METROLOGY, QUALITY, STANDARDIZATION AND CERTIFICATION

METROLOGICAL RISKS IN MANAGEMENT SYSTEM OF PRODUCT QUALITY AT THE MANUFACTURING STAGE

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Abstract. A method of estimating the size of metrological risk using a comprehensive indicator is being proposed in our article. It gives the possibility to assess the weight of the impact of each structural level on the comprehensive indicator, identifies the factors that cause this risk and vulnerabilities in the system of metrological support of production.

Keywords: Product quality, Metrological support, Metrological risks, Management system.

1. Introduction and problem definition

Metrological activity faces various risks. To increase the effectiveness and efficiency of the enterprise, the administration needs to deepen knowledge and improve business skills in the field of risk management, developing and implementing its own documented methodology for managing metrological risks (MRs). The MR management process is one of the elements necessary to ensure metrological confirmation and continuous monitoring of measurement processes. The implementation of MR management systems for production helps to increase the efficiency of industrial measurement systems and reduce costs while ensuring product quality. The main assignment of MR assessment is to systematize possible discrepancies that may arise in product quality control and ranking of MR according to the level of potential danger.

Uncertainty and risk are an integral part of any modern business. The risk management system includes the processes of risk identification and analysis, assessment of its acceptability, and identification of potential opportunities to reduce the amount of risk through the selection, implementation, and control of appropriate actions. An important issue of the enterprise is the process of MR management, as the main risks that determine the degree of management of technological processes, the level of product quality control, and hence the cost of its provision [1].

According to [2], risk management is extremely important to achieve an effective quality management system as an important tool for product quality assurance at the manufacturing stage.

At the manufacturing stage, the company must plan and implement actions to address risks and opportunities. Consideration of both risks and opportunities is the basis for improving product quality and the effectiveness of the quality management system, achieving improved results, and preventing negative actions. Acting as a preventive tool is one of the main goals of the quality management system.

Risk is the effect of uncertainty on goals, any uncertainty can affect product quality both positively and negatively [3-4]. The positive impact of risk can provide an opportunity, but not every impact of risk leads to an opportunity [5].

According to [6], a measurement management system is a set of interconnected or interacted elements necessary to provide metrological confirmation and continuous monitoring of measurement processes.

2. Drawbacks

An effective measurement management system ensures the suitability of measuring equipment and measurement processes for their intended use and performs an important role in achieving product quality objectives at the manufacturing stage and in managing MRs caused by incredible measurement results that adversely affect product quality at the manufacturing stage. The system of metrological support of measurements creates conditions for obtaining measurement information with the properties that are necessary and sufficient for the development of certain solutions. Based on this, the main risk of the system of metrological support of measurements is to obtain information about the measurement, which does not include the properties sufficient to develop the necessary solutions. The consequence of this risk is making the wrong decision. In principle, the wrong management decision can cause significant damage to the company, due to this, it is important to develop a mechanism to reduce such risks.

3. Aim of the Article

The study aims to develop a methodology for assessing the size of the metrological risk of product quality at the manufacturing stage.

4. The Process of Metrological Risks Assessment

To build an effective management system for MRs to ensure product quality at the manufacturing stage, it is necessary to define the concept of this risk. In [7-9] the definitions of risk are given, where the concept of risk is assigned a different meaning: the probability of loss, the possibility of not achieving the goal, deviation from the norm, the degree of uncertainty, a combination of the probability of the event and its consequences.

MR at the manufacturing stage can be defined as the probability of the influence of measurement results on the decision on the suitability of products, and a measure of MR may be production losses from the improbability of control. However, given the complexity of modern technological processes, it is difficult to ensure an adequate assessment of the risks posed by metrological support in product quality. This applies both to determine the impact of metrological activities on product quality and to assess the level of quality losses from the improbability of control.

Therefore, to increase the adequacy of the assessment of MRs of product quality at the manufacturing stage, it is advisable to analyze the metrological support as a comprehensive organizational and technical system integrated into the quality management system of the enterprise.

The risk management process must be an integral part of the processes of the product quality management system and must be integrated into the structure, processes, and activities of the enterprise. The process can be applied at the strategic, operational, project, or program levels as well.

According to [1], MR at the manufacturing stage can be defined as the probability of the influence of measurement results on the decision on the suitability of products, and the measure of MR can be production losses from the probability of measurements. MR management of product quality at the manufacturing stage is based on MR assessment and preventive risk management.

Risk assessment is a combined process of risk identification, analysis, and assessment [3-4]. Risk identification consists of their search, definition, and description. It allows us to determine what may happen, or events that may occur from internal or external sources that may affect the implementation of strategy, product quality, and achievement of organizational goals.

The risk identification process involves finding the causes and sources of risk, events, situations, or circumstances that may affect product quality and achieving goals, and determining the nature of that impact. When identifying MR, special attention should be paid to factors caused by human (operator) influence, factors caused by imperfections in the measurement method, and factors related to the measuring instrument used. Therefore, the process of identifying MR must take into account the deviations of human and organizational factors from the expected conditions, as well as events related to hardware and software.

The main sources of MR are the risk of competence, the risk of the environment and premises, the risk of equipment, the risk of products and services provided by external suppliers, the risks that arise during the measurement process. Risks are analyzed to deepen the understanding of their nature. Risk analysis provides input to assess risk and conclude on the need for risk management and the most cost-effective treatment strategies and methods. The process of risk analysis is to identify and combine the consequences and their probabilities concerning the identified risk events to determine the amount of risk (level of risk).

Risks are ranked to identify the most significant risks or to exclude less significant or minimal risks from further analysis. The ranking is to ensure that resources are focused on the most important risks. However, particular attention should be paid to low risks that arise and form a significant cumulative effect [9]. Risk assessment involves comparing the results of risk analysis with established risk criteria to determine the need for additional action. This process can lead to a decision:

- Do nothing more;
- Consider possible risk influence options;
- Conduct further analysis to understand the risk better;
- Maintain existing means of control;
- View goals.

Decisions about the future need and method of risk management are influenced by the costs and benefits associated with taking the risk and associated with the introduction of improved controls. The importance of reducing MR is the need to justify the decision-making process and plan effective actions to minimize MR product quality at the manufacturing stage. It is also necessary to organize the process of control of the size of the MR, which permits it to react in time to its change and perform the necessary corrective actions. Risk is reduced by the application of control methods. Risk management can be approached in a variety of ways, according to the literature [10-11].

Then the identified risks are monitored. Monitoring of found estimates of risk probability, expected risk, and other factors that may affect the significance of risks. Monitoring and review are to ensure and improve the quality and efficiency of the development, implementation, and results of the process. Permanent monitoring and periodic review of the risk management process and its results should be a planned part of the risk management process [12].

5. Methods for Assessing Metrological Risks of Product Quality at the Manufacturing Stage

Since the main source of MR is the inaccuracy of measurement results in ensuring product quality control at the manufacturing stage, it needs to consider in more detail their specifics. The reliability of measurements is determined by their: infallibility and adequacy. Infallibility is a property of measuring information not to contain hidden errors (unintentional actions of personnel, equipment failures). Adequacy characterizes the degree of conformity of measuring information about product quality to its actual condition. The adequacy of measuring information about product quality is determined by: the way it is presented and the speed of processing, the degree of reflection of the content of the object under study, the value for management, and the achievement of goals.

For a long time, the process of MR assessment at the manufacturing stage gave only generalized characteristics of MR and consisted of a probabilistic analysis of the risks of the producer and consumer. With the introduction of quality management systems into production [2] and measurement management systems [6], new conditions have emerged for effective management of production risks, and in particular, MRs.

Risk analysis [3] - the use of information to identify sources of risk and their quantitative assessments. There are several approaches to solve the problem of risk assessment, which use statistical, probabilistic, expert methods and methods using index estimates, but there is no single methodology that would cover all aspects of the process of assessing the MR of product quality at the manufacturing stage.

5.1. Methods of Assessing Metrological Risk Using a Comprehensive Indicator

The MR assessment system (MRAS) is an important element in improving product quality at the manufacturing stage because the presence of MRs directly affects the quality level. In [1] it was proposed to evaluate the MR of the measurement system in terms of its effectiveness. Since the concept of “MR” includes a set of necessary procedures and actions for the management and monitoring of MR, it is advisable to introduce a special indicator by which we can estimate the MR size. This paper proposes an approach to determining the MR size in the production process using a comprehensive indicator of the MR size. To visualize the degree of interaction of properties and the relationship of the group and individual indicators as components of a comprehensive indicator of the MR size, the scheme of Fig. 1.

The proposed indicator “The size of MR”, indicated in Fig. 1 as $E_{K\kappa}$, is comprehensive, as it includes unit indicators, group indicators of the 1st and 2nd degrees, which characterize the constituent elements of the MR evaluation system. The advantage of such a scheme is that it provides an opportunity to assess the weight of the impact of each structural level on the comprehensive indicator of the MR size.

The group indicators of the 1st degree include the main sources of MRs at the enterprise. Such sources include the risk of incompetence, the environment, the premises where the measurement is performed, the equipment, products, and services provided by external suppliers, the risks that arise during the measurement process.

Group indicators of the 2nd degree of the size of MRs are an integral part of the main sources of MR (lack of qualified staff, necessary measuring instruments, unsuitable environmental conditions).

Since the process of risk analysis is to determine the consequences and their probabilities relative to the identified risk events, it is proposed to include the significance of the consequences of MR, the probability of MR, the ability to detect and identify MR to individual indicators of MR.

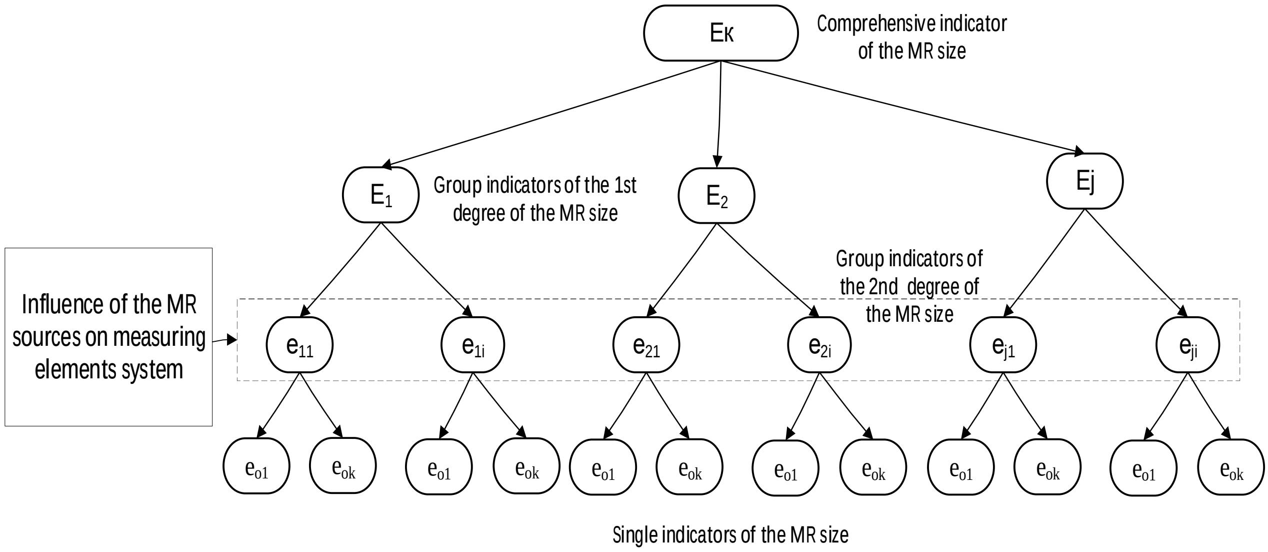

Fig.1. Scheme of a comprehensive indicator of the MR size

The architecture of the proposed system for estimating the size of MR, according to Fig. 1 is based on 4 hierarchical levels of indicators: comprehensive, group indicators of the 1st degree, group indicators of the 2nd, and single ones. Group indicators of the 1st degree are calculated by summing the group indicators of the 2nd degree, which make up the third level. This allows the group indicator of the 1st degree to acquire a value other than zero, even with a zero value of one of the group indicators of the 2nd degree. The obtained value of group indicators of the 1st degree is multiplied among themselves, which ensures the reliability and adequacy of the obtained level of MR because in case of zero of one of the group indicators of the 1st degree it is impossible to talk about the effective functioning of the whole MR evaluation system.

The values of individual indicators of the size of the MR are estimated according to a certain rating scale. The obtained values of unit indicators are multiplied among themselves to obtain a group indicator of the 2nd degree:

$$e_{ij} = \prod_{k=1}^{n} e_{ok}, \qquad (1)$$

where e_{ij} is a group indicator of the 2nd degree of the MR level; e_{ok} is the value of the unit size of the MR.

The sum of the values of group indicators of the 2nd degree for each group indicator of the 1st degree of the level of the elements of MR is determined from the formula:

$$E_j = \sum_{i=1}^{n} e_i, \qquad (2)$$

here E_j is a group indicator of the 1st degree of MR level of the *j-th* element of the MR evaluation system; e_i is the values of group indicators of the 2nd degree of MR size; n is the number of group indicators of the 2nd degree of the MR size.

The calculation of a comprehensive indicator for estimating the size of the MR for the totality of all elements of the MR evaluation system is determined from the ratio:

$$E_k = \prod_{j=1}^{m} a_j \cdot E_j, \qquad (3)$$

here a_j is the weight coefficient of the element of the MR evaluation system, which is determined by the expert method; m is the number of elements of the MR estimation system.

Determination of weights a_j should be carried out by the expert method with a frequency of one year, which takes into account trends in the development and improvement of the MR evaluation system. The block diagram of the algorithm for estimating the size of the MR is presented in fig. 2.

Reducing the MR size consists of the need to develop and implement effective actions to eliminate or reduce the sources of MR. This minimizes the size of the MR to an acceptable value. It is also necessary to organize the process of control of the MR size, which lets to implement in time the necessary corrective measures. The results of the assessment of the size of MR can be used by the company's specialists to decide on the acceptability of these risks, as well as when choosing measures to reduce or eliminate production losses caused by MR.

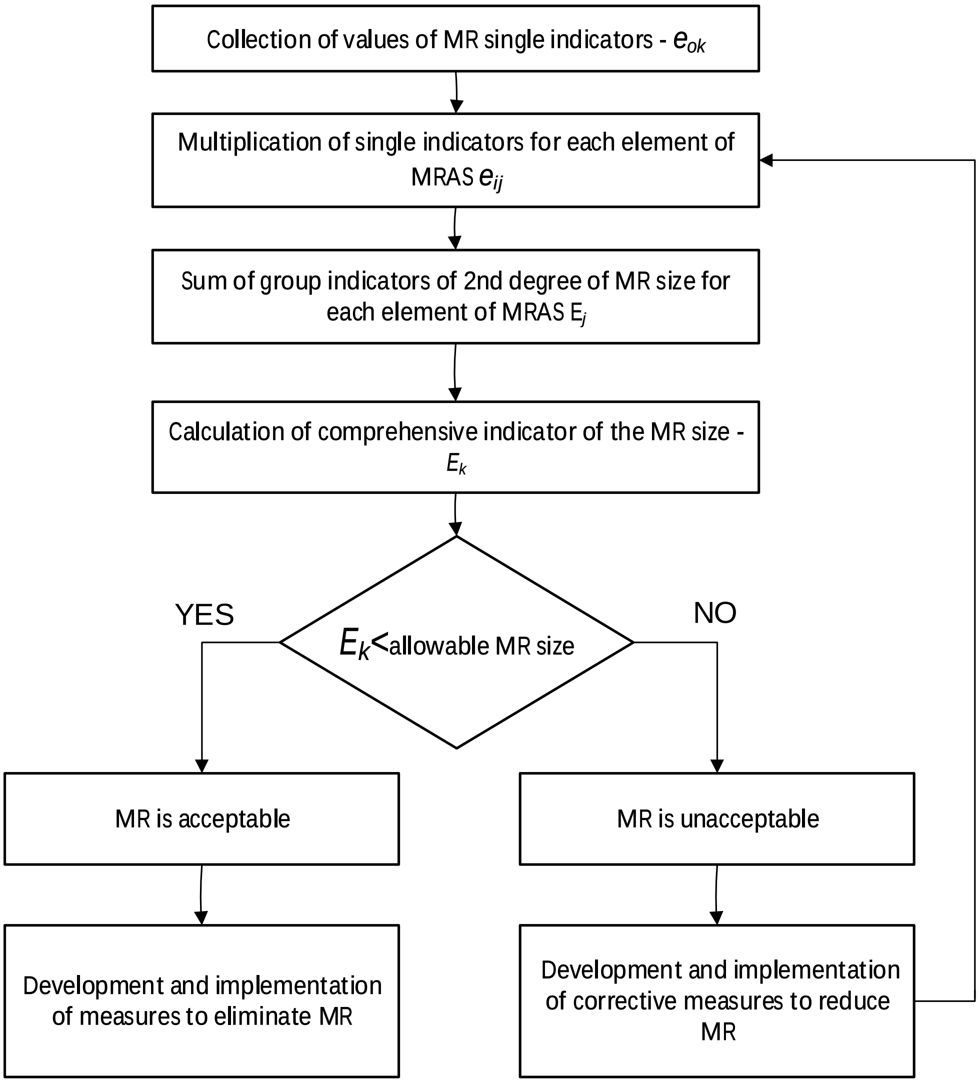

Fig. 2. Block diagram for estimating the MR size

6. Conclusions

1. For effective management of metrological risks of product quality at the manufacturing stage it is necessary to implement a system of risk indicators. Authors have proposed a method of estimating the size of metrological risk using a comprehensive indicator, the main advantages of which are:

– The ability to assess the weight of the impact of each structural level on the comprehensive indicator;

– Quantitative assessments or ranking of metrological risks;

– Identification of factors that cause this risk and vulnerabilities in the system of metrological support of production;

– Identification and comparison of production risks caused by inaccurate measurement results;

– Systematic identification of potential hazards of production.

2. This indicator includes group and single indicators that characterize the components of the metrological risk assessment system. The introduction of such a system avoids losses of the enterprise from the imperfection of the organization of measurements during the manufacture of products because each element of the structural level in some way affects the value of the comprehensive indicator. Therefore, companies need not only to rank risks by significance and pay attention only to those of them that at first glance are associated with the maximum possible losses but also to effectively manage the full range of risks inherent in business.

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8. Conflict of interest

There is no conflict of interest during the writing, preparation, and publication of the article and mutual claims of the co-authors.

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