Application of ergonomic software solutions in the concept of Industry 4.0

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Abstract: *Continuous development of technology brings daily improvements implemented in various processes, systems, machines, tools, or equipment. The development of these technologies is currently most often in the synergy of the Industry 4.0 strategy, which forms a solid foundation for modern industrial practice. In this continuously evolving environment of industrial practice, digital concepts for every manufacturing sector come to the fore. Part of every production sphere is the worker, the person forming part of the production process, who undoubtedly requires the same attention as the production system itself. The ergonomics industry deals with the issue of the humanization of technology in the workplace, where it is necessary to ensure the adaptation of the machine to humans and not by suitable working conditions. The presented article is focused on highlighting and describing the basic connections between the general principles of ergonomics, the principles of modern understanding of ergonomics in digital form, which is rapidly developing in the engineering industry in conjunction with Industry 4.0 strategy for practice. The conclusion of the article provides a general summary of the issue with the ideas of developing the concept of ergonomics software solutions in mechanical engineering. This article was supported by research grants VEGA 1/0431/21 and KEGA 004TUKE-4/2020.*

Keywords*: DIGITAL ERGONOMICS, INDUSTRY 4.0, HUMANISATION OF TECHNOLOGY, SYNERGY, CONCEPTUAL IMPLEMENTATION*

1. Introduction

The knowledge and technologies acquired in the first decades of the new millennium create space for the creation of a more suitable working environment in connection with better working conditions for employees. Continuously improving technologies and principles are part of various methodologies, procedures and concepts that bring the expected improvements in common synergy. [1] The current trend in the field of industrial solutions is the advancement of all manufacturing companies in terms of Industry 4.0, i.e., among other things, in the digitization and interconnection of their machines, equipment, logistics systems, services with active human participation in the workplace. [2] Such mass digitization represents the concept of creating an integrated PC system, which consists of models, simulations, analyses, or 3D visualizations. Not only research and development centres in international corporations, but also research and educational institutions are concerned with the implementation of Industry 4.0 into production practice in general. Examples of the presented issues and research are, for example [3-7].

2. Industry 4.0 and Digital Ergonomics Interaction

The Industry 4.0 concept is currently considered to be the most current part of technological industry development. It represents significant progress towards digitization of industry, digitization of automation and robotization of production, based on the cyber interconnection of production information systems in industrial enterprises, i. e. digitization in all three attributes of the production process - software, equipment, and people. Industry 4.0 in all its modern interpretations (Fig. 1) represents the application of the concept of a digital network interconnection of objects and data exchange with each other in industrial enterprises. [8]

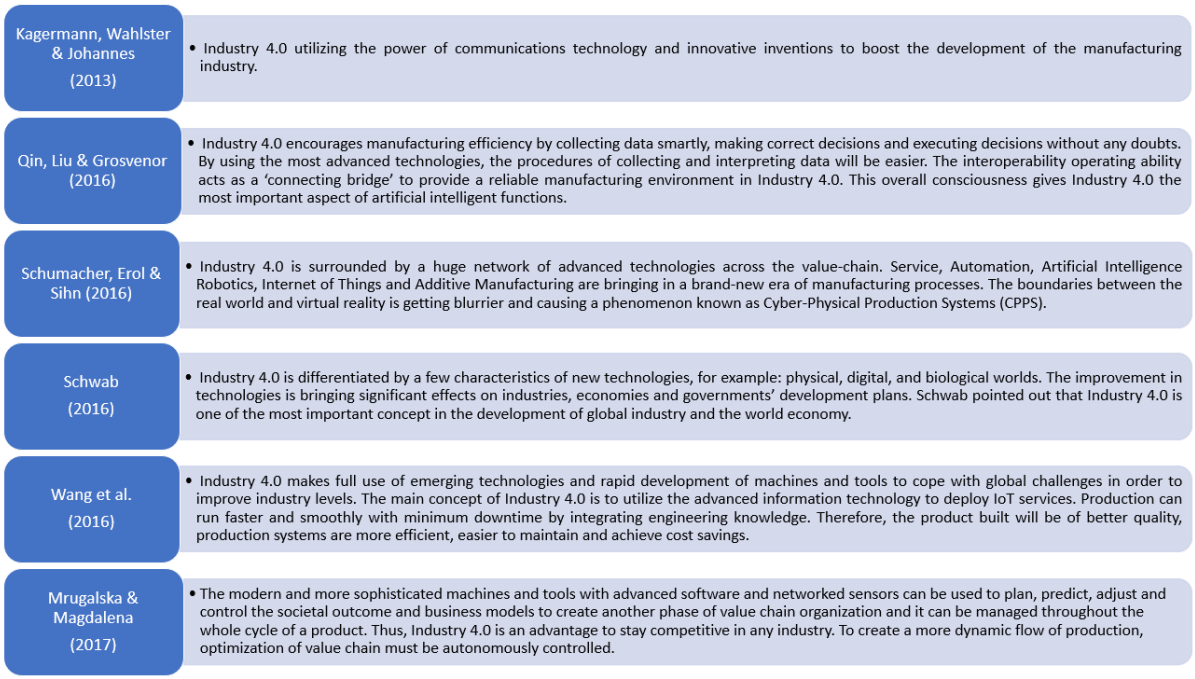

Fig. 1 *Worldwide recognized definitions of Industry 4.0 strategies. [8]*

The fourth industrial revolution is based on new technologies applied in the production process, such as robotics, artificial intelligence, the Internet of Things (IoT), autonomous vehicles or 3D printing. It interprets the application of IoT (Internet of Things) into the production process, thus conceptually creating industrial IoT, i.e. IIoT (Industrial Internet of Things). The current trend of digitization, automation and data exchange of production technologies is based on deep industrial integration through information technology and associated data processing. This integration has four basic characteristics [9]:

- Integration of engineering processes - this is the integration within the entire life cycle (from life cycle planning, development, implementation, testing, to sales services). Integration of engineering processes includes:
    - The general innovation model,
    - Efficiency innovation model,
    - Effective product management.
- Acceleration through exponential technologies - not completely new technologies, they just become more accessible for wider use and their main task is to enable individual solutions, increase flexibility and save costs in the process of industrialization.
- Vertical integration of production systems - information interconnection of all systems across the entire company structure. Smart - production systems, plants, products, interconnected logistics systems, marketing, services oriented to the individual needs of specific client requirements - personalization. Vertical integration of production systems includes:
    - IT Integration,
    - Analysis and data management,
    - Cloud solutions,
    - Operational efficiency 2.0.
- Horizontal integration - interconnection across the supply chain - the interconnection of suppliers - customers, from the manufacturer to the final distribution to the customer, service. It is a new generation of global, value-added connections, networks, involving the integration of partners and customers. Horizontal integration includes:
    - Business model optimization,
    - "Smart" supply chain,
    - "Smart" logistics,
    - IT security management,
    - New taxation models,
    - New IP management.

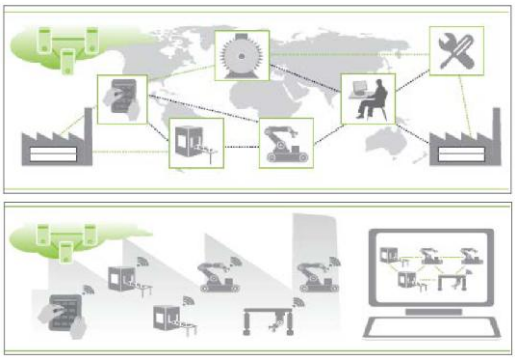

Fig. 2 *Graphical interpretation of horizontal (up) and vertical (down) integration. [9]*

The gradual deployment of intelligent production systems significantly affects, in terms of the Industry 4.0 strategy, the human-machine-environment interaction (Fig. 3) and thus the tasks performed in this interaction and the organization of work as a whole.

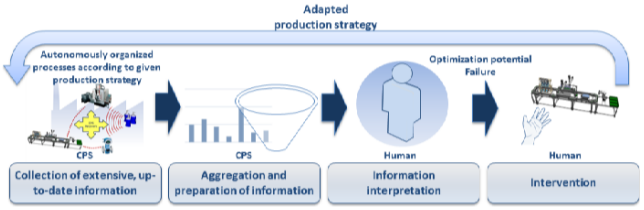

Fig. 3 *Interaction of human and machine in Industry 4.0. [10]*

To ensure the optimal human-machine-environment relationship, the principles of industrial ergonomics are applied in manufacturing companies, which is classified as an area of science aimed at achieving optimal adaptation of the working environment and workers' activities. Comprehensively, several components fall into the field of industrial ergonomics (Figure 4), such as the assessment of physical workload, posture at work, lifting and carrying, machine-human interactions, but also the classification of lighting conditions, thermal comfort, noise, and vibration effects on the worker. [11]

Fig. 4 *Basic interpretation of ergonomics. [11]*

Ensuring an optimal working environment is a demanding process that requires not only technical knowledge but also knowledge of general or specific industrial ergonomics. As technologies, processes or ideologies evolve, so did the views and possibilities of how to correctly identify ergonomics in the concept of a manufacturing company. Chronological complex determination of the term ergonomics is presented in Figure 5. [12]

The work system in industrial practice in connection with a comprehensive ergonomic assessment allows to implement [13]:

- ergonomic rationalization - searching for the most advantageous behaviour of the already existing work system,
- ergonomic modelling - finding out the probable behaviour of the existing system when changing boundary conditions,
- ergonomic analysis - experimental investigation of the structure and behaviour of the existing work system,
- ergonomic design - creating a new work system with the required behaviour.

All the above ergonomic processes can be implemented in the Industry 4.0 strategy concept, forming a new concept called digital ergonomics.

Murrell, H. (1949)	• Adapting work to people.
Grandjean, E. (1983)	• To study of human behaviour during work.
Cribini, G. (1991)	• The subject of ergonomics is all of the relationship that humans established and experience in the course of their activities, through interactions with the environment, objects, work tools and other items.
Pheasant, S. (1996)	• Ergonomics is the science of work, of the people who do it and the ways in which it is done, of the tools and the equipment they use, of the places they work in and the psycho-social aspects of working situations.
ISO 9241-210 (2010)	• Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance.
IEA (2018)	• ISO 9241 + addition:Practitioners of ergonomics and ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people. Ergonomics helps harmonize things that interact with people in terms of people's needs, abilities and limitations.

Fig. 5 *Worldwide recognized definitions of Ergonomics in chronological order. [12]*

3. Digital Ergonomics in Manufacturing Plants

The basic idea of digital ergonomics is the creation of digital twins of the work environment, workers, or work system by the Industry 4.0 strategy. The intersection of the Industry 4.0 concept and digital ergonomics is represented in Figure 6. The digital twin can be understood in ergonomics as a digital sensor model of a real object within the simulation process with an active setup. The basis for the digital twin is cumulative massive data collected in a real-time environment. [14]

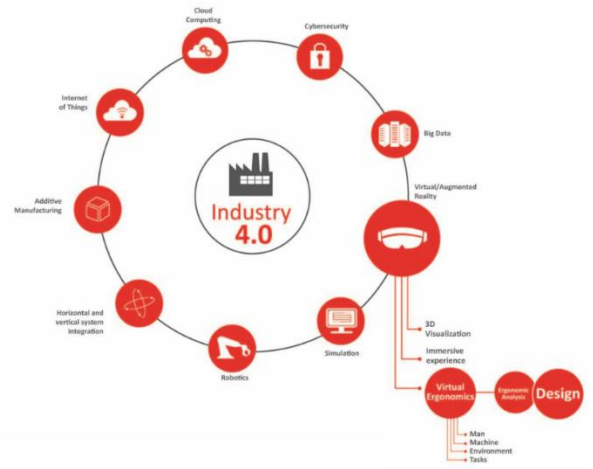

Fig. 6 *Digital ergonomics in Industry 4.0 strategy. [14]*

In the field of ergonomic assessment of the working environment, digital ergonomics can be used in industrial practice, for example, in analyzing the lighting of an individual workplace, production cell or hall. Various software solutions are used for digital analysis, while in practice the free lighting tool Dialux Evo is most often used.

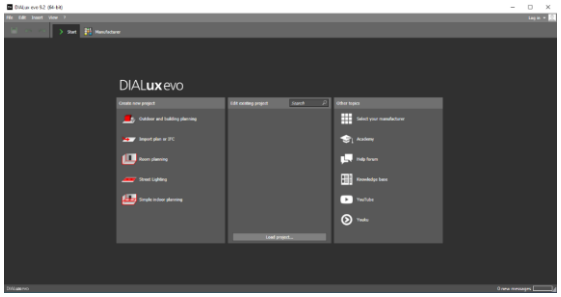

Fig. 7 *Main screen of Dialux Evo.*

With its free availability and wide compatibility, Dialux Evo ensures the possibility of application in production companies in the field of management, design and the design offices of architects. Its advantages include the ability to create your lamps, or the option of choosing from a wide range of predefined lamps from world-renowned lighting manufacturers. Based on the results of the simulation, it is possible to create a lighting study providing information on photometric values, specific flux, or layout of the lighting system. Analyses of lighting systems by implementing elements of digital ergonomics in industrial practice (Fig. 8) ensure compliance with established norms of regulations and standards in the field of work environment lighting.

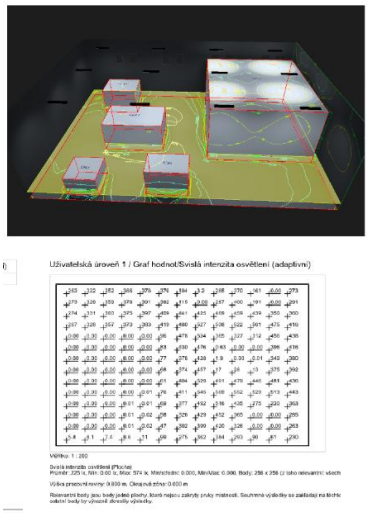

Fig. 8 *Digital interpretation of lighting analysis in industrial practice.*

Elements of digital ergonomics can also be implemented within the ergonomic assessment of the worker's physical load. In industrial practice, by this implementation, it is first and foremost necessary to identify the depth of the analysis. If it is an analysis providing only informative data, it is possible to use several mobile applications for fast screening of physical activity, such as ErgoMine or Intergo, which are mainly a substitute for the so-called ergonomic checklists. For ergonomic analysis of physical activity, complex simulation solutions are used in industrial practice, enabling simulations of work environment and work activities of employees, for example by application of digital ergonomic tool Tecnomatix, module Jack.

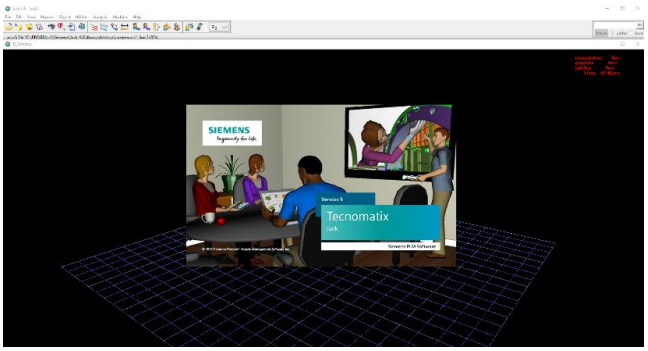

Fig. 9 *Main screen Tecnomatix – Jack modul.*

Work activities performed in industrial practice can be digitized using the Jack module, i.e. create a digital twin of a real work system and then subjected to analyses, based on which it is possible to reduce the risk of workplace risk, increase work efficiency or improve ergonomic standards. The created digital twin provides space to create several alternative improvements with the subsequent selection of the most suitable alternative by ergonomic standards and legislation (Low Back Analysis, NIOSH, OWAS, RULA, REBA, Fatigue Analysis, etc.).

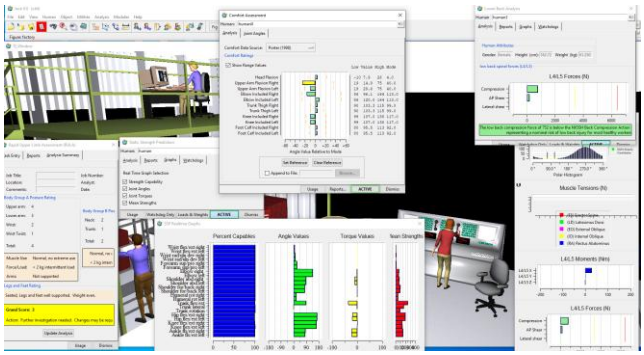

Fig. 10 *Digital interpretation of physical load analysis in industrial practice.*

4. Conclusion

Elimination of risks in ergonomics, increasing the efficiency of ergonomics of work activities, reducing the burden, and improving the factors of the working environment, but also the preventive measures in the system - man-machine - environment, of which the worker is the basic element, are a priority in every industry and non-manufacturing sector. Ergonomic assessment of assembly processes, in production as well as in logistics, administration and maintenance require increasingly complex approaches. These approaches can be provided by implementing digital tools in the process of analysis and assessment. The presented article is a summary of knowledge devoted to the implementation of digital tools in the field of ergonomics, primarily for assessing lighting as a physical factor of the work environment and physical activity, which has a direct impact on the worker. The article presents the basic possibilities of implementation and provides an overview of the issue from practice. In conclusion, it is possible to state the need for such digital connections with practice and follow up on the assessment of possible emerging risks in creating digital ergonomic environments.

5. Acknowledgement

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