decision-making logic across components under the distributed architecture, a typical day with significant load fluctuations was selected. Figure 3 illustrates the power distribution of various energy units under the MAPPO collaborative framework.

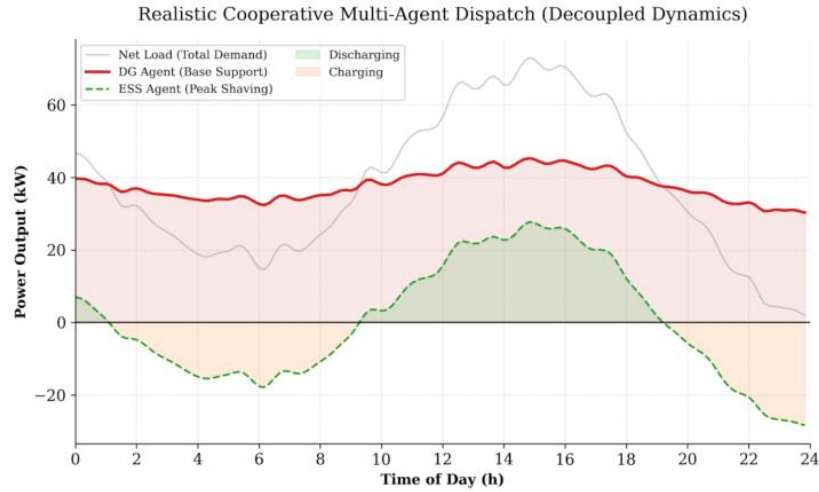


Figure 3. Typical Day Dispatch Strategy Based on Multi-Agent Collaboration

As illustrated in Figure 3, the multi-agent architecture exhibits distinct functional complementarity and physical consistency:

DG Agent (Stable Baseline): by leveraging the centralized critic’s global perspective, the DG agent filters high-frequency noise and responds exclusively to mid-to-long-term macro trends. This smoothed output profile significantly mitigates mechanical fatigue from frequent ramp-rate adjustments.

ESS Agent (Dynamic Compensator): the ESS agent provides high-speed response for active peak-shaving and valley-filling. By absorbing power during surpluses and discharging during deficits, it precisely neutralizes real-time load jitters.

This collaborative mechanism achieves high-precision net-load tracking through effective frequency decoupling. By prioritizing high supply reliability and substituting fuel consumption with battery flexibility, the strategy minimizes operational costs while maximizing the system’s economic potential.

2.4 Annual Operational Performance Evaluation

Table 2 compares the annual performance of the proposed MAPPO algorithm against single-agent TD3 and DQN baselines on the test set.

Table 2. Comparison of Annual Dispatch Performance

Algorithm Model	Total Fuel Cost (10k CNY)	Load Shedding Penalty (10k CNY)	Total Operating Cost (10k CNY)
DQN (Discrete)	33.52	30.15	63.67
Single-Agent TD3	31.16	0.40	31.56
Proposed MAPPO	28.45	0.25	28.70

The results indicate that the proposed multi-agent collaborative algorithm outperforms traditional benchmarks across all economic indicators. It achieves a significant 54.9 % cost reduction compared to the discrete DQN baseline and demonstrates superior robustness in maintaining supply reliability by minimizing the load shedding penalty.

The proposed cooperative MADRL framework demonstrates notable advantages in managing the stochasticity of isolated micro grids by implementing a frequency-decoupled dispatch logic. The diesel generator (DG) agent, leveraging global state information from the centralized critic network, effectively filters high-frequency fluctuations and maintains a stable power baseline. This smooth output profile significantly reduces mechanical fatigue and extends the operational lifetime of the diesel generator. Conversely, the energy storage system (ESS) agent provides high-speed response for active peak-shaving and valley-filling, precisely compensating for real-time load variations and renewable power intermittency. This coordinated specialization mechanism successfully circumvents the curse of dimensionality inherent in large-scale action spaces while enhancing decision-making robustness compared to single-agent baselines.

The superior performance of the proposed method can be attributed to two key factors. First, the CTDE framework enables each agent to focus on its local observations during execution while benefiting from global information during centralized training, effectively addressing the non-stationary problem common in multi-agent environments. Second, the reward reshaping mechanism aligns individual agent incentives with the global economic objective, naturally inducing emergent cooperative behaviors such as the observed frequency decoupling between the DG and ESS agents.

Nevertheless, several limitations of the current approach warrant further investigation. The CTDE architecture remains sensitive to communication quality; limited bandwidth or sensor failures may degrade the critic network’s evaluation accuracy during training. Additionally, the zero-shot transferability of the trained policy under extreme, out-of-distribution meteorological events requires rigorous stress testing to ensure long-term operational resilience. Future work should also explore communication-efficient multi-agent reinforcement learning (Comm-MARL) to enhance decision consistency under realistic communication constraints.

This paper presents a cooperative multi-agent deep reinforcement learning method based on MAPPO for economic dispatch of isolated micro grids under source-load uncertainty. By modeling the energy storage system and diesel generator as independent heterogeneous agents with a reward reshaping mechanism, the proposed approach achieves a coordinated dispatch strategy characterized by frequency-decoupled operation: the diesel generator provides a stable power baseline while the energy storage system compensates for high-frequency fluctuations. Simulation results

demonstrate that the proposed method reduces total annual operating costs by 54.9 % compared to the discrete DQN baseline and maintains superior supply reliability with minimal load shedding, even under extreme operating conditions. The findings confirm the scalability and robustness of the cooperative MADRL framework for complex, high-dimensional energy management tasks in isolated micro grids.

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DUNNING-KRUGER EFFECT IN ARTIFICIAL INTELLIGENCE

Abstract. The article is devoted to the issue of forming approaches to the educational process, taking into account the capabilities of modern technological solutions based on artificial intelligence. The availability and diversity of information change its perception and form a new type of thinking and image of the modern student.

Keywords: artificial intelligence, Dunning-Kruger effect, knowledge, brain, education, facts.

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ЭФФЕКТ ДАНИНГА-КРЮГЕРА В УСЛОВИЯХ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

Аннотация. Статья посвящена вопросу формирования подходов к образовательному процессу с учетом возможностей современных технологических решений на базе искусственного интеллекта. Доступность и многообразие информации изменяет ее восприятие и формирует новый тип мышления и образ современного учащегося.

Ключевые слова: искусственный интеллект, эффект Даннинга-Крюгера, знания, головной мозг, образование, факты.

Artificial intelligence (AI) penetrates all areas of everyday human life, industry, banks, science. It becomes obvious that this cannot be prevented, but it is important to decide how to use this tool most effectively. This is especially true for such important areas of activity as education and science, which, on the one hand, develop and improve these technologies, and on the other, fully experience the strongest pressure of contradictory approaches to this phenomenon. This article is a reflection

of the main ideas presented in the book by William Poundstone “Head in the Cloud: Why Knowing Things Still Matters When Facts Are So Easy to Look Up” [1].

The term “Artificial intelligence (AI)” was proposed by John McCarthy in the summer of 1956 at a conference at Dartmouth College, which became the starting point in the development of artificial intelligence as a research area [2]. This was a metaphor reflecting the scientists’ not entirely clear dream of creating a machine capable of imitating human mental activity.

In English, the phrase artificial intelligence does not have the anthropomorphic coloring that it acquired in the traditional Russian translation: the word “intelligence” rather means “the ability to reason wisely”, and not at all “brainpower” (for which there is an English analogue of intellect).

Numerous discussions about the “benefits and harms” of artificial intelligence create additional noises that make it difficult to objectively assess the state of the issue. The situation is reminiscent of the reasoning about the meaning of the Internet and the manifestation of the Dunning-Kruger effect, when psychology professor David Dunning from Cornell University (USA) and his graduate student Justin Kruger, during the study, deduced some pattern – “The less we know and know how, the more we are unaware of our ignorance.” To test this statement, they conducted a series of tests, offering students tasks to check grammar, logic and sense of humor. Then they asked everyone to rate their own works, as well as how good they are in comparison with the works of the rest (in percent). It turned out that students with low performance have a disproportionately high opinion. Those who completed the least tasks considered that they exceeded the knowledge of two students out of every three. The researchers noticed that in order to assess how correctly you completed the grammar task, you need to know the grammar. To trigger the Dunning-Kruger effect, a person needs rudimentary knowledge and experience in an area which he does not really understand. At the same time, he does not know about his ignorance. For example, a bad driver usually considers himself a good driver. It does not refer to someone who has never got behind the wheel.

The Internet in the mid-1990s opened up a world for everyone in which facts about everything that happened became available to everyone. It is enough to press the phone buttons a couple of times, or utter the cherished words, and, as if by magic, you will get an answer to your question. Thanks to these favorite “magic” devices, you can go online at a cafe table, on a treadmill, at a meeting, at a lecture and in bed before bedtime.

Thus, the question arises – why bother and stuff your head with facts? And now there is not just the Internet, but AI.

It turns out that the head must be developed at least for the sake of knowledge. Transferring the prerogative of knowledge to digital devices is the plot of today. Therefore, whatever your professional knowledge is, it is already in the “cloud” or it will be there soon. Your knowledge will no longer be so relevant in comparison with what is already on the network, and the network itself gives the result faster, but what next? It turns out that you can be replaced by low-paid, poorly competent workers interacting with AI. Instead of real knowledge, a low-paid employee has knowledge of a semi-finished product using neural networks. Today it is obvious that

technological progress will force us to evaluate approaches and concepts about education.

The only question is what will be a blessing for everyone and will we live in the best possible world? There is always a dilemma in training programs: on the one hand, to teach facts or skills: a multiplication table, rules, dates, on the other hand, training in critical thinking and relevant skills (for example, how to search for information). Obviously, students need to accumulate a critical mass of facts that will give an approximate idea of what they know and what they do not know. Only then can they avoid the Dunning-Kruger effect – ignorance of their own ignorance. And only then can they fill the gaps with AI.

During the course of the research professor of English and Literature at the University of Virginia Eric Donald Hirsch Jr. came to the conclusion that students clearly had problems with the cultural background, which is especially noticeable among our students. Together with his assistant, he compiled a list in which there were about five thousand personalities, events and ideas – everything that, in their opinion, every educated person should know about. For example, the list includes such concepts as gamma radiation, absolute zero, tactlessness. They, as Hirsch believed, are part of the information field that every competent person has, the “background” knowledge stored in memory, thanks to which he reads a message that is written at an adequate level for understanding: captures the essence, the subtexts, correlates what he read with the subtext without which what he read would not have been meaningful.

Following the theory of generations of Strauss-Howe [3], which examines the model of generational development, and taking into account the influence of various historical events and technological development, we can talk about today’s generation of millennials (generation Y) and zoomers (generation Z) who will change their approach to classes and type of memory when the approach to classes and type of memory changes: they prefer to remember not the information itself, but the method of obtaining it: for example, how to find it on the Internet. They believe that they do not need to keep large amounts of data in their heads, because it is possible to obtain this information at any time, from any gadget. Their cognitive processes change when the structure of memory changes from operational to long-term, a smaller amount of information goes away.

For those who are accustomed to receiving instant help online from an early age, it is difficult to assimilate traditional views on the need to remember facts. There is less knowledge because there is less need to know anything. Young people do not know many facts that can be considered fundamental in terms of cultural literacy. We live in a time of rational and rationalized ignorance, when information is generated, devalued and outdated at an incredible speed. The very concept of culture is changing. The question is that you can track everything that happens, but is it really necessary? The knowledge of those who are not bright sparks is not necessarily scarce, it is more complete in some respects. For example, the knowledge of a gamer playing video games is encyclopedic in this area. Still, he can be called ignorant regarding things that are considered important.

Is there a clear list of facts that everyone should know? Today, the media is not the best guide. They stimulate the creation of solipsistic information filters, consider

their own individual consciousness to be the only and undoubted reality. They weed out the really important and spread rumours about movie stars, television series, sports matches, street tragedies. And one simply cannot bear to watch anything else. The point is, we do not become less knowledgeable or receive incorrect information because of the Internet and AI, but we are less aware of our ignorance. When we believe the facts are at our fingertips, they are easily forgotten. This phenomenon has its own name, “Google”, and it means involuntarily forgetting the information that can be found on the network.

It will not go anywhere from the “cloud”, it will always be at hand. But this seductive assurance makes no mention of the fact that keeping up to date is knowing not just the facts but the context. Thanks to the ability to cover the situation as a whole, we are able to evaluate the quotient, and also, which is extremely important, we may be able to understand something that we do not know.

Neural networks of the brain develop a new mode of assimilation and memorization of information, according to which facts are less often stored in memory and are forgotten faster. Because of the Internet, people do not become dumber, but may become less aware of their own ignorance. Incomplete knowledge creates distorted mental maps of the world [4]. Misconceptions affect decisions, actions and judgments in both personal and public life.

In real life, knowledge is valued, not only (and not so much) a diploma or useful acquaintances that appear over the years of study (for example). Electronic devices allow you to go headlong into the depths of your own interests, not paying attention to everything else.

Comprehensive and continuous education is not only a means of being healthy and well-off. The process of cognition hones intuition and imagination. Facts deposited in the head are generally accepted reference points in which opinions, cultures, ideologies converge: they are necessary for a friendly conversation, for the formation of one’s points of view, and for the birth of one’s dreams.

Thanks to them, a person as a social being becomes wiser and learns humility underestimated by many – after all, only the knowledgeable is able to realize his own ignorance.

“What do I need to look for?” and “What do I want?” are the only things that are pointless to ask the Internet and AI about.

According to the Federal Law of the Russian Federation, artificial intelligence is a complex of technological solutions that allows imitating a person’s cognitive functions (including self-learning and finding solutions without a predetermined algorithm) and obtaining results when performing specific tasks that are comparable, at least, with the results of human intellectual activity. Undoubtedly, the spread of the use of this tool will continue and the problem is not in the expansion, but in the uncritical assessment of the real possibilities and results of its work. People perceive AI and the neural networks without their own assessment and criticism, that is, they cannot control it [5]. The challenge to the educational system lies in the fact that for the effective use of AI, a person requires high-quality fundamental and preferably interdisciplinary education.

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**MITOCHONDRIAL DYSFUNCTION AS A TARGET FOR WORKPLACE
NUTRITION IN THE PULP AND PAPER INDUSTRY:
A BIOCHEMICAL RATIONALE**

Abstract. Workers in the pulp and paper industry are chronically exposed to a mixture of occupational toxicants. Epidemiological studies indicate increased risks of respiratory, cardiovascular, and malignant diseases. Conventional safety measures do not address mitochondrial dysfunction. This paper provides a biochemical rationale for addressing this issue. Three mechanisms are analyzed: complex IV inhibition caused by hydrogen sulfide and mercaptans; mitochondrial permeability transition pore opening via calcium dysregulation induced by organochlorines; and redox cycling at complexes I and III triggered by chlorinated quinones. Based on these, a modular nutritional strategy is proposed. A basic regimen of N-acetylcysteine, alpha-lipoic acid, zinc, and magnesium is recommended for all workers. Additional nutrients include succinate for personnel exposed to hydrogen sulfide, as well as selenium and coenzyme Q10 for those exposed to chlorine-based compounds. Nutritional support represents a promising, affordable adjunct to existing occupational safety measures in the pulp and paper industry.

Keywords: mitochondrial dysfunction, oxidative stress, pulp and paper industry, occupational toxicology, workplace nutrition, hydrogen sulfide, organochlorines, quinones, N-acetylcysteine, coenzyme Q10.

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МИТОХОНДРИАЛЬНАЯ ДИСФУНКЦИЯ КАК МИШЕНЬ ДЛЯ ПРОИЗВОДСТВЕННОГО ПИТАНИЯ В ЦЕЛЛЮЛОЗНО- БУМАЖНОЙ ПРОМЫШЛЕННОСТИ: БИОХИМИЧЕСКОЕ ОБОСНОВАНИЕ

Аннотация. Работники целлюлозно-бумажной промышленности постоянно подвергаются воздействию смеси профессиональных токсикантов. Эпидемиологические исследования указывают на повышенные риски респираторных, сердечно-сосудистых и онкологических заболеваний. Традиционные меры безопасности не учитывают митохондриальную дисфункцию. В данной статье предлагается биохимический подход к решению этой проблемы. Анализируются три механизма: ингибирование комплекса IV, вызываемое сероводородом и меркаптанами; открытие митохондриальной поры через нарушение кальциевого гомеостаза, индуцированное хлорорганическими соединениями; и редокс-циклирование на комплексах I и III, запускаемое хлорированными хинонами. На их основе предлагается модульная нутритивная стратегия. Базовый набор из N-ацетилцистеина, альфа-липоевой кислоты, цинка и магния рекомендуется всем работникам. Дополнительные нутриенты включают сукцинат для персонала, работающего с сероводородом, а также селен и коэнзим Q10 для контактирующих с хлорсодержащими соединениями. Нутритивная поддержка представляет собой перспективное и доступное дополнение к существующим мерам охраны труда в целлюлозно-бумажной промышленности.

Ключевые слова: митохондриальная дисфункция, окислительный стресс, целлюлозно-бумажная промышленность, профессиональная токсикология, производственное питание, сероводород, хлорорганические соединения, хиноны, N-ацетилцистеин, коэнзим Q10.

Workers in the pulp and paper industry are exposed to a complex mixture of occupational toxicants, including hydrogen sulfide, mercaptans, organochlorines, and chlorinated quinones [1–4]. Epidemiological studies have demonstrated elevated risks of respiratory, cardiovascular, and malignant diseases among pulp and paper workers [5].

Conventional occupational safety measures primarily address acute toxicity and do not sufficiently account for subcellular mechanisms, particularly mitochondrial dysfunction. Mitochondria are central to cellular energy metabolism and are highly vulnerable to chemical toxicants [6].

This paper provides a biochemical rationale for addressing mitochondrial dysfunction in pulp and paper workers through targeted nutritional support. Based on the three main mechanisms of mitochondrial damage caused by pulp and paper toxicants, a modular nutritional strategy is proposed.

Mitochondrial dysfunction refers to impaired oxidative phosphorylation, decreased adenosine triphosphate (ATP) production, loss of membrane potential ($\Delta\Psi_m$), and opening of the mitochondrial permeability transition pore. Oxidative stress

is defined as an imbalance between reactive oxygen species (ROS) and antioxidant defense systems [6]. Although these phenomena are closely linked, they are not identical: mitochondrial dysfunction can occur without significant oxidative stress, and vice versa. However, in the context of pulp and paper industry toxicants, both processes are typically triggered simultaneously, with mitochondria serving as primary targets [4, 6].

Hydrogen sulfide (H_2S) and volatile mercaptans (methyl mercaptan, dimethyl sulfide) are released during sulfate pulping, the main technological stage of pulp production. Once inside cells, H_2S and mercaptans block complex IV (cytochrome c oxidase) of the mitochondrial electron transport chain. Complex IV is responsible for transferring electrons to molecular oxygen, the final electron acceptor. By inhibiting this complex, H_2S and mercaptans prevent oxygen from accepting electrons, causing electrons to back up and accumulate on the preceding complexes I, II, and III. This accumulation leads to increased electron leakage, which generates ROS. Simultaneously, the blockade destabilizes mitochondrial supercomplexes and disrupts cristae morphology [4, 7]. As a result, ATP production decreases and the $\Delta\Psi_m$ collapses [8].

Organochlorines, including dioxins, furans, and chlorophenols, are formed as byproducts during pulp bleaching with chlorine or chlorine dioxide. These compounds persist in the work environment and can enter the body through inhalation or dermal contact. Organochlorines interfere with multiple electron transport chain complexes (I, II, III, and IV), disrupting electron flow at several points simultaneously [2]. This broad inhibition impairs proton pumping across the inner mitochondrial membrane, reducing the proton motive force that drives ATP synthesis. In addition, organochlorines disturb mitochondrial calcium homeostasis, impairing both calcium uptake and release mechanisms, which further compromises mitochondrial function. Chlorophenols act as uncouplers of oxidative phosphorylation: they shuttle protons across the inner membrane, bypassing ATP synthase. This uncoupling dissipates the proton gradient, so electron transport continues but ATP synthesis stops. Consequently, cellular ATP levels drop while oxygen consumption increases, without significant changes in the redox state [3].

Chlorinated quinones (e.g., chlorinated benzoquinones, chlorinated catechols) are also formed as byproducts during pulp bleaching, particularly when chlorine dioxide reacts with lignin [1]. These compounds are known to undergo redox cycling, a process in which they accept and donate electrons repeatedly, generating superoxide radicals. This redox cycling consumes nicotinamide adenine dinucleotide phosphate and depletes cellular glutathione, compromising the antioxidant defense system. In addition, chlorinated quinones act as potent uncouplers of oxidative phosphorylation in mitochondria. Similar to chlorophenols, they disrupt the coupling between electron transport and ATP synthesis by shuttling protons across the inner membrane. The combined effect of redox cycling (ROS generation) and uncoupling (ATP depletion) makes chlorinated quinones particularly harmful to mitochondrial function. As a result, oxygen consumption increases while ATP production decreases, and the cell faces both energy shortage and oxidative damage [1].

So, these three mechanisms – complex IV blockade, uncoupling of oxidative

phosphorylation, and calcium dysregulation – all converge on mitochondrial dysfunction. Therefore, targeted nutritional support aimed at restoring mitochondrial energy production and reducing oxidative stress represents a logical countermeasure for workers exposed to pulp and paper toxicants.

Nutritional support for workers exposed to pulp and paper toxicants should follow three principles. First, it must target specific mechanisms rather than general symptoms. Second, it should be modular – a basic protocol for everyone plus additional nutrients for high-risk groups. Third, it is not a replacement for personal protective equipment but an additional measure. High-dose antioxidant cocktails are not recommended as they may interfere with adaptive cellular responses. Instead, the preferred approach uses precursors of endogenous antioxidants (N-acetylcysteine (NAC), alpha-lipoic acid (ALA)), membrane stabilizers (zinc, magnesium), and mitochondrial substrates (succinate).

All workers at pulp and paper mills should receive a basic regimen regardless of their specific job. This baseline targets common pathways of oxidative stress and membrane integrity. NAC (600 mg/day) serves as a glutathione precursor and directly scavenges electrophiles [9, 10]. Alpha-lipoic acid (300 mg/day) acts as a mitochondrial antioxidant, regenerates glutathione and vitamins C and E, and provides mild chelation [11, 12]. Zinc (15 mg/day) stabilizes mitochondrial membranes, antagonizes heavy metals, and serves as a cofactor for superoxide dismutase [13]. Magnesium (300 mg/day) stabilizes the mitochondrial permeability transition pore and is required for ATP synthesis [14].

Module A: Cooking department (H₂S and mercaptans). Workers exposed to hydrogen sulfide and mercaptans require additional support. Succinate (500 mg/day) enters the electron transport chain at complex II, bypassing the complex IV blockade caused by H₂S [15].

Module B: Bleaching department (chlorine and organochlorines). Workers exposed to chlorine, chlorine dioxide, and organochlorines benefit from selenium and coenzyme Q10 (CoQ10). Selenium (100 µg/day) is a cofactor for glutathione peroxidase, which reduces hydrogen peroxide and lipid peroxides. CoQ10 (200 mg/day) acts as a membrane antioxidant, protects mitochondrial DNA, and shuttles electrons in the electron transport chain [16, 17].

Mixed exposure. For workers with intermittent or mixed exposure, reduced doses are recommended: succinate 250 mg/day, CoQ10 100 mg/day, and selenium 50 µg/day.

The proposed protocol is designed for implementation through workplace catering. Fortified meals (adding NAC, ALA, zinc, magnesium to staple foods) offer the highest compliance at low cost. Alternatively, individual sachets can be provided in the canteen. Targeted modules should be distributed only to specific departments to optimize the risk-benefit ratio. All recommended doses are within safe upper intake levels. NAC at 600 mg/day is safe for long-term use. Succinate and CoQ10 have no known serious side effects. This nutritional support does not replace but complements personal protective equipment and engineering controls.

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MICROENCAPSULATION. AN OVERVIEW

Abstract. Microencapsulation technology has found wide application in various fields. It is used in agriculture, perfumery, medicine, the paint and varnish industry, household chemicals, and many other industries. This article examines the main microencapsulation methods, discusses the specific features of each, and describes their advantages and limitations.

Keywords: microencapsulation, coacervation, interfacial and *in situ* polymerization, microencapsulation methods, spray drying, coating processes, solvent evaporation processes, rotating disk.

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МИКРОКАПСУЛИРОВАНИЕ. ОБЗОР

Аннотация. Технология микрокапсулирования получила широкое применение в различных областях жизни человека. Так, микрокапсулирование используется в таких сферах, как сельское хозяйство, парфюмерия, медицина, лакокрасочная промышленность, бытовая химия и многих других. В статье рассмотрены основные способы микрокапсулирования, обсуждаются особенности каждого из способов, описаны их преимущества и ограничения применения.

Ключевые слова: микрокапсулирование, коацервация, межфазная и *in situ* полимеризация, методы микрокапсулирования, распылительная сушка, процессы нанесения покрытий, процессы испарения растворителей, вращающийся диск.

Introduction

Microencapsulation is the process of encapsulating a core material within a polymer shell [1]. The size of the microcapsules depends on the microencapsulation method. Capsules can range from microns in size to several millimeters [2]. Microencapsulation can influence changes in color, shape, volume, apparent density, reactivity, durability, pressure sensitivity, heat sensitivity, and photosensitivity of the encapsulated substance. For example, the shelf life of a volatile compound can be significantly increased.

In thermochromic systems, the microcapsule shell creates an isolated system and protects the base substance from UV rays, moisture, and oxygen. The microcapsule shell can prevent a chemical reaction between two active particles by physically separating them (encapsulating vitamin E to prevent its oxidation by atmospheric oxygen). Fine powders are encapsulated to reduce agglomeration (e. g., agricultural fertilizers). The microcapsule can retain the substance in a finely dispersed state and release it as needed. Controlled release is often used for pharmaceuticals, while a completely impermeable shell is used for perfume compositions. Liquid encapsulation effectively converts the liquid into a fine powder while maintaining the encapsulated phase. Thus, microencapsulation improves the ease of handling of liquid reactants and allows the chemical reaction to begin upon rupture of the microcapsule. The density of a substance can be increased by encapsulation or decreased by incorporating air into the capsule. Thus, a dense solid can be transformed by encapsulation into a product that floats on the surface of water. This technology is used to encapsulate oil-degrading bacteria used to clean up oil spills in water bodies.

Microcapsules consist of a core-shell structure, where the active substance is surrounded by a shell (reservoir system). Gaseous, liquid, and solid materials – whether hydrophobic or hydrophilic – can be encapsulated. The shell material and microencapsulation method are selected depending on the physical properties of the core and the intended purpose. The shell is typically made of natural or synthetic polymers.

When choosing a microencapsulation process design, it is necessary to consider the entire system: the properties of the encapsulated substance and the shell material, the release mechanism (if necessary), and the purpose of encapsulation.

Microencapsulation methods

Various microencapsulation methods exist, the choice of which depends on the core material, the solubility of the polymer shell, the capsule size, the shell thickness and permeability, and the type and rate of release of the microcapsule's contents.

When selecting a microencapsulation method, criteria such as the core wettability and solubility, the required shell elasticity, and its permeability should be considered. The wettability of the core plays a key role in the shell material's ability to uniformly envelop the core material; the microcapsule's contents (core) should not dissolve in the polymer shell solvent, and the polymer should not significantly dissolve in the core contents; the shell elasticity is primarily determined by the polymer's nature; and the shell permeability determines how long the microcapsule's core contents remain intact. Permeability is divided into two types: the first is for an indefinite period (impermeable shell), in which the contents are not released until rupture; the second type involves the use of a permeable shell, with which the contents can be released at a predetermined time. Microencapsulation methods can be classified into the following groups:

1. Phase separation;
2. Interfacial and in situ polymerization;
3. Spray drying;
4. Solvent evaporation processes;
5. Coating processes;
6. Rotating disk.

Microencapsulation typically uses a combination of several processes [3].

Phase Separation (Coacervation)

Phase separation is a term applied to various processes, such as the formation of a solid or liquid phase from a solution. Examples include the crystallization of a salt or the precipitation of a polymer due to the removal of a solvent from a solution. The new phase is physically distinct and has different properties from the solution and can be separated mechanically.

The word "coacervate" can be defined as an aggregation of colloidal droplets held together by electrostatic forces of attraction. The term "coacervation" is used to describe the formation of a coacervate associated with phase separation. A coacervate forms a distinct liquid layer, but upon stirring, it can form droplets suspended in a polymer-poor phase. Furthermore, it is typically more viscous, more concentrated, and often has the ability to bind to, adsorb, or absorb any solid or liquid added to the system. A polymer solution, usually dilute, is subjected to a process that reduces its solubility in the system to the point where phase separation of the polymer occurs, forming a polymer-rich phase. This polymer-rich phase can be used to process pharmaceuticals and other substances. Alternatively, the formation of a colloid-rich phase can lead to flocculation, resulting in the colloid being present in a more dispersed state and generally unsuitable for encapsulation.

To produce microcapsules using coacervation, it is necessary to select a polymer that will provide the appropriate coating characteristics desired in the final product. It is also important to select a suitable solvent in which the polymer will dissolve completely without dissolving the core.

To encapsulate the core, it is added to a constantly stirred polymer solution to disperse the core within the polymer solution.

To achieve phase separation of the polymer, one of many processes is used, such as the addition of a non-solvent to the polymer. It should be noted that most of the solvent used to dissolve the polymer now forms the polymer-poor phase and forms the suspending medium in which the core and coacervate droplets are mixed. If the solvent is removed, for example by evaporation, the polymer phase becomes polymer-rich and eventually deposits on the core. In this system, since the polymer solvent has been removed, it may be necessary to add another liquid, such as liquid paraffin or water, which does not evaporate significantly and is used to suspend the core and polymer-rich phase.

The polymer-rich droplets containing the core material are further desolvated by a process similar to that described above or by a different process. The polymer can also be cured by a number of methods, such as thermal desolvation or cross-linking, to form microcapsules.

The microcapsules are then separated and washed with a suitable liquid to remove unwanted solvents and excipients [3]. Factors to consider during the coacervation process include:

- Polymer solubility;
- Core solubility;
- Thermal stability of the core and polymer;
- Required microcapsule size range;
- Formation of a coacervate or concentrated polymer solution with suitable characteristics, such as adequate viscosity, deposition on the core, and adhesion to it;
- Required shape characteristics;
- Sensitivity of the core material to the process.

Coacervation is classified as simple or complex; it can also occur as a result of salting-out.

In simple coacervation, a water-miscible solvent in which the polymer is insoluble is added to an aqueous polymer solution, causing the formation of a separate, polymer-rich phase due to partial miscibility.

In salt or ionic coacervation, the polymer is separated from the aqueous solution by salting-out. An electrolyte is added to the aqueous polymer solution, resulting in phase separation. This method can be used to encapsulate water-insoluble substances or dispersed solid particles. The large amount of salt used during salting-out must then be washed out of the system. Microcapsule size is difficult to control during salting-out, and the resulting microcapsules tend to agglomerate. This problem can be solved by adjusting pH or temperature.

Complex coacervation occurs as a result of the mutual neutralization of two or more oppositely charged colloidal materials in an aqueous medium [3].

Complex coacervation is closely related to the precipitation of a colloidal material from a solution: coacervation immediately precedes precipitation. Microencapsulation by complex coacervation consists of three steps:

1. Dispersion of the active component to be encapsulated in an aqueous polyelectrolyte solution;
2. Precipitation of a coacervate around the base material, formed by the addition of an aqueous solution of a second electrolyte of opposite charge;
3. Coacervate gelation.

This principle of phase incompatibility is also used to produce microcapsules based on the incompatibility of different polymers. Polymer-polymer incompatibility depends on the free energy of polymer mixing. The components are emulsified to form a microcapsule and then stabilized by the addition of a hydrocarbon oil and a dehydrating liquid.

Coacervation is reversible and is an equilibrium process [4].

Interfacial and in situ polymerization

The most common method for producing microcapsules is polymerization, which involves the precipitation of monomers on the surface of droplets of an emulsion of the core material, resulting in the formation of a solid polymer shell. These methods can be divided into two main subcategories: in situ polymerization, in which the monomer is typically added only to the aqueous phase of the emulsion; and interfacial polymerization, in which one monomer dissolves in the continuous phase and the other in the dispersed phase. In most cases, the initial stages of the polymerization reaction result in the formation of an oligomer with a relatively low molecular weight. As it grows, it tends to precipitate on the surface of the core droplet, forming a microcapsule. The microencapsulation process involves two main stages: emulsification and microcapsule formation.

Emulsification determines the size of the resulting microcapsules. Various physical parameters, such as apparatus configuration, stirring speed, and the volume ratio of the two phases, can influence the emulsification stage. Physicochemical properties such as interfacial tension, viscosity, density, and the chemical composition of the two phases can also significantly influence the microencapsulation process. Selecting the appropriate surfactant for microcapsule formation is crucial, as it affects not only the average diameter but also the stability of the dispersion. Surfactants serve two functions in microencapsulation: reducing the interfacial tension between the oil and water phases (allowing the formation of smaller microcapsules) and preventing coalescence by adsorption at the oil-water interface, thus forming a layer around the oil droplets.

Interfacial polymerization is a widely used microencapsulation method. Microcapsules produced by this method exhibit high strength and stability, and membrane permeability can be adjusted or modified by selecting appropriate combinations of monomers or cross-linking agents. This method is typically used to produce particles with an average diameter of 1 to 30 μm . The main disadvantages of this technology are its complexity, low reaction rate, the presence of side reactions, and the use of organic solvents. The choice of surfactant is a key parameter for limiting the formation of an aggregated or agglomerated structure. The morphology of the

microcapsules is primarily determined by the solubility of the polycondensate molecules or oligomers formed in the dispersed phase [5].

Spray Drying

Spray drying is a technology in which a feed solution, a mixture of core and shell materials, is atomized and converted into a mist inside a chamber into which hot air is introduced to convert the mist into powder. During spray drying, the core, the inner component of the microcapsule, is entrapped in the dried shell material. The advantages of this method include its suitability for a variety of shell materials, cost-effectiveness, variable encapsulation parameters, applicability to many different types of materials, and ease of scalability.

A disadvantage of this method is that when hot air is used as the drying medium for encapsulation, the dried powder may contain particles with a highly porous structure, making the powder more susceptible to oxidation and, consequently, reducing its shelf life. Therefore, this method cannot be considered universally applicable, as its effectiveness depends on the type of substance being encapsulated [6].

Solvent Evaporation Processes

Microencapsulation by solvent evaporation is the most common method in the pharmaceutical industry. Various solvent evaporation microencapsulation methods exist. The choice of method that ensures effective encapsulation depends on the hydrophilicity or hydrophobicity of the microcapsule core material. For substances insoluble or poorly soluble in water, the oil-in-water method is often used. It also forms the basis for all other methods. The oil-in-water method can be divided into four main stages:

- dissolution of the hydrophobic core material in an organic solvent containing the polymer;
- emulsification of this organic (dispersed) phase in an aqueous phase, called the continuous phase;
- extraction of the solvent from the dispersed phase by the continuous phase, accompanied by solvent evaporation, converting droplets of the dispersed phase into solid particles;
- isolation and drying of the microcapsules to remove residual solvent.

This method is not suitable for encapsulating highly hydrophilic substances. This is because the hydrophilic core may not dissolve in the organic solvent, and during emulsification, the core material will diffuse into the continuous phase, leading to significant loss. There are four methods for encapsulating hydrophilic core materials.

1. Water/oil/water double emulsion method. In this method, an aqueous solution of the hydrophilic core material is emulsified with an organic phase (water/oil emulsion), which is then dispersed in a second aqueous solution, forming a second emulsion (water/oil/water double emulsion);

2. Oil/water cosolvent method. If the core is insoluble in the primary organic solvent, a second solvent, called a cosolvent, is used to dissolve it;

3. Oil/water dispersion method. The microcapsule core material is dispersed as a solid powder in a solution of a polymer and an organic solvent;

4. Oil/oil non-aqueous solvent evaporation method. In this method, the aqueous phase is replaced by oil [7].

Coating Processes

Fluidized bed coating is a microencapsulation method in which the shell material is sprayed onto a fluidized core material. In this case, the core material is fluidized by the addition of air. There are several fluidized bed coating methods: top spray, bottom spray, and tangential spray. In this microencapsulation method, the coating efficiency depends on various parameters, such as the shell material feed rate, nozzle spray pressure, temperature, inlet air velocity, etc.

Disadvantages of this method include expensive equipment, the need for strict parameter control to obtain a uniform product, and the possibility of uneven coating of the capsules [6].

Rotating Disc

The rotating disc method is based on a rotating device fed with a polymer solution containing the core material to be microencapsulated. Due to the high rotational speed, droplets are separated, and during their flight, the particles are dried until a solid capsule structure is formed. The dried particles are extracted. This method is used in the food industry and for flavor encapsulation [3].

Conclusion

Currently, many different microencapsulation methods exist, including interfacial polymerization, spray drying, coating, solvent evaporation, coacervation, and others. Each method has its own advantages and limitations. The choice of method is based on the physicochemical properties of the core material, the required shell characteristics, and the intended use of the resulting microcapsules. Microencapsulation technology has high potential for applications in pharmaceuticals, food, paints, and other industries.

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THE IMPACT OF A COMPREHENSIVE APPROACH IN THE PREVENTION AND TREATMENT OF MASTITIS

Abstract. This article presents a comparative analysis of mastitis pathology in cattle and humans, as well as studies focused on identifying pathogens and reducing inflammatory processes in dairy cows using an enzymatic-biotic complex and an antimicrobial agent based on plant extracts containing microbial metabolites. A comprehensive approach to preventing the development of subclinical mastitis on dairy farms has been validated; this approach is based on improving feed digestibility, boosting the immunity of lactating animals, and treating the udder with a new agent that overcomes the protective mechanisms of mastitis pathogens and suppresses them. A correlation was found between milk parameters and feed digestibility, as well as the possibility of stabilizing these parameters by boosting the animal's immunity during lactation. The key indicators of subclinical mastitis at a farm are *St. Aureus* and *E. coli*, which the developed product successfully suppresses by 98 % and 76 %, respectively. The practical significance of the research lies in a reduction of somatic cell counts by 60,000–80,000 and has the potential to reduce them by up to 150,000. It also improves milk quality to the grade A without any decline in immune function during the lactation period.

Keywords: mastitis, antimicrobial agent, comparative pathology, somatic cells, milk, subclinical mastitis, cattle, microbial resistance, feeding, enzymes.

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ВЛИЯНИЕ КОМПЛЕКСНОГО ПОДХОДА В ПРОФИЛАКТИКЕ И ЛЕЧЕНИИ МАСТИТОВ

Аннотация. В статье приводится сравнительный анализ патологии заболевания мастита у крупного рогатого скота и людей, а также исследования, посвященные выявлению возбудителей и снижению воспалительных процессов у продуктивных коров, за счет ферментативно-биотического комплекса и антимикробного средства на основе растительных экстрактов с метаболитами микроорганизмов. Обоснован комплексный подход в предупреждении развития субклинического мастита на молочных предприятиях, основанный на усвояемости кормов с повышением иммунитета лактирующих животных и обработки вымени новым средством, обходящим защитные механизмы возбудителей маститов с их подавлением. Выявлена зависимость показателей молока от качества усвоения кормов, а также возможность стабилизации показателей при повышении иммунитета животного в процессе лактации. Ключевыми показателями субклинических маститов на предприятии являются *St. aureus*, *E. coli*, которые успешно подавляет разработанное средство на 98 % и 76 % соответственно. Практическая значимость исследований заключается в снижении соматических клеток на 60-80 тыс. с возможностью снижения до 150 тыс., с повышением качества молока до уровня «Экстра» без иммунного проседания в лактационный период.

Ключевые слова: маститы, антимикробное средство, сравнительная патология, соматические клетки, молоко, субклинический мастит, крупный рогатый скот, резистентность микрофлоры, кормление, энзимы.

All mammals are susceptible to developing an infectious inflammatory process in their mammary gland tissue. The underlying causes and progression of mastitis are biologically similar in humans and animals. Mastitis occurs when the body's immune system is compromised in response to exogenous or endogenous factors [1].

Internal and external factors can contribute to lactostasis, which is primarily caused by a blockage in the milk duct due to a buildup of secretions or milk. This blockage can lead to the growth of microorganisms and is the most obvious initiating factor of mastitis. Metabolic disorders, prolactin and oxytocin level fluctuations, and vitamin deficiencies can lead to hormonal imbalances that contribute to mastitis development. Stress is an additional internal factor that affects the body by reducing the activity of white blood cells in breast tissue and increasing cortisol levels. Another factor may be the spread of pathogens that cause chronic diseases through the lymphatic system or bloodstream. Endometritis is most commonly found in cattle-raising facilities, while tonsillitis and dental caries are the most frequent conditions in human medical practice.

Factors that contribute to mastitis include external or endogenous injuries, such as bruises, micro-tears, and lacerations. These injuries can lead to infection by pathogens. Mastitis can also result from pathogens entering the milk duct due to poor hygiene. It can also be caused by poor blood circulation in a specific area, which can result from exposure to cold or heat.

All of the above factors can trigger inflammatory processes in the body if the immune system is weak. However, if the immune system is strong, the likelihood of inflammatory processes decreases significantly because phagocytes neutralize isolated pathogens and prevent infection.

When an inflammatory process develops in human or animal breast tissue, symptoms such as tenderness, hard lumps, swelling, local body temperature increases, and skin redness may occur.

At this point, it is safe to say that the traditional distinction between “pathogenic” and “beneficial” bacteria is outdated; depending on the strain, microorganisms can act differently within the same system. Therefore, it is important to perform strain typing in cases of mastitis in both humans and cows [2].

Pathogens can be transmitted from cows to humans through raw milk, by touching contaminated surfaces, or by touching contaminated objects or towels. Cross-contamination from humans to animals is also possible. One of the earlier studies focused on identifying the relationship between the microorganisms found in dairy cattle and the microorganisms found on the personnel working at the facility. Studies on the transmission of mastitis from cows to humans were conducted between January 2002 and December 2004 at a Hungarian facility; 595 milk samples were collected from cows with subclinical mastitis, from which 375 strains of *Staphylococcus aureus* were isolated, 28 of which were methicillin-resistant *Staphylococcus aureus* (hereinafter MRSA). A genetic typing analysis of 12 swabs taken from workers in close contact with animals revealed virtually identical strains in cows and humans. All isolated strains exhibited the same resistance to ampicillin, cephalixin, tetracycline, and erythromycin, and were susceptible to enrofloxacin, gentamicin, and trimethoprim or sulfamethoxazole [3].

The diagnostic data obtained showed that MRSA strains can be transmitted directly from humans to cows or vice versa, which led to the development of a wide range of methods for phenotyping and genotyping bacteria that cause mastitis over the course of twenty years. The studies were based on an analysis of the genetic similarity

of strains from cows at farms in various countries around the world to identify possible species-to-species transmission of pathogens. The most common Gram-negative microorganisms capable of interspecies transmission are *Escherichia coli*, which can adapt within the host's body, *Pseudomonas aeruginosa*, which causes sepsis, and *S. marcescens*, which is rarely found in humans. Gram-positive microorganisms include: *Staphylococcus aureus*, which has been studied more extensively in animals than in humans; *Streptococcus agalactiae*, which is transmitted only from mother to child in humans, but a single strain can infect an entire cattle herd due to poor hygiene practices on farms; *Streptococcus uberis*, which is less well studied in terms of typing, but is found only in animals [4]. The yeast and mold microorganisms that cause mastitis are *Trichosporon spp.*, *Aspergillus fumigatus*, *A. modulus*, and *Candida spp.* [5].

A review of veterinary and medical data on the clinical presentation of mastitis reveals subclinical and clinical forms, which are common to both species.

Subclinical or latent mastitis can only be diagnosed through laboratory testing, as it progresses without visible signs of infection; therefore, it often becomes chronic or develops into clinical mastitis.

Clinical mastitis is characterized by inflammatory processes and their complications. It is classified as serous, catarrhal, fibrinous, or purulent, depending on the type of pus present. Based on duration, mastitis is classified as acute (lasting up to 10 days), subacute (lasting up to 21 days), or chronic (lasting 30 days or longer).

Serous mastitis occurs when pathogenic microorganisms enter the mammary glands in one of two ways: through the veins and arteries or through the lymphatic system. The affected area swells to twice its normal size. After two days, the milk turns watery and contains flakes. The disease then progresses to a mixed form of serous-catarrhal inflammation.

Meanwhile, catarrhal mastitis develops as a result of improper feeding or milking techniques. When pathogenic microorganisms enter through the teat canal, the body reacts in two ways. In the first case, casein flakes are only visible in the initial streams of milk. In the second case, milk is difficult to express through the ducts because they contain casein flakes, clots, and mucus.

Purulent mastitis is an inflammation of the mammary gland characterized by a full-blown infectious process, unlike lactostasis. It occurs when stagnant secretions become infected with pathogenic microorganisms, which creates favorable conditions for their growth and is accompanied by tissue breakdown and the formation of purulent foci in the mammary glands. This form of mastitis requires systemic treatment and immediate cessation of breastfeeding due to the high levels of bacteria and pus [6].

Fibrinous mastitis is usually a complication of serous mastitis. The affected area swells sharply to 2-2.5 times its normal size, and milk production ceases; instead, a cloudy, yellowish fluid is secreted, containing large amounts of flakes and clots of fibrin protein, which accumulates in the alveoli and milk ducts. General signs of intoxication are observed, such as high fever and weakness; palpation of the udder reveals a crunching sensation, and lameness is characteristic of cattle. For dairy farms, fibrinous mastitis is one of the most dangerous forms, as it can lead to a complete loss of productivity in a quarter of the udder.

There are approximately five main methods of treating mastitis and two supplementary methods; however, one of the most popular traditional methods of treating mastitis as of 2026 is antibiotic therapy. According to studies from 2019–2020, the primary causative agent of mastitis is *Staphylococcus aureus*, accounting for 58.8 % of the 248 samples tested [7].

Antibiotic therapy is more effective in humans than in dairy-producing livestock, particularly cattle. When comparing key parameters for both species, the cure rate following antibiotic therapy for humans averages over 90 %, whereas for cattle, this figure ranges from 25 % to 50 % for *Staphylococcus aureus*, and is close to 90 % only for mastitis caused by *Streptococcus agalactiae*. Delayed treatment is a barrier to effective treatment in humans because it carries a risk of abscess formation. For dairy cattle, the main barrier is high antibiotic resistance, with up to 56 % of cases leading to subclinical recurrence. Subclinical mastitis that occurs on farms following antibiotic therapy contributes to the emergence of resistant strains and increases the risk of transmission via employees. For example, although lactational mastitis accounts for approximately 10 % of cases in humans, it poses a significant problem for dairy farms. On average, it affects 59.7 % of the herd, including cows that produce more than 15 liters of milk per day [8].

The global dairy industry loses up to \$30 billion annually in its fight against mastitis and its consequences. Subclinical mastitis and the overall health of lactating dairy cows are assessed through somatic cell count tests of raw milk. The somatic cell count in a healthy cow's udder ranges from 150,000 to 200,000 cells/mL. In cases of subclinical mastitis, the count exceeds 200,000 to 400,000 cells/mL. This is accompanied by an average decrease in milk yield of 10 to 20 %. Milk with a high somatic cell count does not curdle properly and is unsuitable for producing fermented dairy products. Producers incur significant economic losses due to the lack of demand for their milk and the resulting need to dispose of it or sell it to a dairy processing plant at a price below market value [9].

Further the article will discuss the relevance of developing new methods and medications for treating mastitis, with a particular focus on those that prevent and reduce antibiotic resistance in pathogenic microorganisms. This resistance arises when the disease is treated improperly with antibiotics.

The most promising approach is a comprehensive strategy for the prevention, management, and treatment of mastitis at dairy farms. Our research at a dairy farm in the Siberian region showed that using a specially developed enzymatic-biotic complex to improve fiber and feed digestibility enhances milk quality, evens out milk yields across the herd, positively affects somatic cell counts, and mitigates the effects of natural seasonal variations.

The in vivo experiment involved 680 lactating Holstein cows at various stages of lactation. The first group consisted of cows in early lactation (0–60 days), the second group of cows in mid-lactation (120–179 days), and the third group of cows in late lactation (over 180 days). Each of the three groups was divided into an experimental and a control group. An enzyme-probiotic complex designed to improve the digestibility of feed and fiber was added to the liquid energy supplement at a rate of 2 mL per head per day.

The first noticeable differences between the experimental and control groups were observed on the 7th day of feeding: milk fat content increased by 0.1 %, protein content also increased by 0.1%, cortisol levels began to decrease by an average of 4 µg/mL compared to the control groups, digestibility increased by 7 %, and somatic cell counts decreased.

By day 14, all parameters in the experimental groups had stabilized and the second group's milk yield had increased. Meanwhile, the control groups began to experience fluctuating changes in milk fat content, protein content, and somatic cell count. In the experimental groups, milk yield was consistently 2.3-3.3 kg/day higher, cortisol levels decreased by 28-37%, digestibility increased by 7-9 %, and body temperature stabilized and decreased by 0.4°C, indicating a reduced risk of systemic inflammatory processes and smoother metabolic processes. The results for experimental group two (120-179 days) are noteworthy as benchmark values for the Holstein breed: 34±1.2 kg with 4.0-4.1 % fat and 3.4 % protein, whereas the control group showed the typical stagnation in performance typically observed during this stage of lactation.

The somatic cell count in the experimental group decreased to 260–280 thousand, which is 60-80 thousand per milliliter lower than in the control groups, the count of which was at the limit of the acceptable range for the highest grade. A decrease in somatic cell count is a direct indication of improved immunity; however, a count of 260,000–280,000 indicates a possible prevalence of subclinical mastitis in the herd at 13–15 %. To qualify for the highest milk grade (grade A) this count must be reduced to 150,000, which will be economically beneficial for the enterprise.

Following the discontinuation of the enzymatic-biotic complex addition to the diet after 25 days, a decrease in all parameters was observed in the experimental groups on days 7–10, indicating a prolonged effect.

During the experiment, the farm followed its standard veterinary protocol to prevent mastitis and inflammation. Udder samples were collected from the control and experimental groups during this period to determine microbiological contamination and evaluate the efficacy of a new antimicrobial agent derived from plant extracts and microbial metabolites in combating antibiotic-resistant pathogens, including those causing subclinical mastitis [10].

Laboratory microbiological analyses of swabs identified several microorganisms responsible for mastitis, including *Escherichia coli* and *Staphylococcus aureus*; it is worth noting that *Enterobacteriaceae* were more commonly found in all samples; microorganisms of the genera *Candida* and *Pseudomonas* were also isolated, while no molds were detected upon inoculation onto identification media. *Escherichia coli* serotypes O55 and O111 were more prevalent in the control groups, accounting for 70-80 % of the total number of intestinal microorganisms, whereas in the experimental groups, their numbers decreased after one month of feeding and were distributed across age categories as follows: Group 1 – 27-30 %; Group 2 – 10-15 %; Group 3 – 15-19 %. *Staphylococcus aureus* was present in the selected swabs, accounting for 9-5 % of the total microbial count in both the experimental and control groups.

Subsequent studies focused on determining the activity of a new broad-spectrum antimicrobial agent against the isolated strains of microorganisms, with the aim of

developing a comprehensive set of measures to maintain the health of the dairy cows. Research results have shown that the product is effective against *Staphylococcus aureus* in 98% of cases and penetrates the cell wall more effectively than lysozyme and a number of standard antibiotics used at the facility. The *Escherichia coli* serotypes O55 and O111 proved to be more resistant. The complex demonstrated 76% efficacy, though a decrease in colony growth was observed. The complex was also effective against the other *E. coli* groups and completely suppressed them. Microorganisms of the genera *Candida* and *Pseudomonas* also showed no resistance to the antimicrobial agent. The results obtained indicated the advisability of conducting joint testing at industrial facilities of the enzymatic-biotic complex and the antimicrobial agent based on plant extracts combined with microbial metabolites. This approach is expected to reduce somatic cell counts to 150,000–180,000, which will improve milk quality and prevent the development of subclinical mastitis. An antimicrobial agent will need to be used to treat milking equipment and to rinse the udder after milking, as, in combination with feeding, it will exert a direct antimicrobial effect and stimulate the lysozyme and phagocytic activity of the milk itself. It may be administered by irrigating when the onset of udder inflammation is detected, as the metabolites in the antimicrobial agent break down the biofilms formed by pathogens and thin the exudate, facilitating the access of active ingredients to the site of infection. Further research will focus on a comprehensive approach and the optimization of processing and application conditions. Two formulations will be tested: the standard formulation and a formulation containing an additive designed to form a light film lasting 8 to 12 hours, with the aim of protecting the udder from direct contact with the bedding.

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RECENT ADVANCES IN BETULINIC ACID MODIFICATION

Abstract. The wide range of biological activity of lupane-type compounds has led to their intensive study over the last century. The present paper provides a review of modern approaches to the modification of betulinic acid.

Keywords: betulinic acid, betulin, betulin derivatives, terpenoids.

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СОВРЕМЕННЫЕ ДОСТИЖЕНИЯ В МОДИФИКАЦИИ БЕТУЛИНОВОЙ КИСЛОТЫ

Аннотация. Широкий спектр биологической активности соединений лупанового ряда послужил причиной их интенсивного изучения на протяжении последнего столетия. В данной работе проведен обзор современных подходов к модифицированию бетулиновой кислоты.

Ключевые слова: бетулиновая кислота, бетулин, производные бетулина, терпеноиды.

Since antiquity, efforts have been made to extend human longevity through the application of various natural medicinal substances. The presence of these substances in plant and animal raw materials has sustained their use as active agents to the present day [1]. Advances in science have revealed that the therapeutic effect of such substances derives from the selective action of specific chemical compounds on the organism. Subsequently, these compounds began to be purposefully synthesized in laboratories, with their therapeutic properties enhanced by modifying molecules with various elements or functional groups. An example of such modification is the synthesis of salts, which represents one of the most prevalent and effective methods for improving the pharmacokinetic properties of medicinal substances [2].

Pharmaceutical preparations based on the salt forms of active substances are widely utilized in medicine; as early as 1944–1946, several reports appeared in the

literature regarding the fungicidal action of various fatty acids and their salts. In the course of laboratory and clinical studies, undecylenic acid demonstrated the highest fungicidal activity compared to other compounds investigated [3]. In modern medical practice, undecylenic acid (UA) and zinc undecylenate (ZnUA) **1** are extensively used as antifungal agents. Ointments containing UA have been shown to reduce viral activity in patients with recurrent herpes labialis [4].

Para-aminosalicylic acid (PAS) **2** became an exceptionally valuable substance in the fight against tuberculosis following the publication of data in 1946 regarding its absorption and capacity to inhibit the emergence of resistant strains of *Mycobacterium tuberculosis*. However, it frequently induces gastrointestinal symptoms of such severity that prolonged treatment becomes difficult or impossible. Numerous attempts have been made to mitigate these symptoms through the use of various derivatives, such as calcium, potassium, or sodium salts [5]. Currently, PAS and its salts are actively employed in the treatment of various forms of tuberculosis.

In 1985, data emerged regarding the influence of clorazepate dipotassium **3** on psychomotor skills; currently, clorazepate dipotassium is an effective premedication agent for clear-cornea cataract surgery under retrobulbar anesthesia [6] (see Figure 1).

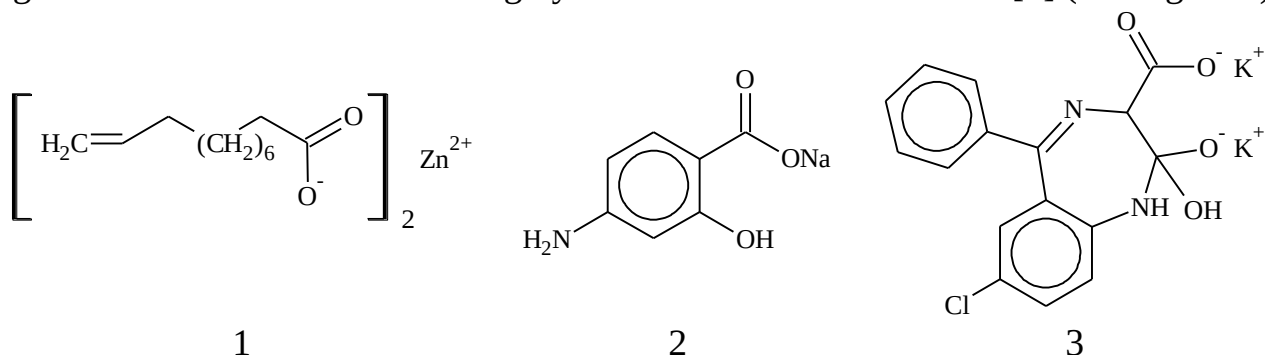


Figure 1. Structural formulas of zinc undecylenate **1**, sodium p-aminosalicylate **2**, and clorazepate dipotassium **3**

Among known plant-derived medicinal substances, betulin (lup-20(29)-ene-3 β ,28-diol) **4** and its derivatives are of particular note.

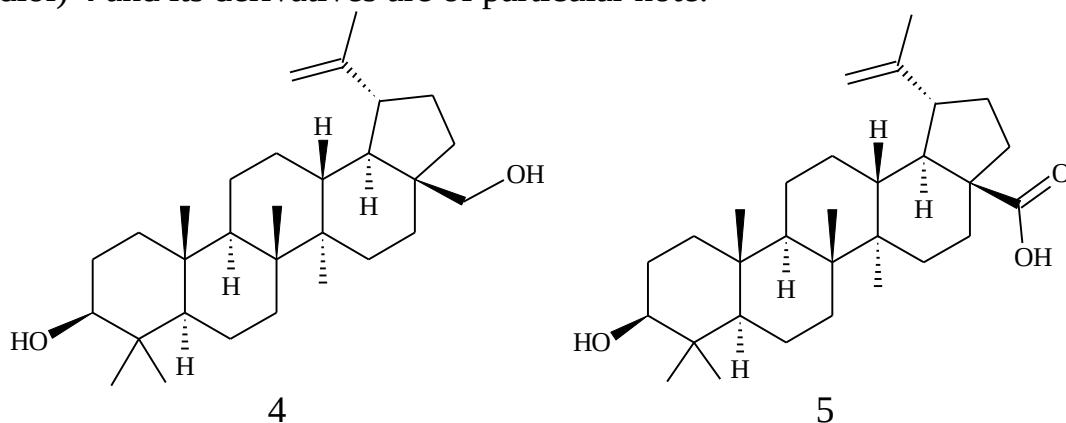


Figure 2. Structural formulas of betulin **4** and betulinic acid **5**

The study of the pharmacological properties of lupan-type pentacyclic triterpenoids, which include betulin and its derivatives, has been ongoing since the late 16th century [7].

Betulin and betulinic [(3 β)-3-hydroxy-lup-20(29)-en-28-oic] acid **5** (Figure 2) possess a number of valuable pharmacological properties, including antitumor, regenerative-promoting, and antiviral effects.

Specifically, betulinic acid and its derivatives have demonstrated anti-HIV activity and cytotoxicity against various tumor cell lines, comparable to that of certain clinically utilized drugs.

Pentacyclic triterpenes are practically insoluble in aqueous media; consequently, their overall absorption index is unsatisfactory. Structural modification of betulinic acid allows for enhanced water solubility without compromising the previously observed anticancer properties [8].

The study of betulinic acid derivatives has made it possible to approach the development of a certified medicinal drug. Bevirimat dimeglumine **6** (Figure 3) is an experimental antiretroviral drug that became the first representative of a new class of HIV-1 medicines known as maturation inhibitors. Although this drug has not been FDA-approved, it has undergone a series of clinical trials.

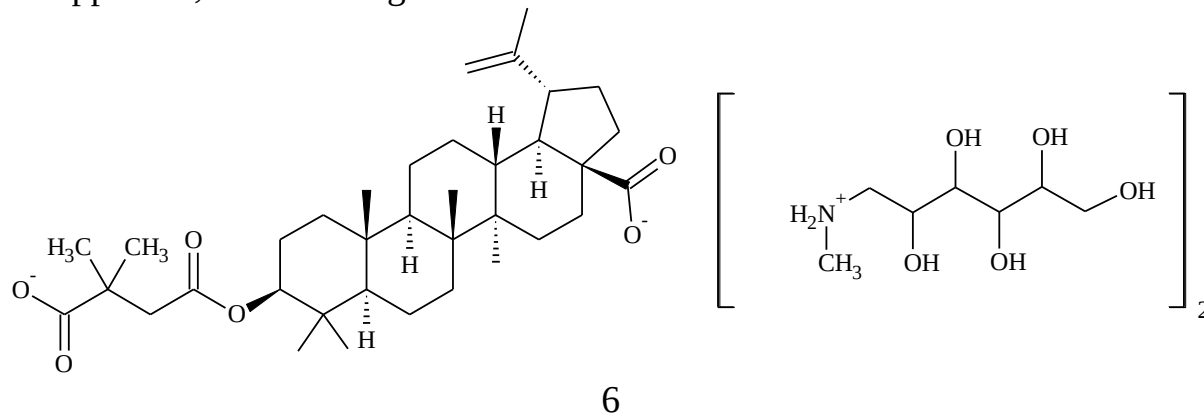


Figure 3. Structural formula of Bevirimat dimeglumine **6**

Bevirimat dimeglumine is effective against all forms of HIV-1 infection and inhibits the replication of both wild-type and drug-resistant HIV-1 isolates; furthermore, its activity varies approximately tenfold across different subtypes, with IC₅₀ (half-maximal inhibitory concentration) values in the nanomolar range [9].

However, in a study utilizing phenotypic and genotypic Gag-PR analysis, the baseline susceptibility to bevirimat dimeglumine was evaluated for a set of 20 patient-derived viral isolates. It was noted that polymorphisms at positions 6–8 in SP1 reduce susceptibility to bevirimat; this finding was consistent with clinical studies [10].

In light of the aforementioned findings, Myriad Pharmaceuticals officially announced the termination of the bevirimat dimeglumine development program in 2010. Currently, analogs of this substance are being developed; for instance, GSK3640254 has demonstrated high activity against all viruses tested [11].

The investigation of betulinic acid is not limited to these findings. Its near-total insolubility in water, attributed to a substantial lipophilic scaffold and an insufficient number of hydrophilic groups, necessitates molecular modification.

A 2015 study proposed that alkali metal salts of betulinic acid would exhibit improved solubility in water, as well as in aqueous solvent mixtures, facilitating the study of their self-assembly properties in such liquids. The formation of fibrillar self-

organized structures from sodium **7** and potassium **8** betulinates in water and aqueous solvent mixtures, leading to the development of supramolecular gels, was reported (Figure 4).

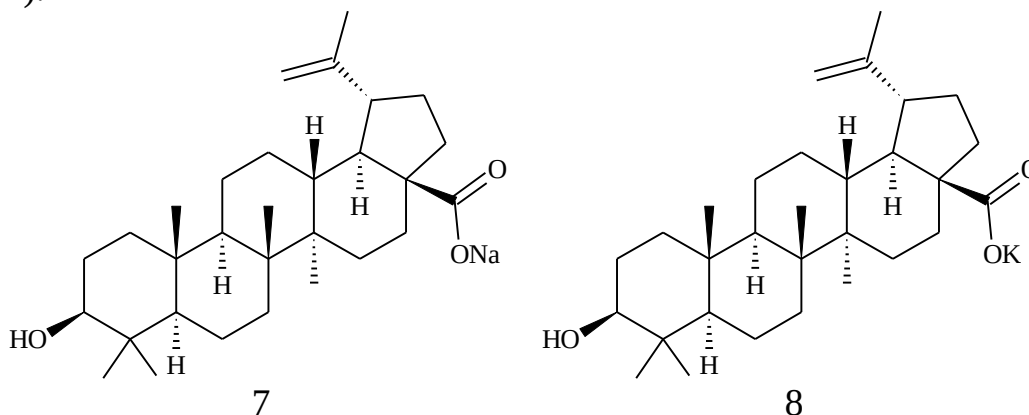


Figure 4. Structural formula of sodium betulinate **7** and potassium betulinate **8**

Epifluorescence microscopy demonstrated the entrapment of a fluorophore, such as rhodamine B, onto the self-organized structures. To remove the toxic dye rhodamine B, a solution of rhodamine B (0.8 mL; 0.03 mM) was prepared in phosphate buffer (0.01 M; pH = 7.2). The sodium betulinate hydrogel removed 80.2 % of the dye within 4 hours, while the potassium betulinate hydrogel removed 90 % within 10 hours and 20 minutes. It was noted that the renewable nature of betulinic acid, combined with its nanometer scale and the vast potential for hydrogel applications, makes it a promising scaffold for the development of advanced materials in nanobiotechnology [12].

A 2024 study examined the potential for drug delivery using Pickering emulsions. A Pickering emulsion-based delivery system effectively encapsulates functional ingredients due to minimal emulsifier requirements, high interfacial stability, and cost-effectiveness. Numerous studies have demonstrated that such systems efficiently incorporate hydrophobic bioactive ingredients and provide precise control over nutrient release. Previous research has indicated significant differences in the stability of Pickering emulsions composed of various oil phases, as well as in the bioavailability of encapsulated functional ingredients. Consequently, the 2024 study investigated the influence of different carrier oils in a self-stabilized water-in-oil (W/O) Pickering emulsion on emulsion stability and the bioavailability of betulin. The results indicated that the oil type is one of the primary factors influencing emulsion stability. Palm and coconut oils provided superior storage and centrifugation stability due to their high saturated fatty acid content. The bioavailability of betulin significantly correlated with the composition and characteristics of the fatty acids in the carrier oils. Carrier oils rich in low-saturated long-chain fatty acids tended to release more free fatty acids, thereby forming larger mixed micelles with a stronger capacity for swelling and dissolution, which resulted in a relatively high bioavailability of betulin. In contrast, the bioavailability of betulin in the emulsion prepared with coconut oil (characterized by a high saturated fatty acid content) was relatively low (1.17%). This study demonstrated that the selection of an appropriate carrier oil is crucial for the development of self-stabilized water-in-oil (W/O) Pickering emulsions, aimed at

effectively enhancing the bioavailability of betulin and other lipophilic bioactive substances [13].

Another 2024 study examined the conversion of betulinic acid into organic salts, representing a strategic approach to modulating physicochemical properties and biological activity. The work reports the synthesis and characterization of 15 novel L-amino acid ethyl ester betulinates ([AAOEt][BA]), comprising an ethyl ester cation of a polar, nonpolar, or charged amino acid [AAOEt] and a betulinic acid anion. With the exception of [ValOEt][BA], a retention or up to a twofold increase in cytotoxicity against hormone-dependent MCF-7 breast cancer cells was observed.

It was found that the most cytotoxic salt, [LysOEt][BA]₂ **9**, reduces clonogenic efficiency by up to 20% compared to betulinic acid (Figure 5).

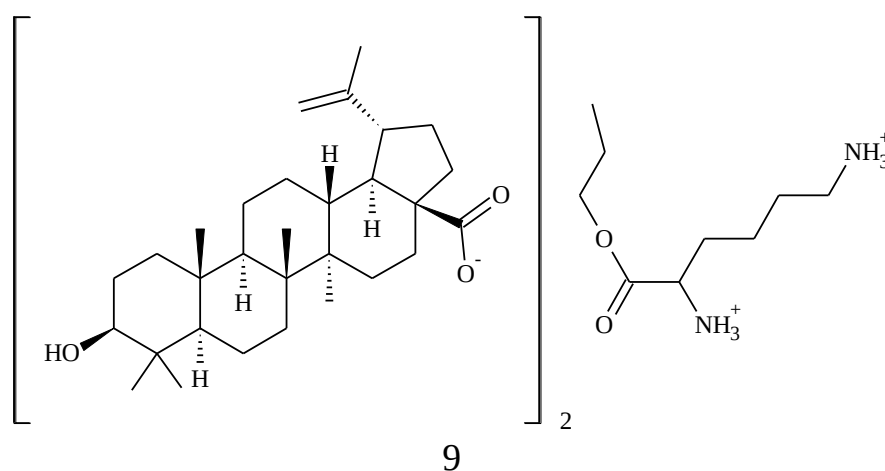


Figure 5. Structural formula of [LysOEt][BA]₂

Based on the data, it was hypothesized that the charged amino acid lysine, incorporated into the novel salts, induces cytotoxicity through a mechanism involving alterations in the organization of membrane lipids, which may be accompanied by the modulation of the viscoelastic properties of the cytoplasm [14].

Current research in 2026 continues to enhance the pharmacokinetic properties of betulinic acid, which suffers from unsatisfactory bioavailability and therapeutic efficacy due to its low water solubility and potential off-target toxicity. Consequently, the development of supramolecular hydrogels capable of encapsulating hydrophobic drugs and achieving controlled release is considered a promising direction. In the present study, a low-molecular-weight supramolecular hydrogel (LMWSH) with a porous structure was developed using the choline salt of betulinic acid – choline betulate **10** – as a hydrogelator (Figure 6).

A high concentration of the hydrogelator led to the formation of distinct granular crystallites within the LMWSH structure, which is analogous to the phase behavior observed at the lower critical solution temperature (LCST) in polymer systems. Specifically, the increase in temperature facilitated molecular interaction of the hydrogelator and enhanced the stability of the LMWSH, indicating a unique entropy-driven process.

The properties of the resulting hydrogel, including robust stability, injectability, high drug release capacity, and a broad spectrum of antitumor activity, demonstrated

its potential for use as a controlled drug delivery vehicle as well as in adjuvant therapy [15].

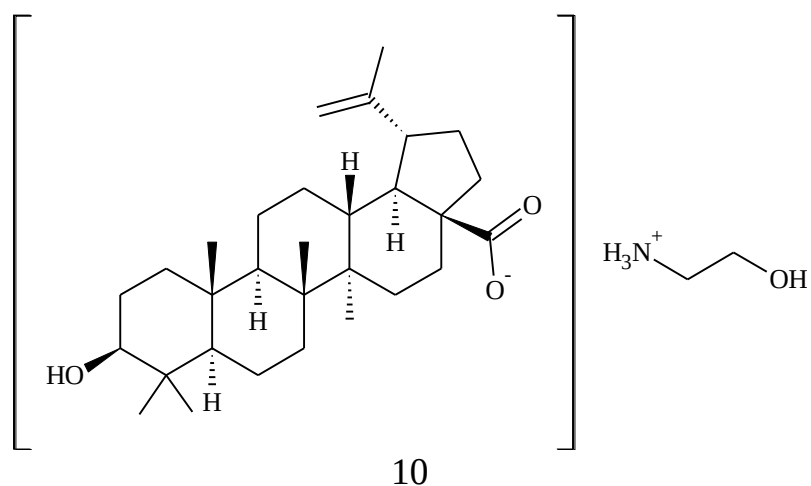


Figure 6. Structural formula of choline betulinate **10**

The modification of betulinic acid has been ongoing since its discovery. Its relative availability and complex pharmaceutical activity render further research aimed at enhancing the properties of this natural compound highly promising.

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A STUDY ON LIGAND-FREE CHITOSAN NANOCARRIERS IN PH-RESPONSIVE ANTI-CANCER DRUG DELIVERY

Abstract. The chitosan drug delivery systems are of great interest because of their biocompatibility and versatility of functions, but the traditional Schiff base conjugation and ligand-based targeting methods have disadvantages like low stability, early release of drug, and complicated synthesis. This research suggests a ligand-free dual (bis) Schiff base conjugation system of anticancer drugs. In this method, chitosan primary amino groups are directly reacted with drug molecules with several carbonyl groups to create stable dual imine bridges through a condensation reaction. This does not require outside targeting ligands and makes the synthesis process easier. The resulting conjugate exhibits greater structural stability, increased drug-loading capacity and decreased batch variability. Notably, the imine bonds do not lose pH-responsive properties, allowing the release of the drugs to be controlled in acidic tumor conditions. On the whole, the strategy has a potential, effective, and scalable platform to develop the advanced chitosan-based targeted drug delivery systems to combat cancer.

Keywords: chitosan, condensation reaction, dual imine linkage, ligand-free conjugation, tumor microenvironment, anticancer drug delivery, pH-responsive release, controlled drug release.

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ИССЛЕДОВАНИЕ НАНОНОСИТЕЛЕЙ НА ОСНОВЕ ХИТОЗАНА БЕЗ ЛИГАНДОВ ДЛЯ ДОСТАВКИ ПРОТИВООПУХОЛЕВЫХ ПРЕПАРАТОВ С рН-ЗАВИСИМОЙ АКТИВАЦИЕЙ

Аннотация. Системы доставки лекарственных средств на основе хитозана представляют большой интерес благодаря своей биосовместимости и функциональной универсальности, однако традиционные методы конъюгации с помощью оснований Шиффа и лиганд-опосредованной таргетированной доставки имеют такие недостатки, как низкая стабильность, преждевременное высвобождение лекарственного средства и сложность синтеза. В данном исследовании предлагается система конъюгации противоопухолевых препаратов с использованием двойных (бис-) оснований Шиффа без применения лигандов. В данном методе первичные аминогруппы хитозана вступают в прямую реакцию с молекулами лекарственного средства, содержащими несколько карбонильных групп, с образованием стабильных двойных иминовых мостиков посредством реакции конденсации. Это не требует использования внешних лигандов для таргетирования и упрощает процесс синтеза. Полученный конъюгат демонстрирует более высокую структурную стабильность, увеличенную емкость по загрузке лекарственного средства и сниженную вариабельность партий. Примечательно, что иминовые связи не теряют свойств, реагирующих на рН, что позволяет контролировать высвобождение лекарств в кислых условиях опухоли. В целом эта стратегия представляет собой потенциальную, эффективную и масштабируемую платформу для разработки передовых систем целевой доставки лекарств на основе хитозана для борьбы с раком.

Ключевые слова: хитозан, реакция конденсации, двойная иминовая связь, лиганд-свободная конъюгация, микроокружение опухоли, доставка

противораковых препаратов, рН-зависимое высвобождение, контролируемое высвобождение препарата.

1. Introduction

The cancer burden of the world population is still increasing, and there are large health care access and outcome disparities between regions and socioeconomic groups. The causes of this rise include aging of the population, changes in lifestyles and exposures to the environment. The incidence of cancer in the world was about 23.56 million cases in 2021 and is expected to increase to 35.3 million cases by 2050. Likewise, the number of cancer-related deaths is predicted to rise to almost 18.5 million in 2050 after 9.7 million in 2022 due to the increasing magnitude of the disease all over the globe. In spite of the improvement in cancer diagnosis and treatment, inequities continue to be a significant issue. The cancer burden is high in high socio-demographic index (SDI) countries, but the robust healthcare systems, early diagnosis, and better access to treatment, result in lower mortality-to-incidence ratios (MIR). Conversely, low human development index (HDI) areas especially in places like Sub-Saharan Africa experience disproportionately high mortality rates because of the lack of healthcare facilities, insufficiency of resources and access to timely diagnosis and treatment. Socioeconomic factors are very important in the determination of cancer. Increased healthcare expenditure, education and awareness are all linked to increased survival rates and disease management. On the other hand, poor populations are usually diagnosed late, have fewer treatment choices and worse prognoses. Such differences can be observed between and within nations, with the most affluent groups having much higher cancer survival rates as compared to lower-income. In the future, it is projected that the incidence and mortality of cancer may almost triple in low-HDI countries by 2050, whereas increases in high-HDI countries are likely to be less pronounced. This broad divide underscores the imperative to adopt fair healthcare policies. Enhancing healthcare facilities, access to early detection and treatment, and investing more in cancer treatment is an essential move towards lowering these disparities. On the whole, to mitigate the increasing cancer burden, a multifaceted, and balanced strategy combining the strengthening of the healthcare system, policy change, education, and international cooperation is necessary. The current disparities in cancer outcomes are also likely to remain and even increase in the next few decades without specific interventions [1-5]. The traditional chemotherapy is linked to some drawbacks such as inability to dissolve in blood, systemic toxicity, premature drug degradation, and non-selectivity to tumors. These obstacles have led to development of improved drug delivery systems which can release drugs in a controlled, stimuli-responsive and targeted manner. Nonetheless, numerous available approaches are based on the exogenous targeting ligands that add other disadvantages including immunogenicity, batch-to-batch inconsistent, complicated synthesis and production, and reduced stability in vivo. Thus, there is an increasing interest in designing ligand-free, biodegradable, and pH-responsive carriers that can exploit inherent physicochemical characteristics – the protonation and deprotonation of imine bonds – to achieve site-specific drug delivery, especially in the acidic tumor microenvironment (TME) and endo/lysosomal compartments [6-7]. This study intends to critically point out the latest developments in the field of chitosan-based dual Schiff base drug conjugates, but particularly ligand-free approaches where anticancer drugs are used as bifunctional

linkers. Emphasis is laid on their synthesis, structural stability, release behavior dependent on pH and their possible use in targeted cancer therapy.

2. Problem Statement

Single Schiff base conjugations have often been used to conjugate anticancer drugs to chitosan, with the advantage of their pH-sensitive cleavage to release drugs in the acidic tumor microenvironment. Besides that, dual Schiff base approaches that involve incorporation of targeting ligands like folic acid or hyaluronic acid have also been pursued to increase the effectiveness of targeting (Figure 1). But single imine bonds tend to be not very stable in physiological conditions, and may readily hydrolyze. In the meantime, ligand-based dual systems are usually more difficult to synthesize, and might have drawbacks including low drug-loading capability and lack of receptor expression uniformity across cell types (Figure 2).

3. Purpose of Study

The aim of the study is to establish and analyze a ligand-free dual (bis) Schiff base conjugation method to surmount the constraints of the traditional ligand-based chitosan systems. In this method the anticancer drugs with more than one carbonyl group react directly with the primary amine groups of chitosan to produce two imine bonds. The resultant dual bonding increases the structural stability of the conjugate without changing its pH-responsive drug release property. It is important to note that the drug molecule itself acts as the reactive site, thus avoiding the use of other targeting ligands and making the synthesis process easier. The strategy will hopefully enhance drug-loading capacity, stability under physiological conditions and efficient drug release within the acidic tumor microenvironment.

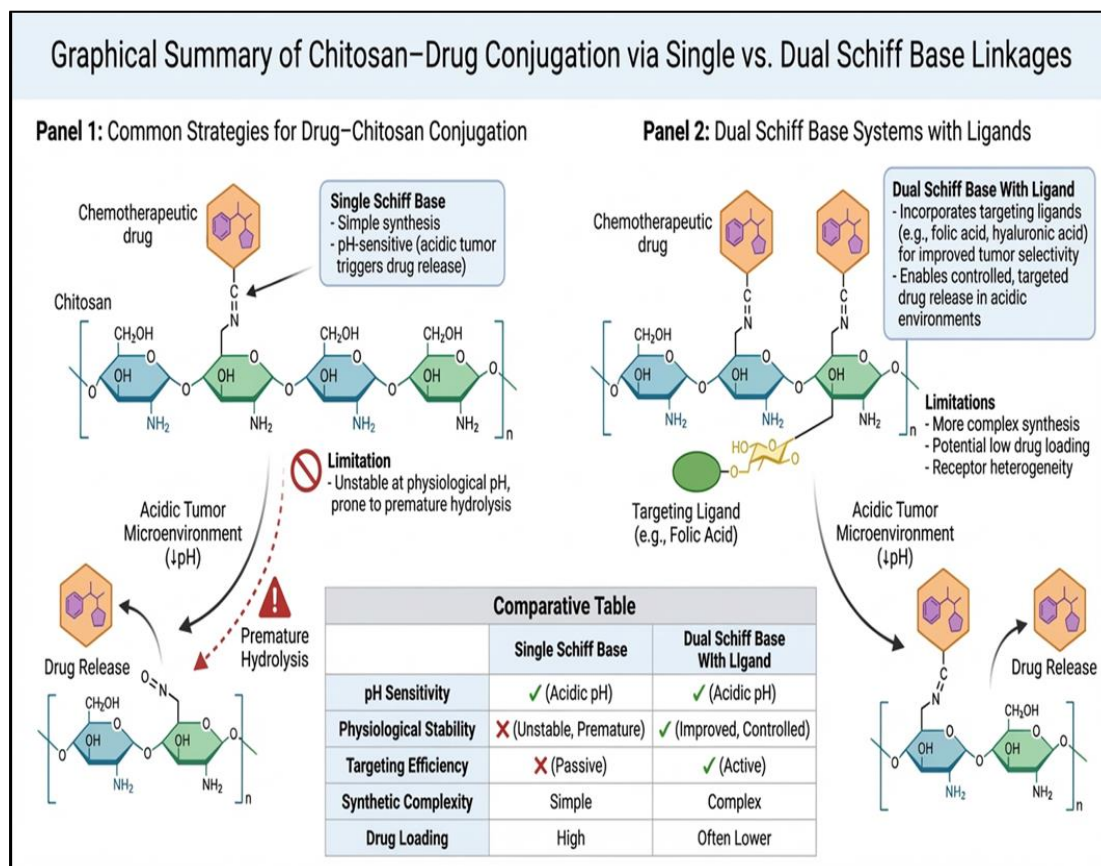


Figure 1. Graphical summary of chitosan drug conjugation via single vs. dual Schiff base linkage. References adopted [6-41]

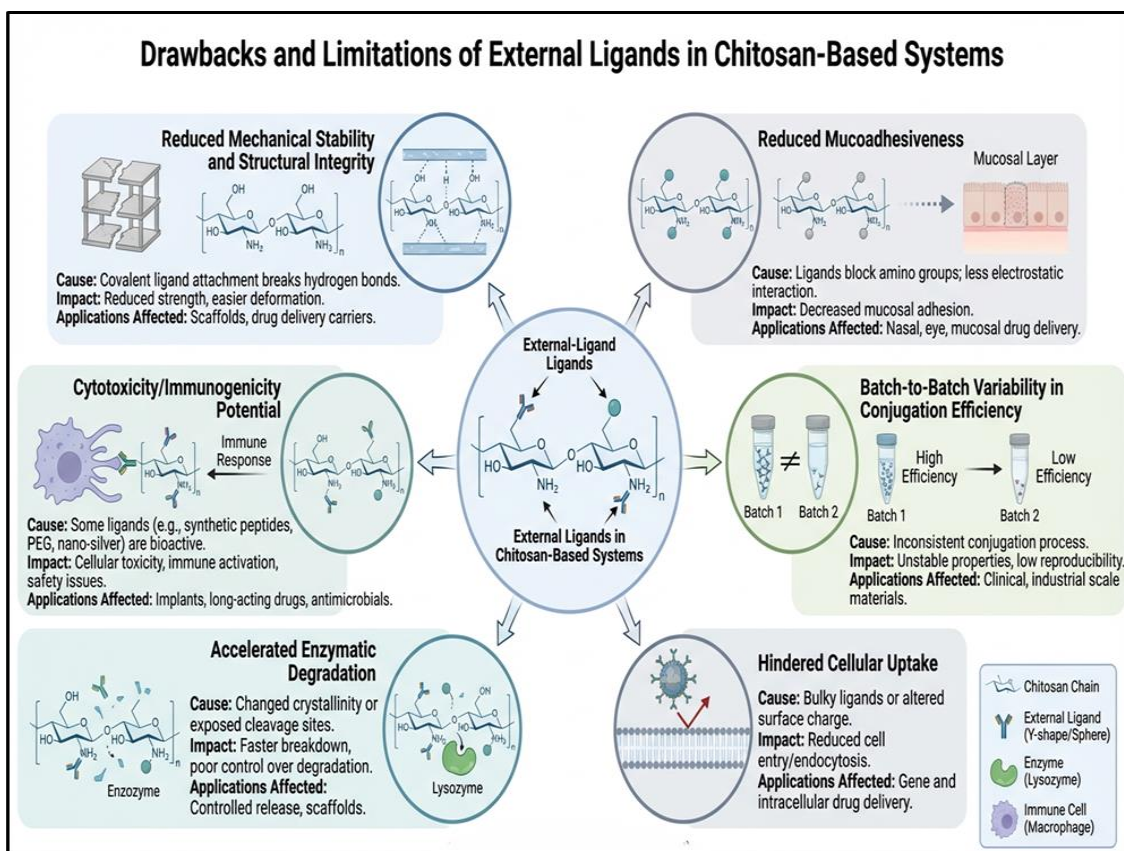


Figure 2. Drawbacks and limitations of external ligands on chitosan-based systems. References adopted [6-41]

4. Material and Methods

The suggested approach entails making a chitosan-drug conjugate through a ligand-free dual (bis) Schiff base formation plan. The chitosan which has a large number of primary amino groups ($-NH_2$) is initially dissolved in a slightly acidic aqueous solution to make it soluble. The chosen anticancer drug with several reactive carbonyl groups ($-CHO$ or $-C=O$) is then added to the system with controlled conditions. The amino groups of chitosan and the carbonyl groups of the drug are allowed to react via a condensation reaction, resulting in the two imine ($-C=N-$) linkages on each drug molecule. The reaction parameters (pH, temperature, molar ratio and time) are optimized to enhance effective dual bond formation and reduce side reactions. The resulting conjugate is further purified to eliminate unreacted drug and by-products and dried to be used further. The resulting dual Schiff base conjugate synthesized is then characterized by suitable analytical methods to establish the formation of imine bonds, level of substitution, and integrity of the structure. Its physicochemical properties, physiological stability as well as pH-responsive drug release behavior are systematically considered to determine its appropriateness in targeted anticancer drug delivery. Figure 3 illustrates a ligand-free dual (bis) Schiff base formation strategy via a condensation reaction between amino groups of chitosan and carbonyl groups of the drug.

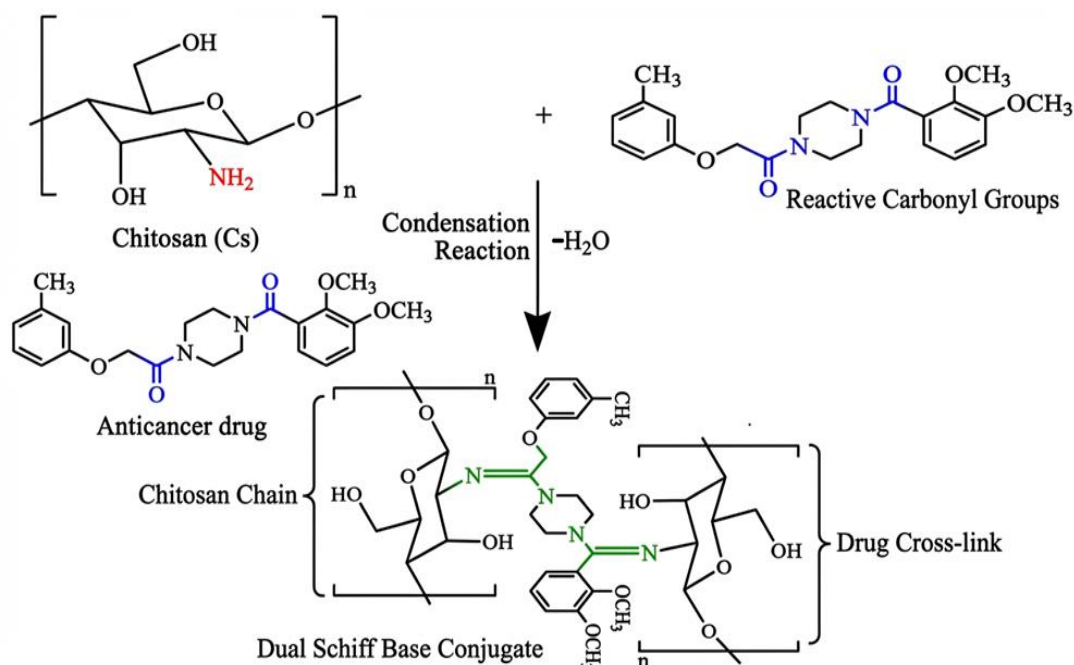


Figure 3. A ligand-free dual (bis) Schiff base formation strategy via a condensation reaction between amino groups of chitosan and carbonyl groups of the drug

5. Conclusion

The dual (bis) ligand-free Schiff base conjugation method offers a useful and effective way of developing chitosan-based anti-cancer drug delivery systems. This approach forms stable dual imine connections between the primary amine groups of chitosan and the carbonyl groups of the drug by allowing direct condensation between the chitosan amino groups and the drug carbonyls without using targeting ligands. This not only makes the synthesis procedure much easier, but also addresses some of the limitations inherent to the traditional ligand-based systems, such as structural instability, lower drug-loading capacity and batch variability. Developing dual Schiff base bonds increases the stability of the conjugate in general under physiological conditions without losing its pH-sensitive nature. This would guarantee reduced untimely drug release in the systemic circulation and targeted release in acidic conditions like tumor tissues and lysosomes. Also, the removal of the bulky ligands allows for retaining the inherent characteristics of chitosan, such as its biocompatibility and the potential to interact with cells. In summary, the given strategy is a well-balanced approach that will provide better stability, increased drug-loading capacity, controlled release dynamics, and easier fabrication. Thus, ligand-free dual Schiff base conjugation is a capable and scalable platform, to design more advanced and targeted drug delivery systems, which hold potential applications in cancer therapy.

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TECHNOLOGY FOR OBTAINING HYALURONIC ACID, STRUCTURAL AND FUNCTIONAL CHARACTERISTICS

Abstract. This review article systematizes current understanding of hyaluronic acid (HA) production technologies and their impact on the polymer's structural and functional properties. Key synthesis methods are considered, including extraction from animal tissues and microbiological fermentation using *Streptococcus spp.* and *Bacillus spp.* strains, as well as the potential for other possible methods. It is demonstrated that the choice of technology determines key parameters of the resulting product, including physical properties, molecular weight distribution, purity, endotoxin content, and stability. Special attention is paid to the relationship between process conditions and the structural and functional properties of HA, including viscosity, biodegradability, and ability to interact with cell receptors. Current approaches to chemical and enzymatic modification of HA to produce derivatives with desired properties are summarized. A conclusion is drawn regarding the need to standardize technological processes to ensure the reproducibility of the quality of HA as a biomedical product. This review will be of interest to specialists in biotechnology, pharmaceutical technology, and regenerative medicine.

Keywords: hyaluronic acid, HA, polysaccharides, biotechnology, synthesis methods.

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ТЕХНОЛОГИЯ ПОЛУЧЕНИЯ ГИАЛУРОНОВОЙ КИСЛОТЫ, СТРУКТУРНО-ФУНКЦИОНАЛЬНАЯ ХАРАКТЕРИСТИКА

Аннотация. В обзорной статье систематизированы современные представления о технологиях получения гиалуроновой кислоты (ГК) и их влиянии на структурно-функциональные характеристики полимера. Рассмотрены основные методы синтеза: экстракция из тканей животных, микробиологическая ферментация с использованием штаммов *Streptococcus spp.* и *Bacillus spp.*, а также перспективы других возможных методов. Показано, что выбор технологии определяет ключевые параметры получаемого продукта – физические свойства, молекулярно-массовое распределение, степень чистоты, наличие эндотоксинов и стабильность. Отдельное внимание уделено взаимосвязи между технологическим режимом и структурно-функциональными свойствами ГК: вязкостью, биodeградируемостью, способностью взаимодействовать с рецепторами клеток. Обобщены современные подходы к химической и ферментативной модификации ГК для получения производных с заданными свойствами. Сделан вывод о необходимости стандартизации технологических процессов для обеспечения воспроизводимости качества ГК как биомедицинского продукта. Обзор представляет интерес для специалистов в области биотехнологии, фармацевтической технологии и регенеративной медицины.

Ключевые слова: гиалуроновая кислота, полисахариды, биотехнология, методы синтеза.

Introduction

Hyaluronic acid (hyaluronan) is a linear heteropolysaccharide composed of repeating disaccharide units of N-acetyl-D-glucosamine and D-glucuronic acid. Due to its unique physicochemical properties (high hydrophilicity, viscoelasticity, biocompatibility), hyaluronic acid finds wide application in ophthalmology, orthopedics, aesthetic medicine, surgery, and pharmaceuticals. The key defining properties of hyaluronic acid – molecular weight, polydispersity, degree of purity, and biological activity – are directly dependent on the production technology and subsequent processing. This review analyzes current methods for obtaining hyaluronic acid, examines their influence on the structural and functional properties of the polymer, and outlines prospects for production standardization.

1.1 Physicochemical Properties of Hyaluronic Acid

The primary structure of HA is simple and uniform. It is a linear, unbranched polymer composed of repeating disaccharide units. Each unit consists of two substances: D-glucuronic acid and N-acetyl-D-glucosamine. These two compounds are linked by alternating β -1,3 and β -1,4 glycosidic bonds (Figure 1).

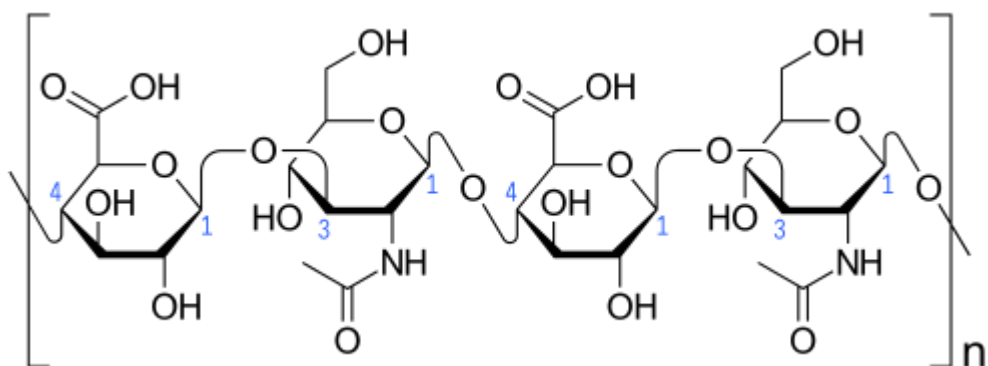


Figure 1. Hyaluronic acid formula

Hyaluronic acid is a high-molecular-weight polymer. In nature, its molecular weight can range from 10^4 to 10^7 Daltons. For example, in human synovial fluid, the molecular weight of HA is approximately 7 million Daltons, which is necessary for its lubricating and shock-absorbing functions. The molecular weight of HA is a critical parameter, as it directly influences its physical properties and biological activity (Figures 2, 3).



Figure 2. High molecular weight HA produced by HTL France

Despite its high molecular weight, HA exhibits exceptional solubility in water, forming clear, viscous solutions. This high solubility is due to its chemical structure, which contains numerous hydrophilic (water-attracting) groups, such as hydroxyl (-OH) and carboxyl (-COOH) groups. A key property is its ability to bind and retain water molecules. Hyaluronic acid can hold up to 1000 times its weight in water, forming a hydrated gel. This ability makes it a crucial molecule for maintaining tissue hydration and structural integrity.



Figure 3. Low molecular weight HA made in China

The flow and deformation behavior of HA are among its most important characteristics. These properties depend on concentration and molecular weight. HA solutions are viscoelastic, meaning they exhibit both viscous and elastic behavior. This is essential for its function in synovial fluid, where it provides both viscosity and elasticity [1].

Table. Comparative Table of Properties: High-Molecular-Weight HA vs. Low-Molecular-Weight HA

Parameter	High-Molecular-Weight HA (HMW HA)	Low-Molecular-Weight HA (LMW HA)
Molecular Weight Range	Typically > 500–1,000 kDa (can reach up to 6,000–10,000 kDa in native tissues)	Typically < 100–250 kDa (includes oligosaccharides < 10 kDa)
Source / Production	Native form; obtained via gentle extraction or optimized microbial fermentation with minimal degradation	Obtained via enzymatic (hyaluronidase) or chemical (acid, alkali, heat) hydrolysis of HMW HA; also produced by some recombinant strains
Water Solubility	Good; forms viscous, entangled solutions even at low concentrations	Excellent; forms less viscous solutions due to shorter polymer chains
Viscoelasticity	High viscoelasticity; exhibits strong gel-like behavior at low shear rates and shear-thinning properties	Low viscoelasticity; behaves more as a Newtonian fluid with minimal elasticity
Hydration Capacity	Very high; can bind up to 1000× its weight in water, forming extensive hydrated networks	Moderate to low; limited ability to retain water due to reduced chain length and network formation
Biostability	Relatively stable but susceptible to degradation by hyaluronidases and reactive oxygen species (ROS)	More rapidly degraded <i>in vivo</i> ; shorter half-life in tissues
Receptor Interaction	Limited interaction with cell surface receptors (e.g., CD44, RHAMM); can form protective pericellular coats	High affinity for receptors; effectively activates intracellular signaling pathways

Upon chemical modification to form a network structure (cross-linking), HA-based hydrogels can absorb significant amounts of water and swell. This swelling capacity is a key parameter for its use in tissue engineering and as dermal fillers.

HA is degraded by enzymes called hyaluronidases, which are present in most tissues. These enzymes cleave the polymer chain, leading to a rapid reduction in molecular weight and, consequently, viscosity. This natural turnover process is rapid;

it is estimated that about one-third of the HA in the human body (approximately 15 grams) is degraded and synthesized daily [2, 3].

1.2 Methods for Obtaining Hyaluronic Acid

Historically, the first source of HA was animal tissues – rooster combs, bovine synovial fluid, the vitreous body of the eye, and human umbilical cords. The process is carried out as follows: the ground raw material is frozen, heated for extraction with hot water, then filtered, and the hyaluronic acid is precipitated. This method allows for a high-quality product, but it is more complex to purify from protein impurities. To obtain low-molecular-weight HA, which penetrates the skin better, enzymatic hydrolysis or chemical cleavage of long HA chains is used. The resulting hyaluronic acid is used in cosmetics, medicine (joint injections, preparations), and dietary supplements. However, this method has several significant limitations: low product yield, risk of contamination with prions and viruses, the possibility of immunogenic reactions due to residual proteins and endotoxins, ethical issues associated with the use of animals, and high purification costs (Figure 4).

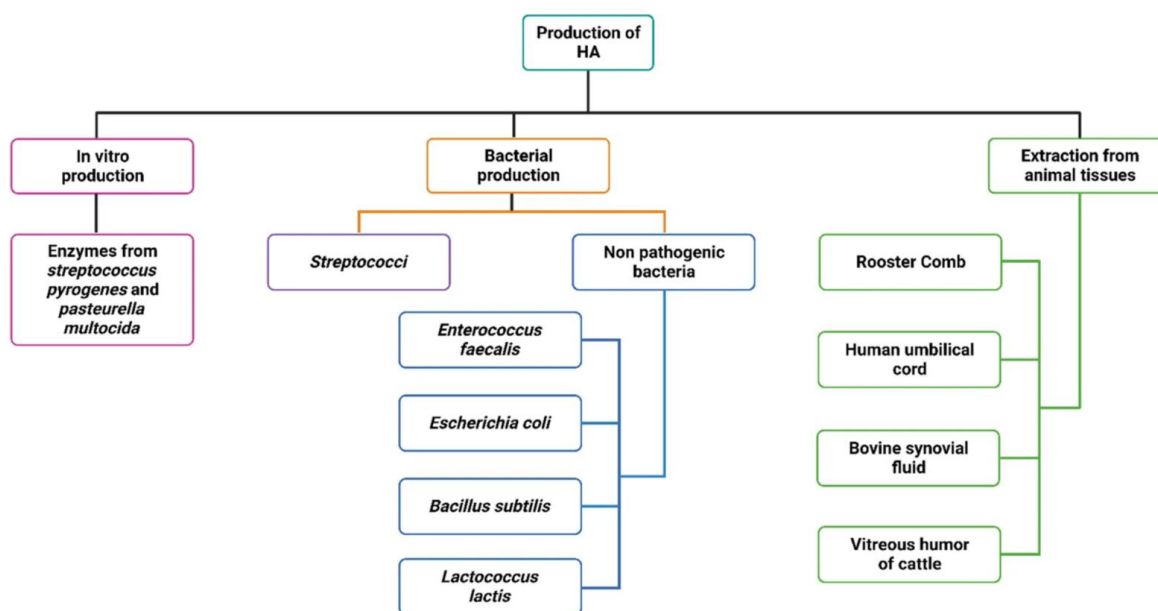


Figure 4. Scheme of sources of obtaining HA

Due to these limitations, the proportion of HA obtained from animal sources has significantly decreased in recent decades, giving way to microbiological production methods.

The microbiotechnological method involves cultivating non-pathogenic bacteria of the genus *Streptococcus* in a special nutrient medium, where they accumulate HA. *Streptococcus zooepidemicus* remains the most studied and widely used industrial strain due to its high productivity and ability to synthesize high-molecular-weight HA. HA biosynthesis in streptococci is carried out by hyaluronan synthase, which catalyzes the polymerization of activated precursors-UDP-N-acetyl-D-glucosamine and UDP-D-glucuronic acid (Figure 5). The reaction occurs on the cytoplasmic membrane, and the growing HA chain is extruded into the extracellular space [4].

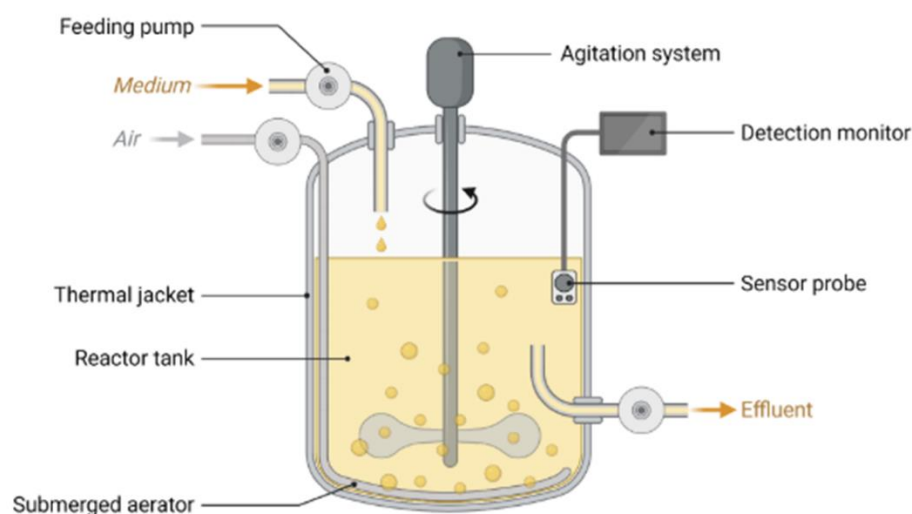


Figure 5. Diagram of the bioreactor for the production of HA

The advantages of this method are: high purity, absence of animal pathogens, and the ability to regulate molecular weight (low and high molecular weight). The process includes: cultivation, extraction, multi-stage purification, precipitation (usually with alcohol), and drying.

The efficiency of microbiological HA synthesis largely depends on cultivation parameters. The optimal conditions for HA production by *Streptococcus zooepidemicus* are a temperature of 37 °C and pH 6.5. Deviation from these parameters leads to a decrease in product yield and changes in its molecular weight characteristics. Traditionally, HA fermentation is carried out on synthetic media containing expensive sources of carbon (glucose) and nitrogen.

In addition to microbiological fermentation, approaches for *in vitro* HA synthesis using chemical and enzymatic methods have been actively developing in the last decade. The main advantage of these approaches lies in the possibility of obtaining narrowly dispersed HA fractions with controlled molecular weight and specific sequence.

Despite significant progress in oligosaccharide chemistry, the chemical synthesis of HA has not yet reached a level that allows for the production of polymers with a high degree of polymerization comparable to natural or microbiological samples.

The purification of HA obtained by microbiological means is a critical step determining the quality of the final product. The main contaminants are cell wall proteins, endotoxins (lipopolysaccharides), nucleic acids, and nutrient medium components [5, 6].

Modern purification approaches include:

1. Affinity chromatography using immobilized proteins that specifically bind HA.
2. Membrane filtration (ultrafiltration, nanofiltration) for fractionation by molecular weight and removal of low-molecular-weight impurities.
3. Precipitation with organic solvents (ethanol, acetone) followed by washing.
4. Anion exchange chromatography to remove anionic impurities.
5. Enzymatic treatment with nucleases and proteases to remove residual nucleic acids and proteins.

Conclusion

Modern technology for hyaluronic acid production has undergone significant evolution: from extraction from animal tissues, characterized by low product yield and risk of contamination, to highly efficient microbiological fermentation methods using natural strains of *Streptococcus zooepidemicus*. Microbiological synthesis is currently the dominant industrial production method, enabling the production of HA with specified molecular weight characteristics while reducing costs and minimizing risks associated with animal-derived raw materials.

A key direction in technology development is the use of renewable raw materials (molasses, whey, palm kernel cake, corn steep liquor), which can reduce production costs by up to 72 % and aligns with the principles of the circular economy. However, the implementation of these approaches is associated with the need to address technological challenges related to raw material heterogeneity and the presence of inhibitory components.

Analysis of the structural and functional characteristics of HA demonstrates the critical dependence of the polymer's biological activity on its molecular weight. High-molecular-weight HA exhibits anti-inflammatory and immunosuppressive properties, providing structural support to tissues, whereas low-molecular-weight fragments possess pro-inflammatory activity, stimulating angiogenesis and cell migration.

Prospects for standardizing hyaluronic acid production are associated with the development of unified requirements for molecular weight characteristics, degree of purity, and endotoxin content for various fields of application. Further research should focus on improving producer strains using genome editing technologies, optimizing fermentation processes using artificial intelligence methods, and creating reference standards of HA with certified molecular weight values to ensure reproducibility of analysis results.

Thus, an integrated approach combining modern biotechnological synthesis methods, an in-depth understanding of structure-function relationships, and rigorous analytical control forms the foundation for producing high-quality hyaluronic acid preparations that meet the growing demands of clinical practice and personalized medicine.

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DIGITAL PHYGITAL LABORATORY FOR DIAGNOSING PSYCHOMOTOR ABILITIES: STRUCTURE AND FUNCTIONAL CAPABILITIES

Abstract. The article presents a description of a digital phygital laboratory for diagnosing psychomotor abilities (State Registration Certificate No. 2026619322). The structure of the laboratory, including data collection, processing and visualization modules, as well as the functional capabilities of the system are considered. The relevance of introducing such laboratories into the training process and the athlete selection system is substantiated. The results can be used in the activities of sports schools, training centers and research organizations.

Keywords: phygital laboratory, psychomotor abilities, diagnostics, digital platform, sports selection, patent.

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ЦИФРОВАЯ ФИДЖИТАЛ-ЛАБОРАТОРИЯ ДИАГНОСТИКИ ПСИХОМОТОРНЫХ СПОСОБНОСТЕЙ: СТРУКТУРА И ФУНКЦИОНАЛЬНЫЕ ВОЗМОЖНОСТИ

Аннотация. В статье представлено описание цифровой фиджитал-лаборатории для диагностики психомоторных способностей (Свидетельство о государственной регистрации № 2026619322). Рассмотрены структура лаборатории, включающая модули сбора данных, обработки и визуализации, а также функциональные возможности системы. Обоснована актуальность внедрения подобных лабораторий в тренировочный процесс и систему отбора

спортсменов. Результаты могут быть использованы в деятельности спортивных школ, центров подготовки и научно-исследовательских организаций.

Ключевые слова: фиджитал-лаборатория, психомоторные способности, диагностика, цифровая платформа, спортивный отбор, патент.

Introduction

The modern system of athlete training requires the introduction of objective methods for assessing psychomotor abilities. Traditional approaches based on pedagogical observation and timing do not always provide a complete picture of an athlete's condition [1, pp. 296–297]. In this regard, the development of specialized hardware-software complexes combining physical and digital components – so-called phygital laboratories (from physical + digital) – is relevant.

In April 2026, the Angarsk State Technical University received state registration certificate No. 2026619322 for the computer program “Digital Phygital Laboratory for Diagnosing Psychomotor Abilities” (authors: Rzhhanov A. A., Eremina I. M.) [2]. The purpose of this article is to describe the structure and functional capabilities of this laboratory, as well as to substantiate its application in sports practice.

Main Part

Relevance of the development. Psychomotor abilities are a key success factor in most sports, especially in team sports and complex-coordination events. As V. P. Ozerov and co-authors note, diagnosing psychomotor abilities requires standardized procedures and specialized equipment [3, pp. 11–13]. However, existing market solutions are often expensive and not always adapted to the needs of specific sports organizations.

The developed phygital laboratory aims to solve the following tasks:

- rapid diagnostics of psychomotor abilities of athletes of various skill levels;
- formation of a digital athlete profile with the ability to track performance dynamics;
- integration of data into the training process to increase its efficiency;
- objectification of selection and recruitment procedures in sports schools.

Structure of the digital phygital laboratory. The laboratory is built on a modular principle and includes three main components (Figure).

The data collection module records the following indicators:

- simple and complex visuomotor reaction time;
- accuracy of reproducing force and movement amplitude;
- coordination abilities (static and dynamic balance);
- movement frequency (tapping test).

Data collection is carried out using external devices (sensor panels, button blocks, balance platforms) and wearable sensors (accelerometers, gyroscopes). The technical implementation of the module relies on the methodology presented in foreign research on the diagnosis of physical and cognitive abilities [4].

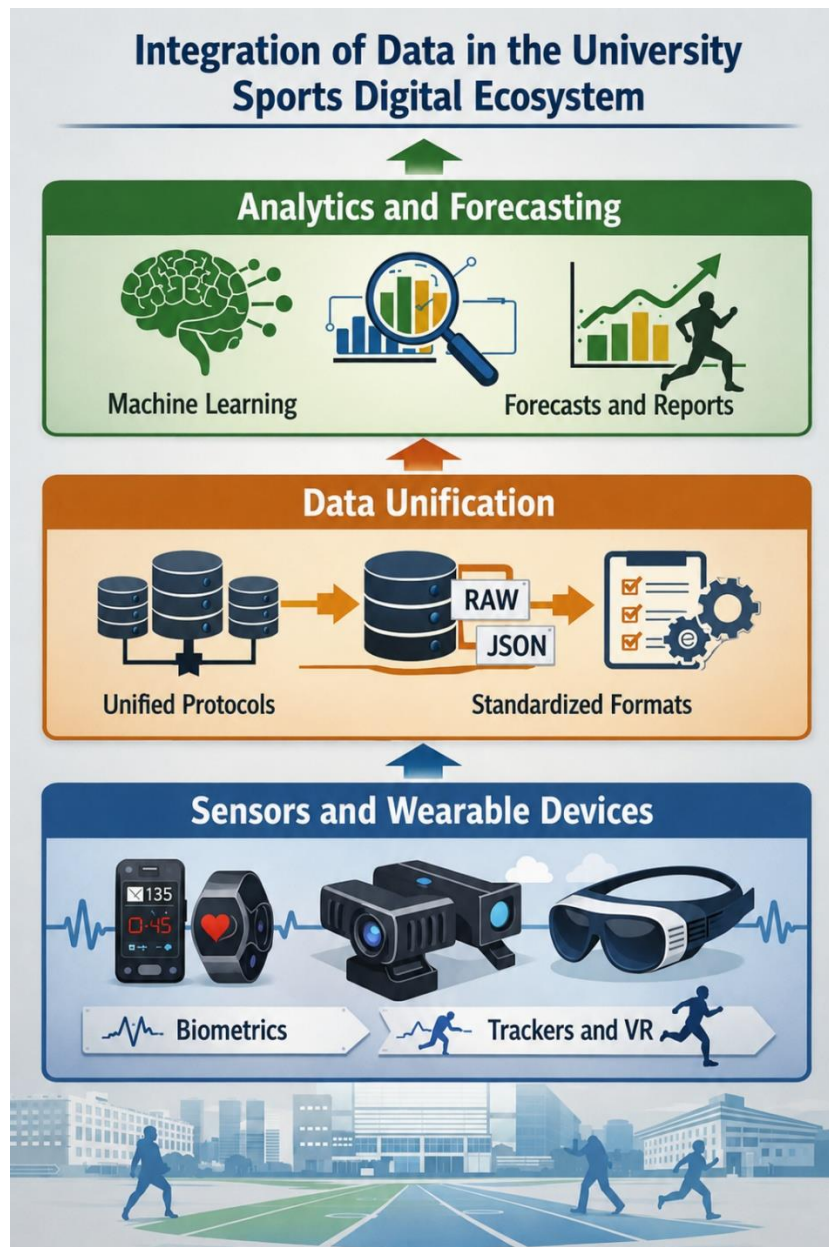


Figure. Structure of the digital phygital laboratory

The processing and analysis module performs primary statistical processing of the obtained data, comparison with normative values (according to the scales of V. I. Lyakh [5, p. 78] and V. P. Ozerov [3, pp. 11–13]) and forms a conclusion about the current level of development of the subject's psychomotor abilities.

The visualization and storage module provides:

- display of results in a clear graphical form;
- generation of reports for the coach and athlete;
- long-term data storage with retrospective analysis capability;
- data export in formats compatible with external information systems.

Functional capabilities. The developed laboratory allows for both single diagnostic sessions and regular monitoring of athletes' psychomotor status. The Table presents the main functional capabilities of the system.

Table. Main functional capabilities of the digital phygital laboratory

Function	Description	Usage mode
Reaction time diagnostics	Measurement of simple and complex reaction to visual stimulus	Single / monitoring
Coordination assessment	Static and dynamic balance tests	Single / monitoring
Tapping test	Assessment of maximum movement frequency	Single / monitoring
Profile formation	Construction of individual psychomotor profile	Automatic
Comparison with norms	Automatic comparison with normative scales	Automatic
Data export	Export in CSV, JSON, XML formats	On request

Practical significance. The introduction of a digital phygital laboratory into the activities of sports organizations allows for:

1. increasing the objectivity of assessing psychomotor abilities through digital registration of indicators;
2. reducing the time spent on diagnostics (from 40–50 minutes to 15–20 minutes per subject);
3. ensuring comparability of results through standardized procedures and unified assessment scales;
4. creating a database for scientific research and improving training methods.

The laboratory is of particular importance for the sports selection system. As K. K. Markov and V. Yu. Lebedinsky note, without an objective assessment of psychomotor qualities, it is impossible to build an adequate model of an athlete [1, p. 298]. The proposed solution makes it possible to identify athletes with high potential at early stages of training and determine directions for their further development. Furthermore, modern research confirms the specificity of the level of development of psychomotor abilities in athletes of different specializations [6, pp. 42–49], and the use of phygital programs improves the quality of technical movements, for example, in volleyball [7, pp. 154–158]. This substantiates the need for an individual approach implemented in this laboratory.

Conclusion

The digital phygital laboratory for diagnosing psychomotor abilities (certificate No. 2026619322) is a modern hardware-software complex that combines physical measuring devices and data processing software. The main advantages of the laboratory are:

- modular structure allowing adaptation of the system to specific tasks;
- use of standardized diagnostic methods [3, 5, 8];
- possibility of integration into the training process and athlete selection system;
- accessibility for use in sports schools and training centers.

Prospects for further development of the laboratory are associated with the introduction of artificial intelligence elements for predicting sports results based on psychomotor profiles, as well as with the development of a mobile version of the system for diagnostics in the field.

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APPLICATION D'UNE DISPERSION AQUEUSE DE POLYURÉTHANE POUR LA FORMATION DE TISSUS REVÊTUS DESTINÉS À L'HABILLEMENT

Annotation. L'article examine les questions de sécurité des matériaux destinés à l'habillement avec un revêtement polymère à base de dispersions aqueuses de polyuréthane. Une analyse comparative des caractéristiques du cuir naturel, des matériaux en PVC, des polyuréthanes traditionnels et des dispersions aqueuses de polyuréthane a été réalisée. Une attention particulière est accordée à la technologie de moussage mécanique des compositions aqueuses de polyuréthane comme méthode de formation d'une structure poreuse du revêtement et d'économie de matière première polymère. Des données expérimentales sur l'influence du taux de mousse (dans la plage de 1,0 à 2,5) sur la densité et la viscosité dynamique de la composition sont présentées. Les régularités des changements des propriétés rhéologiques avec l'augmentation du taux de mousse ont été établies. Sur la base des résultats obtenus, les plages optimales de taux de mousse pour différents types de matériaux d'habillement ont été déterminées: 1,25-1,5 – pour les revêtements denses à structure microporeuse ; 2,0-2,5 – pour les matériaux à perméabilité à l'air et à la vapeur accrue ; 1,75 – taux de mousse universel. La régulation du taux de mousse permet de modifier les propriétés hygiéniques et physico-mécaniques des tissus revêtus finis tout en réduisant simultanément la consommation de polymère, ce qui correspond aux principes du développement durable et de l'économie des ressources.

Mots-clés: polyuréthane, éco-cuir, tissus revêtus, taux de mousse, structure poreuse, propriétés rhéologiques, économie des ressources.

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APPLICATION OF AQUEOUS POLYURETHANE DISPERSION IN THE FORMATION OF COATED FABRICS FOR CLOTHING PURPOSES

Abstract. The article examines the safety issues of clothing materials with a polymer coating based on aqueous polyurethane dispersions. A comparative analysis of the characteristics of natural leather, PVC materials, traditional polyurethanes, and aqueous polyurethane dispersions has been carried out. Attention is paid to the technology of mechanical foaming of aqueous polyurethane compositions as a method for forming a porous coating structure and saving polymer raw materials. Experimental data on the influence of the foam expansion ratio (in the range from 1.0 to 2.5) on the density and dynamic viscosity of the composition are presented. The patterns of changes in rheological properties with an increase in the foam expansion ratio have been established. Based on the obtained results, optimal foam expansion ratio ranges for various types of clothing materials have been determined: 1.25-1.5 – for dense coatings with a fine-porous structure; 2.0-2.5 – for materials with increased air and vapor permeability; 1.75 – universal expansion ratio. Regulating the foam expansion ratio makes it possible to change the hygienic and physical-mechanical properties of finished coated fabrics while simultaneously reducing polymer consumption, which corresponds to the principles of sustainable development and resource conservation.

Keywords: polyurethane, eco-leather, coated fabrics, foam expansion ratio, porous structure, rheological properties, resource conservation.

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ПРИМЕНЕНИЕ ВОДНОЙ ПОЛИУРЕТАНОВОЙ ДИСПЕРСИИ ПРИ ФОРМИРОВАНИИ ТКАНЕЙ С ПОКРЫТИЕМ ОДЕЖНОГО НАЗНАЧЕНИЯ

Аннотация. В статье рассматриваются вопросы безопасности материалов одежного назначения с полимерным покрытием на основе водных полиуретановых дисперсий. Проведен сравнительный анализ характеристик натуральной кожи, ПВХ-материалов, традиционных полиуретанов и водных полиуретановых дисперсий. Внимание уделено технологии механического вспенивания водных полиуретановых композиций как методу формирования пористой структуры покрытия и экономии полимерного сырья. Представлены

экспериментальные данные по влиянию кратности пены (в диапазоне от 1,0 до 2,5) на плотность, динамическую вязкость композиции. Установлены закономерности изменения реологических свойств при увеличении кратности пены. На основе полученных результатов определены оптимальные диапазоны кратности пены для различных типов материалов одежного назначения: 1,25-1,5 – для плотных покрытий с мелкопористой структурой, 2,0-2,5 – для материалов с повышенной воздухо- и паропроницаемостью, 1,75 – универсальная кратность. Регулирование кратности пены позволяет изменять гигиенические и физико-механические свойства готовых тканей с покрытием при одновременном снижении расхода полимера, что соответствует принципам устойчивого развития и ресурсосбережения.

Ключевые слова: полиуретан, экокожа, ткани с покрытием, кратность пены, пористая структура, реологические свойства, ресурсосбережение.

Au cours du dernier siècle, la conscience écologique de la société a considérablement augmenté [1]. Les consommateurs modernes et les normes législatives imposent des exigences strictes concernant les aspects écologiques et toxicologiques de la production des biens de consommation courante. L'industrie textile et l'industrie légère, qui reposaient sur l'utilisation de solvants volatils, sont aujourd'hui confrontées au défi de la transition vers de nouvelles technologies, plus sûres pour l'homme et l'environnement.

Cette question est devenue particulièrement aiguë dans la production de matériaux revêtus. Le cuir naturel traditionnel, malgré ses propriétés uniques, est produit en utilisant des sels de chrome, ce qui crée un problème d'élimination des déchets solides contenant du chrome et de traitement des eaux usées [1]. Le système de tannage aux sels de chrome, qui reste à ce jour la méthode de tannage du cuir la plus répandue, est sous la pression constante des groupes écologiques et des normes internationales en raison de la pollution et des causes toxicologiques [2]. Les sels de chrome sont utilisés dans environ 90 % de la production mondiale de tannage. Il devient de plus en plus difficile pour les tanneurs de respecter les réglementations constamment mises à jour concernant la teneur en chrome dans les eaux usées, ainsi que dans les déchets solides contenant du chrome, tels que les copeaux, les chutes de cuir et la poussière de polissage [1].

Les alternatives synthétiques consistent généralement en un support textile recouvert de deux couches ou plus de polymères synthétiques [3]. Les cuirs artificiels à base de vinyle (PVC), quant à eux, nécessitent l'ajout de plastifiants et, lors de leur élimination ou de leur combustion, peuvent libérer des dioxines.

De ce fait, le profond intérêt pour les technologies propres stimule le développement de cuirs artificiels à base de polyuréthane (« éco-cuirs »), qui sont positionnés comme une alternative tant aux cuirs naturels qu'aux matériaux en PVC [4]. Les compositions de polyuréthane (PU), contrairement au vinyle, ne nécessitent pas de plastifiants, grâce à quoi le revêtement ne se fissure pas et conserve son élasticité pendant toute la durée de vie. De plus, le PU est considéré comme plus sûr du point de vue des émissions de substances nocives dans l'atmosphère lors de sa transformation et de son utilisation. Les polyuréthanes sont des polymères hétérochaînes dont la

macromolécule contient un groupe uréthane non substitué et/ou substitué —N(R)—C(O)O— , где R = H, alkyles, aryle ou acyle. Les macromolécules de polyuréthane peuvent également contenir des groupes fonctionnels éther-oxydes et esters, des groupes urée, amides et certains autres groupes fonctionnels. Le mécanisme de synthèse chimique du polyuréthane est en plusieurs étapes; toutes les propriétés requises sont établies précisément lors de la synthèse chimique du polymère [5].

Les polyuréthanes traditionnels se présentent sous forme de solutions de polyuréthane dans des solvants organiques (toluène, xylène, acétone, N-méthylpyrrolidone, diméthylformamide, etc.). Leur technologie de transformation repose sur l'évaporation de ces solvants pendant le processus de formation du revêtement, ce qui s'accompagne d'émissions significatives de composés organiques volatils (COV) dans l'atmosphère. Bien que le polyuréthane lui-même, après durcissement, soit un matériau chimiquement stable et sûr, le cycle technologique de son application à partir de solutions crée une charge écologique importante et nécessite de puissants systèmes de ventilation. Les dispersions aqueuses de polyuréthane diffèrent des systèmes traditionnels en ce que le polymère ne se trouve pas à l'état dissous, mais sous forme d'un système colloïdal stable où le milieu de dispersion est l'eau et la phase dispersée est constituée de particules de polyuréthane. Ce sont des systèmes colloïdaux complexes, stabilisés par l'introduction de groupes hydrophiles (de type ionique ou non ionique) dans la chaîne du polymère lors de la phase de synthèse [5, 6].

La comparaison des propriétés de base des polymères utilisés pour l'enduction des tissus est présentée dans le tableau 1.

Tableau 1. Caractéristiques comparatives des matériaux revêtus

Paramètre	Cuir naturel (tannage au chrome)	Cuir artificiel PVC	PU traditionnel	Éco-cuir PU (à base aqueuse)
Plastification	Non requise	Requise (migration des phtalates)	Non requise ou minimale	Non requise
Écologie de production	Consommation d'eau élevée, effluents chromés	Émissions de COV, utilisation de solvants	Toxicité lors de l'application	Pas de COV
Écologie d'élimination	Problème d'élimination des déchets chromés	Émissions de dioxines lors de la combustion	Moyenne (recyclage possible)	Possibilité de recyclage
Élasticité et résistance au froid	Élevée	Satisfaisante (perte du plastifiant)	Élevée	Élevée, durable
Résistance à l'usure	Élevée	Moyenne	Élevée	Élevée, effet de restauration
Capacité de moussage	Non applicable	Limitée	Faible (mousse instable)	Élevée

Théoriquement, les revêtements poreux en polyuréthane modernes possèdent une capacité de restauration grâce à la teneur élevée en liaisons physiques (liaisons hydrogène et de van der Waals), qui constituent 50 à 90 % du nombre total de liaisons

transversales. En cas de dommage mécanique (perforation), ces liaisons sont capables de se rompre et de se réorganiser, ce qui entraîne le rapprochement des bords de la perforation et la réduction de sa surface visible, améliorant ainsi l'aspect esthétique du produit [7], ce qui constitue également un avantage de l'utilisation du polyuréthane pour la formation de revêtements sur tissu.

Les dispersions aqueuses de PU peuvent être utilisées dans différentes technologies de formation de revêtement polyuréthane sur tissu, y compris l'application directe (à la racle), l'application par transfert et la technologie de moussage. L'utilisation du moussage de la composition de polyuréthane présente un intérêt particulier, car l'introduction d'air dans la matrice polymère permet de résoudre deux problèmes [4]:

- la formation d'une structure poreuse: permet d'obtenir un matériau dont le toucher et la perméabilité à l'air se rapprochent de ceux du cuir naturel,
- l'économie de matière première: le moussage augmente le volume de la composition, réduisant ainsi la consommation de polymère par mètre carré de tissu fini sans perte d'épaisseur du revêtement, ce qui correspond aux principes d'économie des ressources.

Du point de vue de la sécurité écologique, l'application d'un revêtement polymère par moussage représente un type particulier de finition en termes d'émissions. Les méthodes de finition en continu ne nécessitent pas de lavage après la fixation de la substance fonctionnelle. Cela signifie que les émissions potentielles liées à la pollution de l'eau sont limitées aux pertes systémiques et à l'eau utilisée pour le nettoyage de l'ensemble de l'équipement. Les résidus des compositions polymères sont réutilisés, ce qui empêche leur déversement et leur mélange avec les eaux usées. Lors de l'utilisation des matériaux et produits finis, aucune substance nocive ou toxique n'est libérée dans l'environnement [8].

Les propriétés rhéologiques des compositions sont la base pour le contrôle du processus de formation du revêtement. La viscosité, le taux de mousse du système polymère déterminent son comportement à toutes les étapes du cycle technologique, et la variation du taux de mousse permet également de contrôler la formation de la structure poreuse, ce qui permet par la suite d'améliorer les propriétés hygiéniques du tissu revêtu fini. De ce fait, l'étude des propriétés rhéologiques des dispersions aqueuses de polyuréthane modernes est une tâche actuelle.

Le sujet de l'étude était une dispersion aqueuse de polyuréthane. Les technologies modernes permettent de faire varier le taux de mousse d'une telle composition, ce qui ouvre de larges possibilités pour contrôler la structure et, par conséquent, les propriétés du revêtement formé.

Le taux de mousse est le rapport du volume de mousse au volume de la phase liquide initiale. En modifiant cet indicateur au cours du processus de moussage mécanique, on peut obtenir des matériaux avec différentes morphologies: des films monolithiques avec des pores fermés isolés aux structures hautement poreuses avec des pores interconnectés.

Le moussage de la dispersion aqueuse de polyuréthane a été réalisé mécaniquement à l'aide d'un mélangeur de laboratoire à vitesse de rotation fixe de l'organe de travail. Le taux de mousse a été varié dans la plage de 1,5 à 2,5 en modifiant

la durée de mélange et le degré d'aération de la composition. La composition de polyuréthane sans moussage ($\beta_{n0} = 1$) a été prise comme échantillon témoin.

Les études rhéologiques de la mousse obtenue ont été réalisées à l'aide d'un viscosimètre rotatif RM100 PLUS Lamy Rheology à un taux de cisaillement de 500 s^{-1} . La température de mesure était de $20 \pm 0,2 \text{ }^{\circ}\text{C}$. L'incertitude de mesure était de $\pm 1 \%$.

Le tableau 2 présente les propriétés de la composition de polyuréthane moussée.

Tableau 2. Propriétés de la composition de polyuréthane moussée

Taux de mousse	Densité de la composition, g/cm^3	Viscosité dynamique de la composition, $\text{mPa}\cdot\text{s}$	Rayon moyen des bulles d'air, μm	Rayon des bulles du groupe le plus nombreux, μm
1,0	0,95	239	—	—
1,25	0,90	264	90,1	65-77
1,5	0,81	295	94,8	75-88
1,75	0,61	311	115,9	110-125
2,0	0,49	341	130,4	130-146
2,25	0,42	389	147,3	136-141
2,5	0,39	436	150,0	140-154

Comme on pouvait s'y attendre, l'augmentation du taux de mousse entraîne logiquement une diminution de la densité de la composition. Pour un taux de mousse de 2,5, la densité diminue de plus de 2,4 fois par rapport à la dispersion initiale, ce qui confirme l'efficacité du moussage mécanique comme méthode d'économie des ressources: tout en conservant l'épaisseur de la couche appliquée, la consommation de polymère par unité de surface diminue proportionnellement.

On observe une augmentation monotone de la viscosité dynamique de la composition avec l'augmentation du taux de mousse. Lors du passage du taux de 1,0 à 2,5, la viscosité passe de 239 à 436 $\text{mPa}\cdot\text{s}$ (presque 1,8 fois). Cette régularité s'explique par l'augmentation de la fraction volumique de la phase gazeuse, ce qui entraîne une augmentation de l'interaction hydrodynamique entre les bulles. D'un point de vue technologique, cela signifie que lors de la transformation de mousses à taux élevé, il est nécessaire de prendre en compte les charges de cisaillement accrues et d'ajuster les paramètres d'application (réduire la vitesse de déplacement du tissu, réguler la durée et la température de polymérisation).

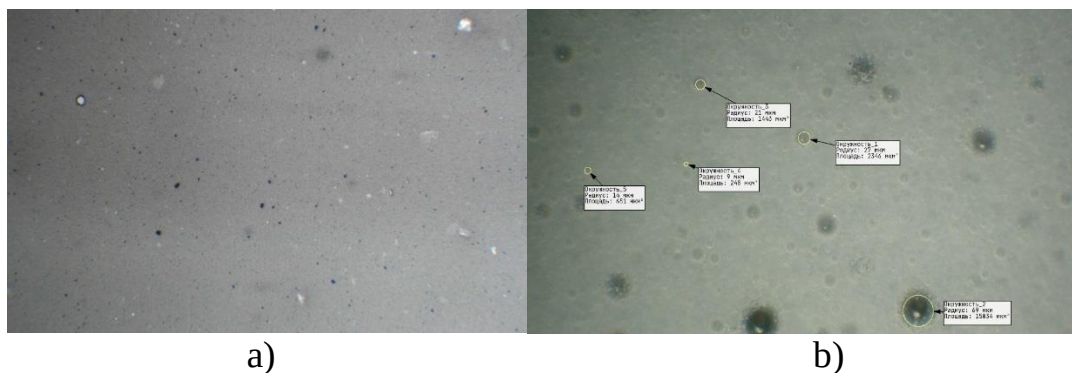


Figure. Microphotographies de la composition PU avant (a) et après (b) moussage

Avec l'augmentation du taux de mousse de 1,5 à 2,5, le rayon moyen des bulles augmente successivement (de 94,8 à 150 μm). Le groupe de bulles le plus nombreux se déplace également vers la zone des tailles plus grandes (de 75-88 μm à 140-154 μm).

Les régularités identifiées permettent un contrôle dirigé de la structure et des propriétés du revêtement formé en choisissant le taux de mousse optimal. Pour obtenir des matériaux à résistance accrue et à surface lisse (par exemple, pour les tissus de trenches), il est conseillé d'utiliser un taux de mousse dans la plage de 1,25 à 1,5. Cela assure la formation d'une structure microporeuse avec une augmentation modérée de la viscosité. Pour les matériaux soumis à des exigences accrues de perméabilité à l'air et à la vapeur d'eau, le taux optimal est de 2,0 à 2,5. La structure macroporeuse assure les propriétés hygiéniques nécessaires, mais nécessite un contrôle de la stabilité de la mousse et un ajustement des conditions de séchage pour prévenir le retrait et les défauts du revêtement. Le taux de mousse de 1,75 peut être considéré comme universel, offrant une combinaison équilibrée de porosité, de densité et de viscosité pour une large gamme de matériaux destinés à l'habillement.

L'étude a montré que l'utilisation de dispersions aqueuses de polyuréthane pour la formation de tissus revêtus destinés à l'habillement est une direction prometteuse et écologiquement responsable. Le remplacement des solvants organiques par de l'eau comme milieu de dispersion permet de réduire considérablement les émissions de composés organiques volatils, améliorant ainsi la sécurité du processus de production et la conformité aux normes environnementales modernes.

La technologie de moussage mécanique des compositions aqueuses de polyuréthane offre des possibilités supplémentaires pour contrôler la structure et les propriétés des revêtements. Les résultats expérimentaux ont démontré une relation claire entre le taux de mousse et les caractéristiques clés de la composition: densité, viscosité dynamique et paramètres de la structure poreuse. L'augmentation du taux de mousse de 1,0 à 2,5 entraîne une diminution de la densité de plus de 2,4 fois et une augmentation de la viscosité de 1,8 fois, tandis que le rayon moyen des bulles passe de 90 à 150 μm .

Ainsi, la régulation du taux de mousse est un outil efficace pour ajuster les propriétés hygiéniques et physico-mécaniques des tissus revêtus finis tout en réduisant simultanément la consommation de polymère, ce qui correspond pleinement aux principes du développement durable et de l'économie des ressources dans l'industrie textile moderne.

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