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ERGONOMIC THINKING IN THE DESIGN OF HUMAN-MACHINE SYSTEMS

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ABSTRACT *In the era of Industry 4.0, human-machine systems have become highly complex and contain a large number of elements and sources of information. It increases the complexity of human-machine system management, which leads to the manifestation of the human factor phenomenon. The consequence is that currently, 70% to 90% of accidents and disasters are related to the human factor. Therefore, the safety of human-machine systems largely depends on human abilities, cognitive, behavioral, and psycho-physiological features. It is shown that the study of individual characteristics of a person will allow the management of the human factor in the human-machine system. The crucial point of human factor management is the availability of systemic ergonomic thinking in the designer of the human-machine system. The formation of such thinking is connected with learning and the gradual acquisition of the necessary knowledge and skills. To understand the principles of ergonomic thinking formation, the evolution of ergonomic thinking in the design of human-machine systems is shown. Due to analysis of the sequence of ergonomic thought development, it is shown how approaches to ensuring the safety of human-machine systems have been rethought from the middle of the 20th century until now. Currently, the global social processes and technologies of Industry 4.0 have fundamentally changed the concept of "work", parameters of the labour market, and safety requirements and caused the emergence of a new model of the labour paradigm "Work 4.0", which, in turn, became the driver of the revision of the concept of "workplace" established in society and the emergence of the digital workplace. The article presents the definition of a "digital workplace" and analyses its essential characteristics. The next stage of the work was a model of the structure of the engineer's ergonomic thinking, the main feature of which is the priority of solving the problems of human-machine interaction. The work also shows that ergonomic thinking is one of the elements of safety culture. In combination with other elements such as a human-centered approach, ecological thinking and others, ergonomic thinking creates a space of a safety culture. Based on the presented results, the importance of engineers' ergonomic thinking is substantiated. It is shown how to implement the formation of ergonomic thinking through the training system.*
Keywords: *human-machine system; ergonomic thinking; safety; designing; Work 4.0; digital workplace.*

ЕРГОНОМІЧНЕ МИСЛЕННЯ У ПРОЕКТУВАННІ ЛЮДИНО-МАШИННИХ СИСТЕМ

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АНОТАЦІЯ *В епоху Індустрії 4.0 людино-машинні системи стали надскладними і містять велику кількість елементів і джерел інформації. Це підвищує складність управління людино-машинною системою, що призводить до прояву феномену людського фактора. Наслідком цього є те, що наразі від 70 % до 90 % аварій і катастроф пов'язані саме з людським фактором. Отже, безпека людино-машинних систем значною мірою залежить від урахування можливостей людини, її когнітивних, поведінкових та психофізіологічних особливостей. Показано, що дослідження індивідуальних особливостей людини дозволить здійснювати управління людським фактором у людино-машинній системі. Ключовим моментом управління людським фактором є наявність системного ергономічного мислення у проектувальника людино-машинної системи. Формування такого мислення пов'язане з навчанням та поетапним набуттям необхідних знань та умінь. Для розуміння принципів формування ергономічного мислення показано еволюцію ергономічної думки у проектуванні людино-машинних систем. Через аналіз послідовності розвитку ергономічної думки показано як відбувалось переосмислення підходів до забезпечення безпеки людино-машинних систем з середини XX сторіччя і до сьогодні. Наразі глобальні соціальні процеси і технології Індустрії 4.0 докорінно змінили поняття "праця", параметри ринку праці, вимоги до безпеки та обумовили появу нової моделі трудової парадигми «Праця 4.0», яка, у свою чергу, стала драйвером перегляду усталеного в суспільстві поняття «робоче місце» і появи цифрового робочого місця. У роботі представлено визначення поняття «цифрове робоче місце» і проаналізовані його ключові характеристики. Наступним етапом роботи стало створення моделі структури ергономічного мислення інженера, основною ознакою якого є пріоритетність вирішення проблем людино-машинної взаємодії. Також у роботі показано, що ергономічне мислення є одним з елементів культури безпеки. У поєднанні з іншими елементами такими, як людино-центричний підхід, екологічне мислення та іншими, ергономічне мислення створює простір формування культури безпеки. На підставі представлених результатів обґрунтовано*

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важливість формування ергономічного мислення у інженера. Показано, як реалізувати формування ергономічного мислення через систему навчання.
***Ключові слова**: людино-машинна система; ергономічне мислення; безпека; проектування; Праця 4.0; цифрове робоче місце.*

Introduction

In the era of Industry 4.0, human-machine systems (HMS) have become highly complex and contain a large number of elements and sources of information. Moreover, permanent improvements and automation of human-machine systems are accompanied by a further increase in information sources (sensors, detectors, etc.). As a result, it generates plenty of information flows of different natures, methods of their processing, visualization types, and modelling and analysis tools. It increases the complexity of human-machine system management, which leads to the manifestation of the human factor phenomenon. The consequence is that 70% to 90% of accidents and disasters currently are related to the human factor [1–3].

In the process of work, HMS operators face high demands and the pace of work and experience severe stress, so they sense an excessive information load. As a result, it leads to a deterioration in the efficiency and reliability of their activities (Fig. 1).

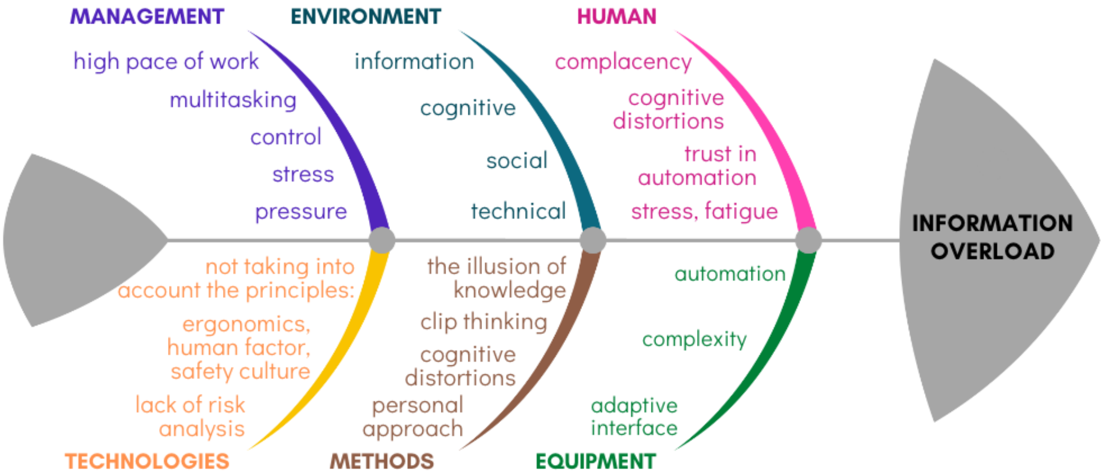

Fig. 1 – Negative consequences of the impact of information overload on a person

Thus, the safety of human-machine systems largely depends on considering a person's capabilities and cognitive, behavioral and psychophysiological characteristics. In this regard, human factor management in HMS is relevant today.

However, the problem of managing the human factor is complex and transdisciplinary. The human factor problems are considered in many articles [3–5]. Various approaches, methods, and strategies are used to solve problems. Priority is those that give the most tangible results. For example, a systematic approach that considers error as a consequence rather than the cause of a problem is more effective than an individual one that focuses on the mistakes of individual people. The operator error prevention strategy is based on error elimination during the design, and the predictive approach makes it possible to anticipate their occurrence. Thus, it is essential to implement the central idea – the idea of system protection.

That is why the crucial point in human factor management is the presence of systematic ergonomic thinking of the designer of HMS. The formation of such thinking is associated with training and the gradual acquisition of the necessary knowledge and skills.

In this regard, the focus of the article is directed to:

1) consideration of the idea and components of the concept of “ergonomic thinking”;

2) analysis of the evolution of ergonomic thought in the design of HMS;

3) consideration of essential principles of ergonomic design of HMS.

The aim of the article

The article aims the analysis and development the concept of “ergonomic thinking”. The task is the formation of a set of ergonomic thinking principles. The motivation is to draw attention to the problem of ergonomic thinking formation among HMS developers.

Materials and Results

As a rule, under human-machine system design, it is used an approach in which the content, principles, and procedures for operating the system are developed without considering a person and his role in this system [6–8]. However, in conditions of a high level of automation and digitalization of work processes, it is necessary to rethink the approach to the design of human-machine systems. In this case, the research focus must be

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on the person and his capabilities because an increase in the share of artificial intelligence in decision-making creates only the illusion of increasing the security of the human-machine system. It makes it possible, on the one hand, to create an ergonomic design, thus, the person will have an essential role, and on the other hand, to increase the safety level of the human-machine system.

Considering a person as a crucial element of the design object makes it possible to view the designed system as a multi-factorial organism. At the same time, the centre of attention is the person. Achieving this understanding is possible only if the training of future specialists is directed towards a specific safety mindset development. That is, it is necessary to understand the safety implementation principles based on the principles of achieving ergonomic and risk management.

From the history of ergonomics development, it is known how ideas about improving the safety and efficiency of human activity, workplaces and working environment, and even human life transformed. Back in the 50's of the previous century, Japanese scientists with American ones developed approaches to improving quality, which showed their effectiveness and proved the viability due to the Japanese "economic miracle". Generally, the Japanese school of quality is based on creating and developing a specific mindset among all performers and participants in the production process. All quality assurance work is based on continuous training on quality and enhancement of knowledge and developing a certain "quality" mindset in the employee.

However, unlike "quality thinking", the "ergonomic" one is not developed by HMS designers. Moreover, experts ignore "ergonomic" thinking and provide knowledge about it in a limited amount.

Let's analyze which ways the safety and efficiency of human-machine systems have been improving. There are many directions, sciences, and disciplines dedicated to the design of human-machine interaction and its impact on safety (Fig. 2).

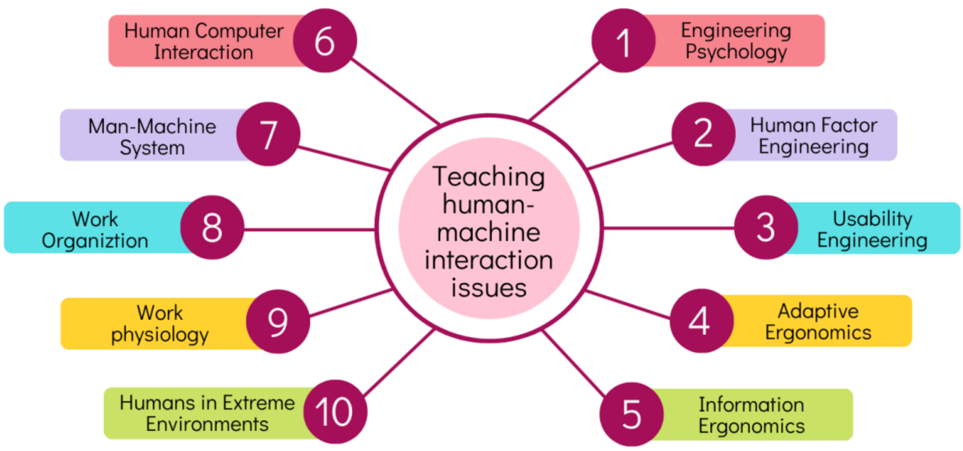

Fig. 2 – Educational and scientific-practical areas of human-machine interaction

The development of ergonomic thought has been complex and fascinating. The growth of complexity and automation in systems, the need to make decisions in a limited time, and the increase in the cost of erroneous human actions have led to a significant increase in the complexity of human functioning in human-machine systems. And as a result, it has led to errors in the operator's activity, accidents and disasters, and the emergence of the problem of the human factor and engineering psychology. Namely, engineering psychology created the basis for the transition of the design of human-machine systems from technocentric to anthropocentric. Engineering psychology researches the processes and means of information interaction between a human and a machine, also equipment of automation. It let laid the foundation for understanding the role of a person's individuality in ensuring the safety of systems functioning [9,10].

Human factor engineering creates the basis for studying the cognitive perception of information sources. The task is to prepare students to use modern concepts and system-forming principles in human factor engineering, cognitive ergonomics and neuroergonomics to optimize the interaction in the human-machine system and increase the system safety at the stage of its design [11–14]. It should be noted that human factors engineering is not the only discipline for students to acquire the necessary safety skills. In addition to it, the following academic disciplines are also taught: Human Factors and Ergonomics, Ergonomics, Human-Computer Interaction, Human Machine Interaction, Man-Machine System, Physical ergonomics, Usability Testing, Work Organization, Humans and Indoor Environments, Humans in Extreme Environments, and Work physiology. Many universities offer bachelor's, master's, and doctoral programs in human factors engineering.

One of the "thin" places for ensuring the reliability and fault tolerance of human-machine interaction is the provision of such interface qualities as ergonomics [15,16]. The process of designing and developing software, in particular, the interface, involves various specialists – usability engineers, graphic designers, programmers, and testers. Some interface developers have practically no required knowledge about the human-user for whom the interface is being developed. However, it is impossible to create reliable and safe software products without knowledge of the human factor, ergonomics, psychology and human-computer interaction.

Usability engineering has emerged as a field of software development at the intersection of such scientific disciplines as experimental psychology, human-computer interaction, and computer science. Usability Engineering is closely related to human factors, cognitive sciences, engineering psychology, ergonomics and technical aesthetics. For instance, the "smart" interface development (a user interface that provides control, monitoring, and visualization between a person and a device) requires a deep understanding of human psychology, the psychophysiology of perception and the processes of thinking and cognition. Their appearance exacerbated the problem of understanding human nature. However, there was a gradual evolution of the problem and the creation of controversy in this area. The commonly accepted interpretation of the concept of usability did not take into account the cognitive aspect of human-computer interaction, focusing only on the effectiveness and satisfaction of the consumer. Since the mid-2000s, at the suggestion of D. Norman, the term "usability" has been gradually replaced by UX (user experience). At the same time, the sphere has significantly moved away from user-centred design (UCD) and cognitive ergonomics. User interface development has moved into the realm of specialists who are not familiar with and do not use the necessary knowledge for program interface development, namely, human perception, operator errors, the psychology of perception and behavior, and the ergonomic properties of systems.

Today, the performance of work tasks increasingly depends on the creation, search, use, exchange and organization of information [17,18]. At the same time, human works in a multi-channel and information-intensive working environment. The development of information and communication technologies (ICT) has led to a growing information load on a human, an accelerated pace of work and multitasking for him. Thus, information load management has become a central issue of ergonomics. Until now, experts have approached the problem of information load mainly from the point of cognitive ergonomics. Traditionally, cognitive ergonomics has emphasized the need to match the characteristics of information systems with human cognitive abilities, focusing on issues of usability and user experience related to working tools in complex or safety-critical work environments. At the same time, little attention was paid to the factors causing ergonomic problems in mental work processes that exist in usual office conditions. Such factors include, for example, information load and multitasking.

Thus, today there is a need to create a new direction in ergonomics – information ergonomics focusing on managing the information load in conditions of information-intensive work.

Information ergonomics deals with the fit between user behavior and a digital, information-intensive work environment. Due to a holistic approach, information ergonomics is not limited to how operators interact with digital applications. Its aim is an improvement of the operators' productivity and mental well-being by regulating the information load on them.

A specific goal of information ergonomics is to identify the information load in intellectual work and to develop methods of more effective management of it. Information load can be related to the content of work, work processes, work organization, work environment or ways of acting in a work community. Thus, information ergonomics aims to research factors that limit a person's ability to process information.

The current state of ergonomics is associated with a shift in emphasis from an adaptation of humans to techniques or an adaptation of equipment to humans to the formation of a "human-machine" symbiosis [19,20].

Today, efforts are aimed at rethinking and setting a balance between human involvement and automation, design and user support, and expediency and necessity from a computational, cognitive, ergonomic or organizational point of view. At this stage, researchers try to create such systems that would maximally reveal and use the potential of each element of the system to use all resources more rationally, in particular, time and energy. The adaptive ergonomics principle is a relatively new concept in ergonomics. In this case, we are talking about controlled ergonomic individualization, which implements due to adaptive self-adjusting systems and devices that can provide ergonomic individualization.

The adaptation property of a system is in changing operating conditions both within the system itself and concerning the external environment. In such a system, it takes place not a rigid but a flexible distribution of information and control functions between a human and a machine. Until recently, the adaptation property of a system has been realized due to the adaptive capabilities of a person, the flexibility and plasticity of his behavior and the possibility of changing it depending on the specific situation. At present, the issue of implementing adaptation mechanisms using computer intelligence is on the agenda: the intelligent information and control environment of an ergatic system should change its parameters and functions depending on the current psychophysiological state of a human and performance indicators.

One of the ways to ensure the safety of HMS is standardization. Under normal conditions, the system's reliability is provided by the requirements of various standards, which implement different approaches, methods, parameters, criteria, algorithms, and programs. Divergent learning is sufficient for this. However, under the influence of external and internal stress factors, the reliability of systems begins to be directly affected by neuroergonomic, psychophysiological, and psychological

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aspects of human perception of information. As a result, the human factor arises.

The most famous international standards are ISO 9241 – Ergonomics and human-computer interaction, ISO 9241-110:2020 – Interaction principles, ISO 9241-210:2019 – Human-centred design for interactive systems, ISO 9241-220:2019 – Processes for enabling, executing and assessing human-centred design within organizations [21–23]. For example, ISO 9241-210 describes six principles to consider when creating a product within a human-centred design. One of them is the ergonomic principle of selecting a multidisciplinary team for development since it is necessary to consider the opinions of representatives of different professions. However, researchers note that these principles are not always used in the design of human-machine systems.

The above can be represented as a scheme of the evolution of ergonomic thought development in human-machine systems design (Fig. 3).

Thus, the problems in the design and operation of HMS using ICT are still very relevant. The development of technologies and the quality of the interface is not going as the experts would like. For example, despite the high level of automation in Unmanned aerial vehicles, the level of accidents caused by the human factor is high. And in general, the number of accidents in systems due to human factors remains consistently high.

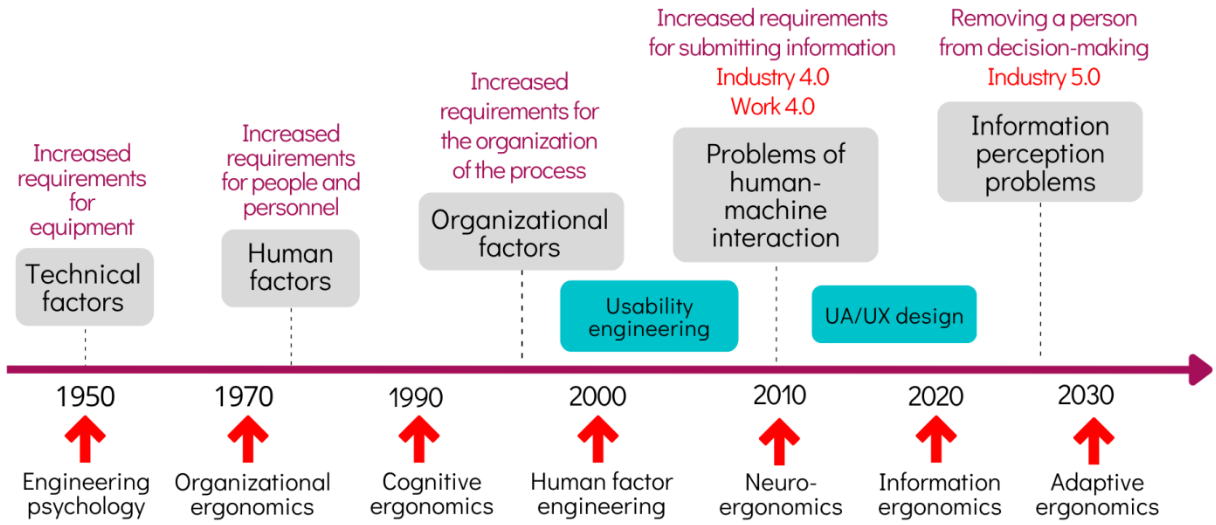

Fig. 3 – Evolution of ergonomic thought in human-machine systems design

Discussion

Transformation of the labour paradigm. Today, there is a rethinking of approaches to providing the safety of human-machine systems. The prerequisites for this are apparent. It is a change in the human attitude to safety issues at the workplace. In particular, demand for a safe and high-quality working environment, a decrease in dangers and the need to develop a safety culture. And also, the development of innovations in production and industrial technologies in the era of Industry 4.0: modern IT technologies, the digital transformation of management, and production processes and changes in the professional data and competencies of employees put forward new requirements for the management of safety processes [24–26].

Modern technologies and the digitalization of production impact the reformation and rethinking of safety issues. Enterprises are interested in programs that will allow finding effective digital solutions for automating routine processes, in particular, reducing the time to analyze safety and occupational hygiene, reducing injuries and improving safety culture. Digital technology, means of automation and robotics, application of nanotechnology, artificial intelligence, “The Internet of Things”, “Big data”, and sensor technologies are becoming more applicable for increasing human-machine systems safety. Currently, Ukrainian enterprises have reached maturity level, which helps to introduce such technologies to raise safety and occupational health [24–26].

Thus, the global processes and technologies of Industry 4.0 fundamentally change the world of work, its institutions, organizational structures, parameters of the labour market, and safety requirements and cause the emergence of a new model of the labour paradigm “Work 4.0” (Fig. 4).

Work 4.0 is a concept that discusses the future of work in the EU. It describes how the world of work will gradually change in the next decade in response to digitalization and Industry 4.0 [27].

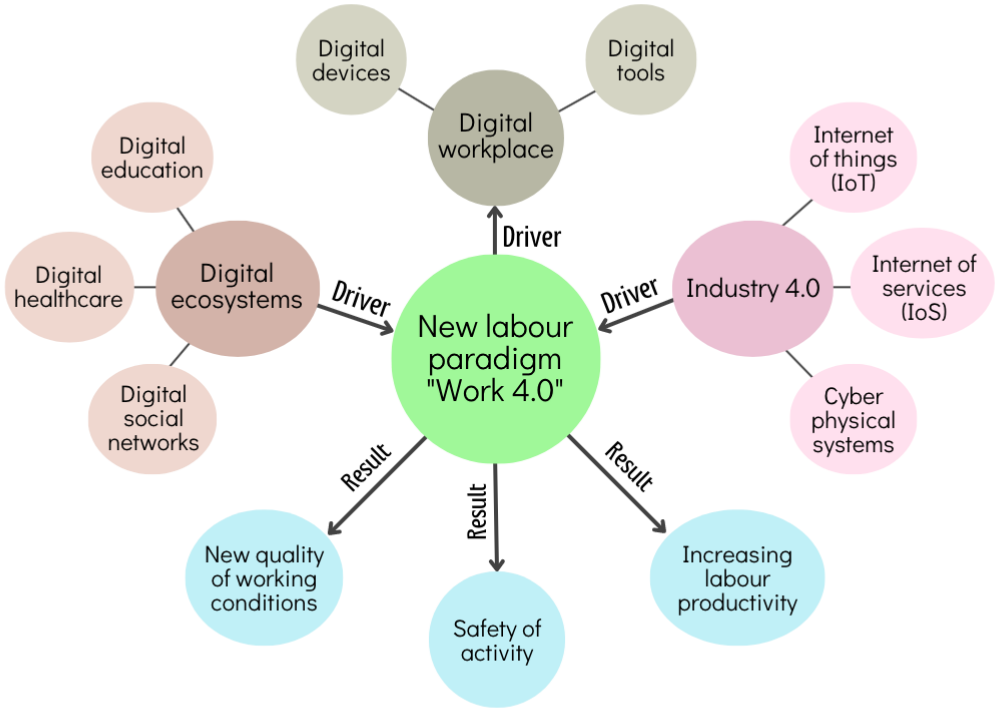

Fig. 4 – Model of the new labour paradigm "Work 4.0"

Conceptually, Work 4.0 reflects the fourth phase of labour relations, the use of digital technologies (for example, the Internet), and increased flexibility in the work organization. That is why the drivers of Work 4.0 are Industry 4.0 and digital ecosystems. The concept of Work 4.0 includes the following key points [27]:

1) the transformation of economic sectors and types of activities and their impact on employment;

2) the creation of new markets and new forms of work through digital platforms;

3) problems related to Big Data (for example, data protection);

4) the relationship between the use of human and machine labour (depreciation of experience, individual support);

5) the possibility of flexible working conditions regarding time and location;

6) significant changes in organizational structures.

The concept of Work 4.0 has created a vision of quality workplaces in the age of digital technologies and become a ground for:

1) transition from unemployment to employment insurance;

2) promotion of flexible working hours;

3) new ergonomic approaches to safety and occupational health;

4) data protection;

5) improvement of social protection for self-employed persons, etc.

Thus, "Work 4.0" is a new social and labour reality of the beginning of the 21st century forming under the influence of current realities.

Transformation of the workplace. Work 4.0 is the driver of revising the concept of the "workplace" established in society. In the digital world, workplaces mustn't be tied to physical locations. Thus, they become mobile. That is virtual and digital world provides opportunities for employees to be permanently online. This trend is spreading quickly, and employees perceive it positively.

A digital workplace is a virtual equivalent of a physical workplace that requires proper organization, use and management, as it should become the guarantee of increased employees' efficiency and the creation of more favourable working conditions for them [28].

The following aspects can be highlighted in the concept of a digital workplace:

1) humans have the highest priority;

2) advances in technology lead to changes in the digital workplace, which is why technology is always a relevant issue;

3) the development of a "digital" workplace means treating it as a whole, in which the technologies, processes, and employees are organically combined.

The digital workplace is a strategy to improve employee performance through a more user-friendly work environment.

Creating a digital workplace makes it possible:

1) move from routine and repetitive patterns of work to variable and dynamic work;

2) increase employee engagement (often with the help of engagement programs implemented by HR specialists);

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3) apply new forms of internal (employee) and external (client) interaction that takes place in social networks;

4) use new ways of working, such as crowdsourcing and division of work between executors and micro-work (execution of small tasks within the project via the Internet).

Programs for the dissemination of digital skills and competencies, incentives for career growth, the objective need to establish a balance between work and socio-family life, and personal development motivations contribute to the culture of digital workplaces.

Formation of ergonomic thinking.

Thinking problems. Most of the issues of ergonomic thinking development are related to the differentiation of knowledge. However, knowledge convergence, interdisciplinary approaches, and strategies are needed to ensure HMS safety [11, 29, 30].

An obstacle to the design of safe and effective HMS for modern specialists is ignorance of ergonomic laws and cognitive aspects of human interaction with technologies and equipment to consider the human factor at all stages of the HMS life cycle.

It is the development of ergonomic thinking among future engineers that should be paid attention to because it is a system of views of a person on the development of HMS and the role of humans in them; it is an understanding of the complex processes of human-machine interaction; the ability to predict risks in these systems and plan the development of systems with a preliminary consideration of these risks.

The lack of ergonomic thinking leads to the lack of predictive risk control, which increases the frequency of their implementation and even the severity of the consequences. That is, we have a colossal problem - the disproportionality of the knowledge of the person-developer and the person-operator with a significant and continuous increase in the complexity of HMS and the level of threats from them.

Design problems. The way to achieve HMS fault tolerance is possible due to the application of a systematic approach and the idea of system protection. The main principle is to predict the worst and prepare for its implementation at all stages of the HMS life cycle. At the same time, organizational culture is getting crucial importance. And the process of creating the system itself is based on the need to develop the system with increased resistance to human errors. Protection, barriers, and safeguards are at the heart of the system approach, which makes it possible for proactive rather than retrospective risk management.

The creation of viable fault-tolerant HMS can follow three paths according to Shell's model and Reason's "systemic pathogens" model:

1) design of risk-resistant systems for which the realization of risks itself is not critical (for example, alarm signals, physical barriers, automatic shut-down, etc.);

2) design of human activity in HMS, when the accent is on an individual personal approach and the main role is played by the professional selection, professional training, intelligent decision support systems and others (this especially applies to activities with a high degree of uncertainty, for example, surgeons, pilots, dispatchers, unmanned aerial vehicle operators, etc.);

3) designing a safety culture based on procedures, administrative control, and management (i.e. control of risks associated with systematic errors).

It is on the understanding of these three ways the transformation of the modern engineer's thinking is based.

Transformation of the engineer's thinking.

An analysis of the activities of outstanding engineers (I. Vyshnegradskyi, A. Eiffel, E. Paton, G. Ford, F. Porsche, O. Shargei (Y. Kondratyuk), etc.) makes it possible to assert that a specific type of thinking is the basis of the success of their activities, which is characterized by the multifaceted vision of a technical problem, the ability to identify and resolve technical contradictions and the physical contradictions hidden in them, while purposefully generating paradoxical ideas.

The professional training of future engineers requires special attention to the formation of engineering thinking, capable of ensuring compliance with the selected principles of engineering activity. The future engineer of the industry, in addition to mastering the necessary "core" of professional knowledge, must learn to think systematically, overcome the inertia of thinking, identify and resolve emerging technical contradictions, generate non-standard technical ideas, master the skills of multivariate problem solving and their objective assessment. Systems thinking is a type of thinking that has a holistic perception of objects and phenomena, given their interrelationships. Systems thinking should be cyclical, i.e. identifying structure, establishing connections, setting goals, searching for and choosing alternatives, implementing, and again in a circle. Engineering thinking is professional thinking aimed at the development and operation of new high-performance, reliable, safe and aesthetic equipment, the development and implementation of progressive technology, at increasing the quality of products and the level of production organization. Note that this definition consists of concepts that form the purpose and tasks of ergonomics. And in our opinion, creating competitive products and highly efficient fault-tolerant systems with the help of engineering thinking is impossible without the parallel growth of an engineer's ergonomic consciousness and the transformation of his ergonomic thinking.

Ergonomic thinking. An engineer's ergonomic thinking is a sign of his education and a guarantee of high qualification. A necessary feature of ergonomic thinking is the recognition of the exceptional priority of problems of human-machine interaction concerning others among all issues of human activity. In our opinion, the model of the structure of the engineer's ergonomic thinking looks like this (Fig. 5).

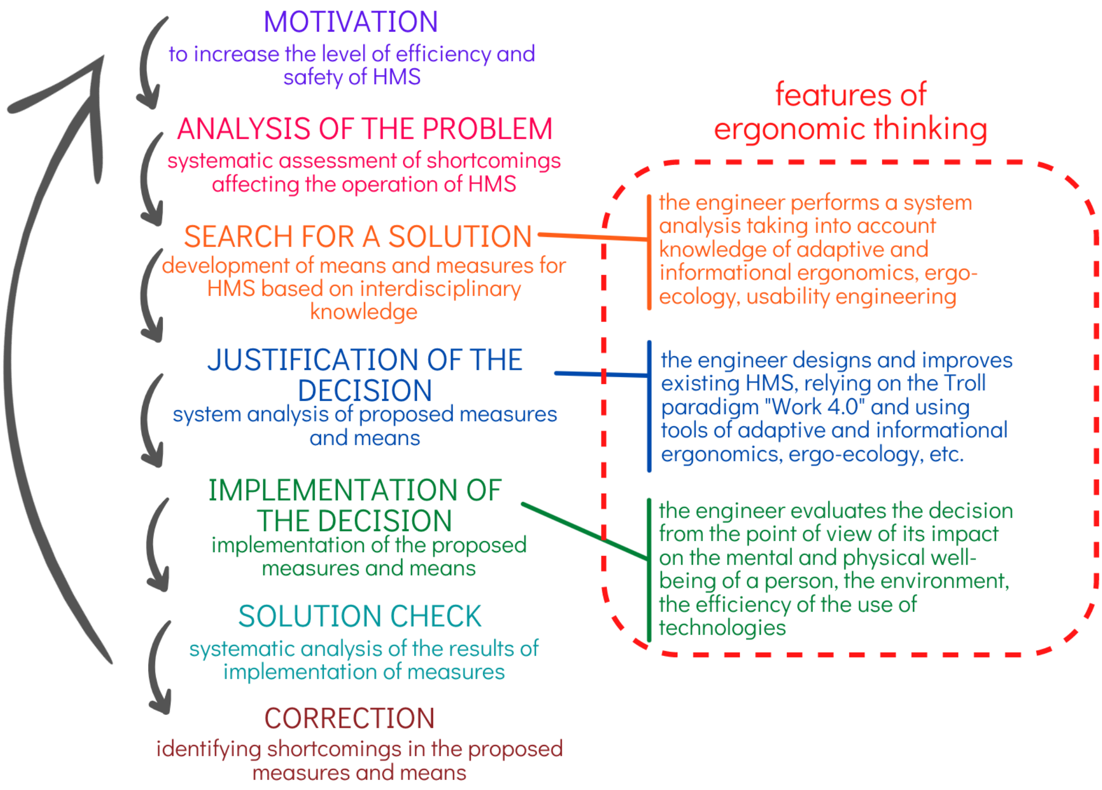

Fig. 5 – A model of the structure of the engineer's ergonomic thinking

It should be noted that ergonomic thinking is one of the elements of safety culture. In combination with other elements such as a human-centered approach, ecological thinking, and others, ergonomic thinking creates a space for the safety culture (Fig. 6).

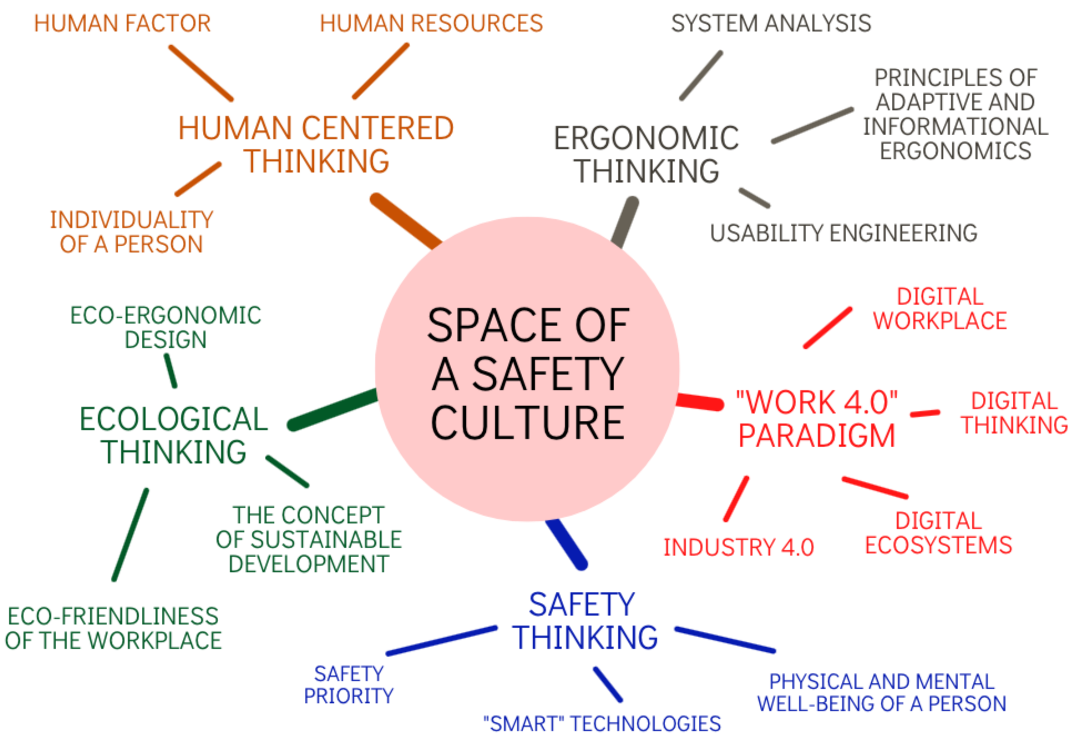

Fig. 6 – Space of safety culture

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It should be noted that the formation of a safety culture in society goes slowly. The main reasons are insufficient attention to these issues in the educational process, both in educational institutions and in the workplace. Culture is an acquired characteristic, not innate. Thus, it develops throughout human life. The same with safety culture – it must be formed through the continuous training of a specialist. Therefore, safety culture is an integral part of ergonomic thinking, and the level of its development is an indicator of a human understanding of the importance of ensuring the safety of human-machine interaction.

As mentioned above, mastering the principles of ergonomics and human factor engineering is an effective tool for the formation of ergonomic thinking in an engineer; principles of biomimetics and biological adaptation of living organisms to the living conditions; psychological laws and patterns of human existence as an element of the social system. They combine the principles of operation of man-machine systems and include information about human resources, technical capabilities of the equipment and the safety of the workplace and environment. That is, the main goal of acquiring such knowledge is to ensure the safety of the operation of man-machine systems. But it is based on quality assurance, fault tolerance, mastery of the human factor, and risk management. Therefore, the formation of ergonomic thinking is essential for achieving the goal of safety.

Conclusions

The era of Industry 4.0 has significant changes in the functioning of HMS, which led to a change in views on work, as a result of which a new “Work 4.0” paradigm emerged, a shift in what the workplace should be, the result of which was the emergence of a digital workplace, a change in human perception of the environment, as a result of which ecological thinking and the concept of sustainable development of society emerged. These achievements became a breakthrough but did not solve the issue of HMS safety. That is why the aim was to research the engineer’s ergonomic thinking for increasing the safety of HMS.

Consideration of the idea and components of the concept of “ergonomic thinking”, analysis of the evolution of ergonomic thought in the design of HMS, the research of the principles of ergonomic design of HMS makes it possible;

1) to substantiate the importance of the formation of ergonomic thinking in an engineer to improve the safety of HMS.

2) to suggest a model of the structure of the engineer’s ergonomic thinking.

3) to show how the training system develops an engineer’s ergonomic thinking.

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