Applicability of different modeling approaches to process quality management, according to the human-machine system

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Abstract: *Quality is a process of continuous improvement or improvement of the processes creating the product. Our ability to manage quality characteristics has a significant impact on the depth of our knowledge of the process used for the desired transformation. The application of knowledge in process management depends on the dominant factor for management: human or machine. Each requires an appropriate form of transfer of knowledge. Depending on the type of "human-machine system", it is possible to use various mathematical and logical tools to formalize the information. This article attempts to classify the types of mathematical and logical tools applicable to process management, depending on the "human-machine system" use.*
Keywords*: QUALITY, QUALITY MANAGEMENT, QUALITY MANAGEMENT SYSTEM, HUMAN–MACHINE SYSTEM, Modelling*

To achieve high quality production processes, modern enterprises need to master the processes used and achieve repeatable results. In the 21st century, manufacturing companies are focusing mainly on automated production. But this is not always the right decision, due to the need to take into account the level of knowledge of the human factor used in the implementation, management andcontrol of automated processes [1].

The ability to implement a particular process used in the creation of a particular product depends on the degree of knowledge of its nature and the capabilities we have to transmit the necessary information to the active element that manages it [2]. However perfect or automated the process may be, in essence it cannot be initiated or executed without the direct or indirect involvement of human. Human participation in the transformation process requires us to get acquainted with the main variants of the "human-machine" system performing specific processes, which will determine the possible methods for transmitting information to the active element of the system [4].

"Human-machine" system

The publication (K. I. Kirov, Analysis of the possibilities and limitation of the system "human - machine" in the manufacturing 2018 [6]) presents a classification of production processes, depending on the role of the active element of the system - human and / or machine. According to the presented classification the possible types of the system are:

- • **Type A -** A system that has only one active element, the "human". Human is the bearer of technology and he without a tool, based on their capabilities, knowledge and resources provided by nature, realizes the desired process of transformation.
- **Type B** – A system that has one active element "man" and one passive element "instrument". Human is the bearer of technology and he through the use of a specific tool, based on their capabilities and knowledge, realizes the desired process of transformation.
- **Type C** – A system that has two active elements "human" and "machine", as well as one passive "tool". In this case, the controller of the process is the human. It uses and manages specific technology to perform the transformation, using all three possible elements of the system.
- **Type D** – The system, again, has all the active elements, similar to type C. The difference is in the control of the conversion process. In this case, the active element is the "machine".
- **Type E -** A system that has one active element "machine" and one passive element "tool". The machine is a carrier of technology and it through the use of a specific tool, based on formalized knowledge of technology and sensitive capabilities, realizes the process of transformation.
- **Type F -** A system that has only one active element is a "machine". The machine is a carrier of technology and it without a tool, based on its capabilities and formalized information realizes the transformation process.

The review of the types of process execution systems confirms the two active elements of the human-machine system. It is logical to assume that each of them will use different methods for acquiring, processing and transmitting information..

Information and its significance for the implementation of production processes

The implementation and management of each of the production processes is impossible without having the necessary knowledge of the process and the object of transformation. The ability to perform the necessary transformation requires in-depth knowledge of the technology through which we will achieve the desired results, as well as the way it will be applied to the specific object. In essence, the description of the method and object of transformation is information necessary for the adequate implementation of the production process..

The need to convey information requires its transformation in a way that is "understandable" or "interpretable" by the subjects or objects that will use it. Achieving such a transformation requires the development of developed formal tools of science, such as mathematics and logic. The development of formal tools allows us to document (record) information with a significant level of "density", "precision" and "usefulness". Such a record allows the active element of the system to "read", "understand" and "execute".

The transformation of information into knowledge presupposes the ability of the perceiving subject / object to interpret the existing information and to qualitatively transform it into specific hypotheses, rules, models, theories and / or laws [5]. The "laboratory" in which the qualitative development of knowledge takes place, so far, is only the human brain, of course supported by the technological tools available to a particular civilization. The need for the knowledge creator at the relevant level also requires various tools for formalizing, processing, transmitting and storing knowledge, such as information. The tools used to formalize this level of "compressed" information are again mathematics and logic.

Specifics in the perception of information from the active element of the " human-machine" system

Today's economic situation requires extremely rapid readjustment of industrial structures to new production. The needs and criteria that determine the competence of the staff and the technologies used also change dynamically over time. In order to meet the needs, the current production and educational technologies must be used in the training. If we add the effects of globalization, as a basic criterion for success, there is a need to have modern

communication skills, to achieve rapid integration and efficiency in international teams, and in a modern production environment.

It is desirable to apply all the presented requirements with relatively limited resources. Therefore, the basis for the success of any organization is its ability to manage the efficiency and effectiveness of the production process, as well as its ability to quickly adapt to the needs of the modern economy..

Achieving the desired competitiveness at the modern level of automation of production equipment requires extremely high competence of the involved specialists. Competence determined by the knowledge and ability of specialists to communicate with each other and with production equipment, for the purposes of planning, design, programming, management, control and analysis of production processes. The ability of human and machine to "understand" and perform the necessary activities in the planned way, to a large extent become critical to achieving the competitiveness of production structures.

The analysis and identification of the possibilities and limitations of the "man-machine" system are important for future research in improving the achieved quality and productivity of production structures.

The role that human plays is essential to achieving the quality characteristic of the product created by the process. The requirements for human qualification and experience depend on the type of human machine system. Types A to C must have similar requirements due to the fact that the qualification and experience are decisive for the quality of the created product. In type C, despite the use of means of production, their active management during the transformation process is realized again by the human operator, in a way that directly affects the result of the activity. It is difficult to say unequivocally what the trend is, but in general the influence of qualifications and experience on the quality achieved decreases from type A to type C.

In types D, E and F, the process technology and its control are integrated to one degree or another in the means of production. The human is needed at the stages of: setup, programming of the execution cycle, control, integration of the process in the production cycle, etc. Despite its formal absence from the direct implementation of the process, it plays a significant role in achieving effective and efficient management. When the conditions change, each participant in the production process has an impact on the planned result. Therefore, it is impossible to say that the qualification and experience of the specialists involved in the process does not affect the quality of the formed product and the implementation of the process. In fact, the importance of qualifications and experience in these types of human-machine systems is crucial.

Unfortunately, it is difficult to achieve standardization of the requirements for the qualification of specialists, because the variety of means of production and the specifics of production for each of the products is significant. Relieving conditions is that the approach we use standard modern automation tools, improving the dialogue between human and machine. Such an approach allows the achievement of standardization in the field of education and educational degrees, allowing the human factor to obtain the necessary knowledge and skills for their management. Such training must be followed by adaptation and gaining experience in a specific production environment.

Retaining factors on the development of the capacity of the "human-machine" system

The main restraining factors in the development of the "human-machine" system are rooted in its inhomogeneity, it is a form of union between living nature and inanimate matter. The development of modern technologies for information processing gives us the opportunity to create machines with automated control, exceeding the capabilities of living organisms. If we try to compare the two active elements in the system, we will find restraining factors for the development and achievement of the top capabilities in terms of the capacity of the "human-machine" system..

The main advantage of the element "human" is contained in his creative nature, in his ability to formalize and interpret the information gained as a result of his experience in performing specific processes. Performing certain activities, he gains certain knowledge, qualifications and experience. Analyzing the acquired information on the basis of its creative interpretation, he can build knowledge of a higher order, allowing him to achieve continuous improvement and refinement of his knowledge of the process, as well as use them to improve the results of its management. Using the expressive means of logic and mathematics, it is possible to formalize them and make them suitable for storage, training of other subjects, as well as suitable for modeling and transmitting the necessary information to modern computer-controlled machines..

From a modern point of view, there are significant problems in building staff with a certain qualification for modern industry. The main problem is hidden in the transmission of information in the "human-to-human" system, and that is speed. The main disadvantages are related to the assimilation of information in training and exchange. Human uses information to form knowledge, and with its application in practice he gains experience, which determines his qualification. The specificity of the "human" is contained in the qualitative transformation of information. The ability to perceive, interpret and use certain information is individual to each individual. The ability of a certain subject to transform information into knowledge, as well as his ability to gain experience from the practical application of his knowledge, is also individual. That is why the society has introduced the concept of qualification, which corresponds to predetermined quality levels of knowledge and experience. The normal cycle of education of the subject is 12 years. Given that the means of production change on average in cycles of 4 to 7 years, it is an obvious problem facing the education system.

The problem is exacerbated by the recursion of knowledge and its key role in the management process. As already mentioned, the human can participate in the direct implementation, design, management, control, programming, integration, analysis and more. activities included in the production process. Each of them requires knowledge and experience from a different level, but necessarily requires the "human" to have the necessary knowledge and experience from all integrated levels. For example, in order to be able to create a program for processing a specific part for a CNC machine, it is necessary to have knowledge and experience in: execution, design, management and control of the process, ie. you need to have a qualification, for example for a turner, technologist, programmer, CNC machine operator and quality control.

The inhomogeneity of the human-machine system predetermines specific problems. With the help of the dynamic development of technology and science, we have the opportunity to create machines and installations that have the ability to realize the transformations we want,, as well as to manage them during[1] their implementation. The "machine" has the quality to quickly[2] absorb the information it needs to manage the process. The speed of information exchange depends on the element of the system providing it to the machine. In the case that the information is provided by a human, it corresponds to his capabilities, if it is a machine, then the speed of information exchange is determined by the capabilities of the means of communication. That is why human has created modern tools for programming CAD / CAM / CAE systems, reducing the adverse effects of human in transmitting information. It is important to realize that the machine needs a high level of formalization of information, which includes the necessary knowledge and experience of man. The management of modern

[1] In real time

[2] Compared to human

production systems is carried out through the use of formal means that allow communication between the systems "human-human", "human-machine" and "machine-machine"..

If we try to summarize, the problems facing the human-machine system are the following:

- Inhomogeneous nature of the "human-machine" system, as a form of union between living and non-living matter. This predetermines the main problem, the impossibility of direct exchange of information between human and machine;
- The need for human to formalize knowledge and turn it into information "understandable" for the machine, with or without technological aids;
- The need for human to formalize knowledge and turn it into information "understandable" for the machine, with or without technological aids;
- Inability of machines to build and exchange knowledge and gain experience (at the present stage);
- Problems related to the speed of decision-making in management, as well as their objectivity.

Defining the active element of the "human machine" system determines the possibilities and approaches to be used in the management of processes and their interaction.

Basic process process-human-machine

Knowledge of the process is a key criterion for the ability to use it for its intended purpose in the context of human activity. In fact, processes exist in nature without our participation. They may create things that are necessary or not for our existence. The key to process knowledge lies in the relationship between the concepts of "process" and "technology". If we carefully analyze the essence of the concepts and their relationship we can define the following three statements. First, processes exist in nature, by themselves, whether or not human participates in them. Second, technology is a reflection of human knowledge of the nature of certain processes existing in nature. Third, the ability to actually implement a specific technology, at the initiative of man, proves the adequacy of our knowledge of the process. These three statements also determine the possible relationship of human to the process..

Human knowledge of the process goes through certain qualitative states. In cases where humanity does not have the necessary knowledge of the nature of ongoing processes, it is not able to reproduce the process and can only have observations of its course, without being able to build a formal description suitable for its implementation and management. In cases where the human "has the technology" to perform and manage the process on his own initiative, its formal description may be at qualitatively different levels: hypothesis, model, theory and law, corresponding to the level of knowledge of the process. In essence, a formal description is needed to make a sequence of decisions that allow us to fully or partially implement the desired process. Each of the qualitatively different levels uses different formal tools to present knowledge. Information model of the process determines its capabilities in implementation and management. It is necessary to pay attention that the formal tools used by the human must be interpreted in a way suitable for "understanding" by the machine in order to be applicable for execution and management of the realized process.

It is logical to orient the research to the applicability of various tools for formalization of knowledge, to the qualitative level of knowledge of the process, as well as the possibility of the active element of the "human-machine" system to use them..

Levels of the information model of the process

The effective and efficient implementation and management of the process can be achieved with the correct choice and application of the information model. The quality level of the model is determined by the knowledge about it. The objectivity of knowledge is a basic characteristic that determines the precision of the built information model and logically, the ability to manage the process [3].

Law is the only form of scientific knowledge that can be defined as objective knowledge. It necessarily requires in-depth knowledge of the nature of the analyzed phenomenon (process). The laws discovered by science are always related to nature. The formal description of the law is usually realized through the tools of theoretical mathematics and achieve the desired accuracy in forecasting. They allow subsequent theoretical analysis of mathematical structures, allowing the discovery of characteristic properties or hidden possibilities of the studied phenomenon. The current level of the information model is perfect and can be denoted as a level **α**.

The most commonly used and practical concept for society is theory. The theory always has elements of subjectivism, inability to prove and / or achieve the desired prediction accuracy. Depending on the used mathematical means for formal description, the formed model can be filled with tools of theoretical and applied mathematics. The current level of the information model can be defined as a level **β** .

When studying specific phenomena for which we cannot obtain the necessary objective information or we are not interested in the essence of the phenomenon, but only in its behavior, we usually proceed to the construction of models. The methodology for creating the model presupposes a formal description for solving specific practical tasks or process management. The models are probabilistic and in most cases are sensitive to changes in the field of study or the object of study. The current level of the information model can be defined as a level **γ.**

The approach to constructing the formal hypothesis description does not differ significantly from the modeling approach presented above. To achieve and clarify the criteria under which we will use the current level, it is sufficient to assume that the current level of knowledge is applicable in the absence of objective information. The current level can be defined as a level **δ.**

Table 1

level of knowledge	level **α**	level **β**	level **γ**	level **δ**
Logical model				
Theoretical model				
Deterministic model				
Stochastic model				
Planned experiment				
Probabilistic model				

Each of the knowledge levels is possible to use different tools for description and subsequent implementation and management. The applicability of the individual tools to the level of knowledge is presented in Table 1.

Conclusion

The implementation and management of each of the production processes is impossible without having the necessary knowledge of the process and the object of transformation.

The possible relations of human to the process are: First, the processes exist in nature, in themselves, whether human participates or not in them. Second, technology is a reflection of human knowledge of the nature of certain processes existing in nature. Third, the ability to actually implement a specific technology, at the

initiative of man, proves the adequacy of our knowledge of the process.

Inhomogeneous nature of the "man-machine" system, as a form of union between living and non-living matter. This predetermines the main problem, the impossibility of direct exchange of information between human and machine.

The effective and efficient implementation and management of the process can be achieved with the correct choice and application of the information model. The quality level of the model is determined by the knowledge about it. The objectivity of knowledge is a basic characteristic that determines the precision of the built information model and logically, the ability to manage the process.

Each of the knowledge levels is possible to use different tools for description and subsequent implementation and management.

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