ANNALS OF THE UNIVERSITY OF ORADEA
Fascicle of Management and Technological Engineering
ISSUE #2, AUGUST 2014, http://www.imtuoradea.ro/auo.fmte/

EVALUATION OF A LEVEL OF QUALITY OF MANUFACTURING PROCESS ON HEAVY ENGINEERING ENTERPRISES

Viktor D. Kovalev[1], Yana V. Vasilchenko[1], Dejan T. Riznić[2]
[1] Donbass State Engineering Academy (DSEA), Mechanical Engineering Faculty, 84300 Kramatorsk, Department of Machine Tools and Instruments, Ukraine, e-mail: kovalov_viktor@mail.ru and yana.vasilchenko@mail.ru
[2] University of Belgrade, Technical Faculty in Bor, Bor, Serbia, e-mail: riznic.dejan@open.telekom.rs

Abstract**—**The paper considers the solution of scientific and technical problems of increasing the efficiency of the cutting tool through the development of a quality management system during its operation, definition of rational regulations of general machine-building process and the establishment of standards of cutting. The principles of quality management system operation process, in accordance with which this process is aimed at consumers and is considered as a set of processes: organizational, management of resources, maintenance of technological systems , set- information , machining and provide customer feedback (assessment , analysis, improvement) . Output parameters of each process included in the system, are used as input for the subsequent process. Its change allows controlling the quality of the process of operation of the tools.

Keywords**—**quality management systems (QMS), international standards, manufacturing process.

I. . INTRODUCTION: METHODS OF QUALITY MANAGEMENT

THE implementation of international standards ISO 9000 version 2000 [6] (this standard has been revised by: ISO 9000:2005), which regulate the development of quality products and processes control systems, development of standards and regulations in force, is effected in Ukraine currently. Therefore issues of certification of production processes, especially the heavy machining, have the particular importance.

The following principles of ISO 9000: 2000: form the basis of the quality control system of machining process:

1) *the orientation to the requirements to the machining process put forward by consumers;*
2) *setting goals, directions, machining tasks by analyzing the conditions and characteristics of the process on heavy machines;*
3) *consideration of mechanical treatment questions, which not only directly related to the heavy parts machining, but also other information, technical-and-economic, institutional and other processes necessary for the securing the sound realization of the machining process;*
4) *identify of all the parameters that provide a rational machining, establishing the mechanisms of interaction between them;*
5) *control of the machining process as a single system with an integrated approach to assessing the level of quality of the process and ways to improve it;*
6) *usage of qualimetric approach to quantify the machining process, consists in building a hierarchical structure of processing properties, determining their weightsand evaluation on the different levels of review that provide a comprehensive assessment of process;*
7) *determination of dependence for the formation of the objective functions and decision-making in assessing the rational regulation of machining with the stochastic nature of heavy machinery;*
8) *determination of the parameters that control the quality of machining. [13, 16, 17]*

The process is considered as a collection of processes such as organizational [12], resource management [7], service of technological system [3], preparatory-and-information, processing of parts and process of providing feedback (evaluation, analysis, improvement) in the construction of structure of system of mechanical treatment on heavy machines (figure 1).

Survey of international standards for quality management systems (QMS) is shown in papers [1, 4, 5, 15, 18, 19, 20].

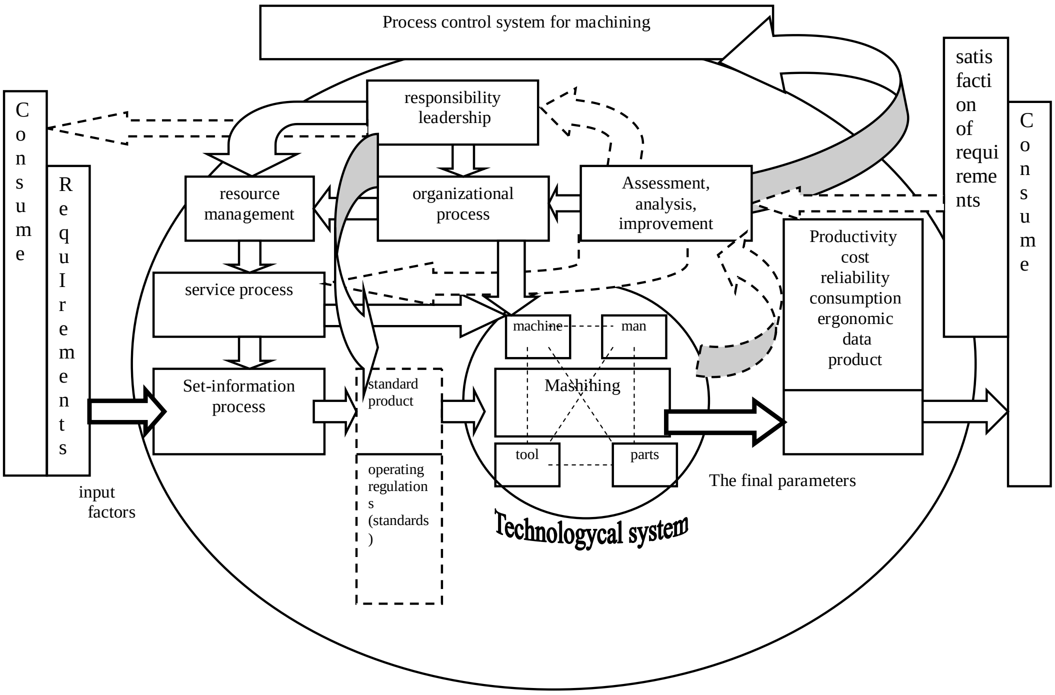

Fig.1. - Model of a process of tool exploitation control system in accordance with ISO 9000:2000

II. QUALITY MANAGEMENT SYSTEM PROCESS MACHINING

The developed system is focused on the consumer, which creates at first requirements for the quality of the process of machining and then controls the accuracy of their performance [9, 11]. Rational approach of the machining process means such a process of its use, where together with high performance and minimal cost, less consumption can be achieved with a given level of instrument reliability and psychophysical load on machine operator. In some cases, due to the industrial situation additional requirements for the treatment process may be nominated for example, ensuring a stable chip breaking, minimization of energy consumption, etc. Additional objective functions or constraints are formed in this case.

The developed machining process quality control system provides the special role for the "governance", which can be assigned on service of technical supervision. It is necessary to develop methods for the quantitative assessment of its quality for controlling quality of the process. The following is a range of issues related to qualimetrical approach to assessing the quality of the machining process.

Assessment of the quality level of the process is a relative description of its quality based on a comparison of the estimated values of the quality of the process with the base. Assessment of the quality level of machining process is performed by using the methods of applied qualimetry whose objectives are to develop specific methodologies and quality assessment of objects of different types and applications.

The basic principles of qualimetry legitimized by standards ISO 9000 currently according to which the definitions of quality indicators are given.

The quality of the machining process is the ability of set process properties to fulfill the requirements met by his production. Assessment of the quality level of machining process can be made for certain types of equipment, for the workplace, site, department, for the enterprise generally, etc.

When selecting properties that characterize the machining process, it is necessary to analyze their number, range, relationships and structure. The range of properties is set both with the general recommendations regarding the quality of products or processes and the requirements to the process of machining for specific conditions of its occurrence and objectives of quality. This also includes the following demands made by the theory of decision-making:

1) *Fullness - the use of any additional properties does not change the results.*
2) *Operationality - every property must have a comprehensible statement, a clear and unambiguous meaning, ease of use.*
3) *Decomposition - a set of properties should make possible their simplification, expansion on the parts both quality of the product in general and its complex properties into simpler ones.*
4) *Redundant - various properties should not consider the same aspect of the consequences, dropping at least one will change the results.*
5) *Minimality.*
6) *Measurability.*

Rational number of properties is calculated using information theory. Found that with increase of the number of properties over 10 the awareness about the quality of the process slowly changing. The properties that make up the quality of the machining process have a complex relationship and are a system. Relationships between the properties are so complex that their quantitative analysis is difficult. The structure of the properties is appropriate to streamline in a hierarchical tree.

To assess the quality of the machining process a block diagram of all the most important properties that characterize the process was composed. The quality of the processing, as the most generalized, complex property of the process, considered at the highest zero level of the block diagram and components of it are below.

The hierarchical structure is constructed so that each property of *J*-level review was determined by the properties of the level *J* +1. Block diagram was built down to simple properties, that is to properties which are evaluated simply enough. In the latter case the properties lying at the lowest level can be called conditionally simple.

An algorithm of complex evaluation of the quality of machining processes presented in Fig.2. Machining process has an almost infinite number of properties that characterize its quality. Machining process has an almost infinite number of properties that characterize the quality. However in practice, in calculation of the complex index of quality ($Y_E^{complex}$) the relatively limited number of properties (n)is always taken into account, significantly lower than the theoretically possible number (n_T),that is ratio $n << n_T$ is always observed.

But it is obvious that the quantity $Y_E^{complex}$ depends on the number of properties taken into account (n). Here we have to consider two trends. The first trend is to build a computational model of the quality process, which is most consistent with a real process of machining.

In this regard, there is a tendency to increase the number of properties taken into account in the model of quality. In this case,

$$K_J^I = \mathrm{f}\ \frac{P_I}{P_I^E} \qquad (1)$$

where K_I^J - assessment of a comprehensive *I*-property on *J* level of consideration.

$P_I\ u\ P_I^E$ - manufacturing indicators of quality of *I*-propertyre spectively the actual and reference. The level of quality of operation (discussed at the level *J*+1) is equal to

$$Y_E^{J+1} = \sum_{I=1}^{n} K_I^J \cdot B_I^J \qquad (2)$$

where B_I^J -the weight of *I*-property on the *J*-th level of consideration.

The other hand, there is a desire to reduce the number of properties, given that the production figures of conditionally simple properties are determined statistically or experimentally. Their collection is time consuming and expensive.

A judicious combination of both of these trends, concluded in the decision to randomize property, is used in determining the necessary and sufficient number of quality properties which are better taken into account in order to get the right comprehensive assessment of quality of process within the required accuracy.

When selecting a single indicator to assess the quality of the tool life applied three approaches:

1) *Only objective indicators were used, that is indicators based on the various accounting data, quantitative assessments, measurements, etc. Such indicators are most reliable, but sometimes require a long examination. In some cases, such as assessment of the level of progressiveness of process, they are not applicable.*
2) *Were used only subjective indicators. These methods allow on the basis of a cursory examination by the ball or expert assessment draw conclusions about the level of quality. Subjective methods are much less accurate. However they are irreplaceable in some cases when it is impossible to get an objective assessment.*
3) *The combination of objective and subjective assessments - the most reliable way to obtain a single performance. Using maximum opportunity to make an objective assessment. And only in the case of failure estimate methods were used.*

Value of the actual quality indicators P_{fact} is a constant inherent characteristic of each property, determined on the basis of surveys, observations, tests, etc. in production.

Thus, quality control was developed for the first time on the basis of integrating of parameters of rational machining process and the definition of relationships between its parameters a system of machining process. It improves machining process efficiency in heavy machines by reducing costs, improving productivity and reliability of the system, reduce the amount of the instrument and improve working conditions machine operator.

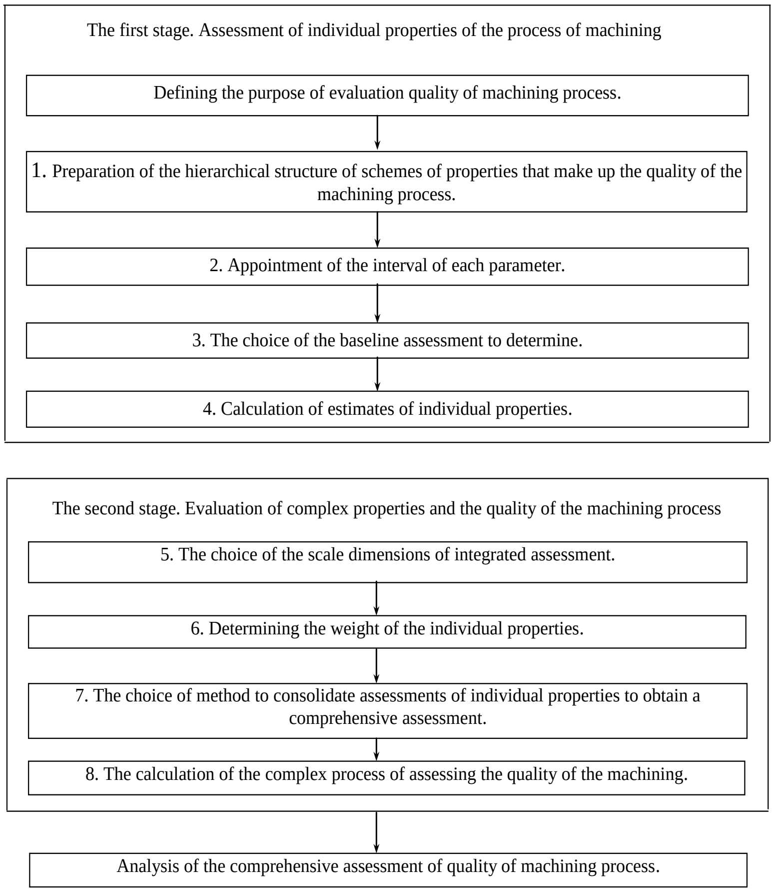

Fig. 2. - An algorithm of complex evaluation of the quality of machining processes

When assessing level of exploitation indicators, which can be divided into five groups, were used: 1) the absolute indicator, characterized by the numerical value of the measured parameter; 2) the specific relative indicators, characterized by the ratio of the numerical value of the measured parameter to any expenses; 3) the relative indicators of share of deviations in the sampling from the given operating conditions; 4) the relative indicators of the ratio of the numerical value of the measured parameter to the numerical value of the normative parameter; 5) overall indicators, characterized by the tool utilization factor. The most comprehensive indicator that would reveal the exploitation of the tool as a whole is the operation ratio of the cutting tool, which reflects the degree of tool resource utilization. Since as the basis for its determination the actual consumption of the instrument, which is the output (final) parameter of the whole process of exploitation, is laid, this indicator is a generalized index, indirectly takes into account different aspects of the process of exploitation. But the value of this parameter can not reveal the causes and the reserves of changes in the level of exploitation of the tool. Therefore, along with him, were used other special indicators characterizing certain aspects of the process of exploitation [14].

The research methodology of level of the tool exploitation is developed on the basis of qualimetry- the science of quality. In the qualimetry, along with changes in the quality of the object, there is an important problem of determining the level of quality of the different processes. The process of cutting tool exploitation can be regarded as an object in terms of its quality. Under the quantitative evaluation in the qualimetry we mean a function of the ratio of quality index of considered object to that of the quality of the object, taken as a reference (or base)., The three-level description of the properties, forming the quality of the tool exploitation is shown in the present hierarchy of properties (Fig. 3). Each of the properties of the third level can be decomposed into lower-level properties, such as the quality of workpieces is characterized by an allowance, hardness, surface defects; the state of the equipment - rigidity, accuracy and vibration resistance, etc. Justification of range of indicators and determination of weight of individual properties were made on the basis of peer review. The actual levels of properties (absolute values) were determined based on data bank, the questionnaire, moment observations, long-term statistical studies, laboratory experiments in this paper. As the base norm figures, standards and other regulatory documents were used.

Thus the level of cutting tool exploitation can be defined by pattern:

$$Y_{\ni} = {}_{i=1}^{n} K_i^m \cdot B_i^m \qquad (3)$$

where K_i^m - the current estimate of quality of *i*-th properties of *m*-th level;

B_i^m - weighting coefficient of the current complex index of *m*-th level;

i - number of properties of *m*-th level = 1 .. *n*.

Ongoing evaluation of the quality of *m*-th level is determined:

$$K_i^m = \frac{P_i^{fact}}{P_i^{base}} \quad (4)$$

where P_i^{fact} - the actual value of the quality coefficient;

P_i^{base} - the basic (reference) value of the quality coefficient.

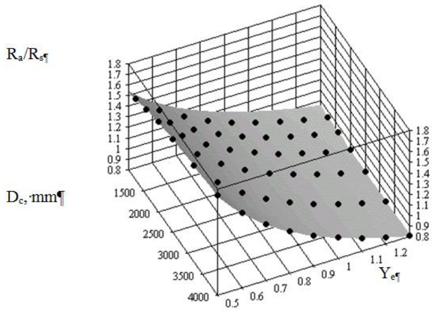

Fig. 3. The influence of quality level of the tool exploitation Q_l on change of the actual flow R_a compared with standard Rs for machine tools of different D_c sizes

Indicator of any level is defined as the sum of lower-level indicators, multiplied by its own weighting coefficients, that is, using convolution [12].

Expert evaluation of the properties that characterize the quality of exploitation has identified the most significant of them that were considered in the development of a rational system of the tool exploitation [7].

Determination of quality estimates of the tool exploitation were based on a comparison of the actual quality indicators derived from the data bank, with a baseline that matched standard values. Statistical studies have shown a fairly close correlation dependence of changing the flow rate cutting tool on the quality level of its operation (correlation coefficient 0.82). All mathematical models taken as a principle of parameter optimization of the tool exploitation, are valid only for a certain fixed levels of exploitation in which actual indicators are very close to their standard base values (Y_e= 1).

Deviation of exploitation indicators from their baseline values leads in practice to a change in the actual flow tool R_a, compared to its standard value R_s, in the accordance with the established correlation dependence:

$$R_a = R_s Y_e^{m_e} \quad (5)$$

where m_e - is the index of degree of influence of exploitation level on the cutter consumption.

Analysis of changes in Y_e on heavy machine tools of different sizes showed that with increasing D_c (maximum diameter of the workpiece over the body), the degree of influence of exploitation level on tool expense increases slightly that can be explained by the increase of parameters dispersion and the presence of a large number of organizational and ergonomic factors on the heavy machine tools of larger sizes.

The definition of tool life based on the probability of its destruction has the special importance in the development of mathematical models to determine the tools flow of heavy machine tools.

In the development of mathematical models to determine the flow of heavy machine tools on special importance has the definition of tool life based on the probability of its destruction.

To determine the normative flow technique, based on the use of the probabilistic approach to estimate the share of the actual work period of equipment associated with the cutting of materials, to the calendar period of the exploitation of heavy machine tools was developed [8]. Normative values of cutting tools flow were determined based on the total tool life. Study of the conditions for heavy lathes machining using data bank sampled in 170 plants of various industries and with more than 3,000 cases of processing of hard alloy cutters on heavy machine tools, indicate that a significant proportion of tool failures for heavy machine tools (75%) were chipping and breakage. Tool life is random in nature and subject to significant dispersion (tool life variation coefficient comes to 1.2) [2, 3].

Under these conditions, the well-known wear resistant characteristics connecting the tool life with cutting conditions elements are needed to be clarified. And, in the case of the prevailing of the insert wear the most significant factor affecting the durability period, is the cutting speed. The destruction of cemented carbide insert is mainly dependent on feed. Increasing of feed rate reduces the tool life of the tools that are replaced due to their destruction, as well as increases the proportion of destruction in the total number of failures, when using the tool. Tool life, as well as the number of periods of the durability associated with the feed rates with power laws, the exponents of which fluctuate within a wide range and characterize the degree of influence of feed on tool life and the period of its destruction.

For medium-sized machine tools were found that the feed S, corresponding to the period of durability, is: $S_k = C_k K\text{-}m_k$, where m_k = 0.3-1; often for K = 3 - 5 m_k = 0.45-0.70.

In order to establish the causes of variation of the exponent m_k the production experiment,in which not only the failure mode (wear and destruction), but its cause (the sample size is 42) were examined, was held. Thus, it was possible to separate failures, depending on the feed, and the "purely random failures" into which the failures of tools with manufacturing defects, breakage of tools inaccidental installing much more feed than recommended, randomly stopping of the machine tool, the erroneous turning on of fast support moving and etc. were referred.

With increasing of purely random failures proportion qc influence of feed on overall probability of failures due to destruction of the instrument and there through - on number of periods of cutting tools resistance *K* reduced, which leads to an increase of m_k: $m_k = m_{k0} + aq_c$ where m_k- indicator of relative resistance periods number for all kinds of tool failure, m_{k0} -indicator of relative resistance periods number for cutters with failures, depending on the feed; $a = (m_k - m_{k0}) / q_c$ - the factor that shows the intensity of "purely accidental" failures influence on m_k.

As shown by statistical observations, the impact of "purely random" failures on the probability of failure decreases with increase of machine tool standard size D_c (maximum diameter of the workpiece above the body) when working with heavy machine tools. This is explained by the fact that with increasing the size machine tool, usually grows qualification of workers, and their responsibility for the correctness of the different machine tool mechanisms switching due to the high cost of parts, tools and machines. This is also testified by the fact that the actual period of stability with increasing Dc significantly higher (up to 100 min) than its economic value. Researches of actual cutting conditions, used in heavy lathes, show that probability of machine tool stopping due to its overloading is practically equal to zero for machine tools with $D_c \geq 1250$ mm [10]. Therefore, probability of "purely random" failures is reduced to a value equal to 0.1-0.15 with increasing of D_c. And, most of its value occurs when roughing.

Within the group of heavy machine tools the value of m_k is determined:

$m_k = m_{k0} - bD_s$,

where *b* - coefficient reflecting the degree of influence of D_s on m_k (the sample size is 74).

Using the relation of feed with a number of stability periods, and therefore with a probability of tool destruction for heavy machine tools, the probability of fracture of the insert is determined by:

$$q_p = c_q \left(\frac{S \sigma_b^n t^x}{D_c^z} \right)^{\frac{1}{m_{k0} - bD_c}} \quad (6)$$

where C_q- constant depending on the processing conditions;

σ_b - the ultimate strength of the material; *t*-cutting depth.

The obtained expression is used to determine a correction factor for tool life which takes into account the probability of destruction of cutting tool, working on a heavy lathe.

Accounting of dissipation of stability period when working on heavy lathes is made by introducing a correction factor, which takes into account level of reliability of the instrument. Experimental tests of allocation of tool life of 3 batches of cutters (211 pieces) with the cross-section of 75x75 in the conditions of “Novokramatorsky Machine building Plant” showed that for a set of cutters failed due to wearing out, the coefficient of variation V_T is equal to 0.55-0.75, and for cutters failed by the destruction V_T = 0.76-1.15.

A linear relationship between the coefficients of variation and feed: $V_T = \mu + 0.8\ S$, where μ - constant depending on the manufacturing conditions usage of which allowed to develop a mathematical model of the middle stability period adjustments depending on the level of reliability of the instrument (Figure 4).

Thus, the cutting tool life for heavy machine tools, determined in accordance with generally known wear resistant characteristics (such as Taylor) is corrected by the correction factors that take into account the probability of failure and the required level of reliability of the instrument. The suggested approach was used in determining the standard tool flow in the processing of heavy machines.

To determine the control parameters in accordance with the established methodology of assessing the quality of the tool exploitation system of decision-making was developed. This system involves the use of data bank precedents and indicators of the tool exploitation level (feedback) for multi-criteria evaluation of the exploitation process quality, along with cutting standards

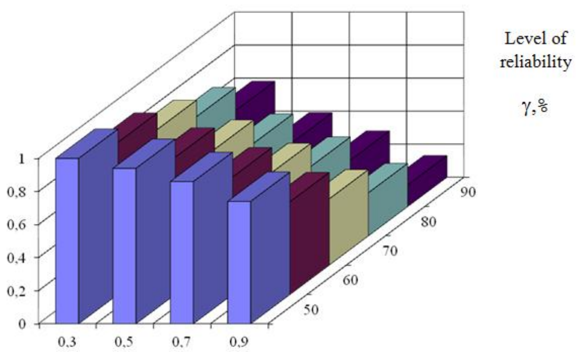

Fig. 4. Correction factors for the period of stability

III. CONCLUSION

1) *A model of the process control system for tool operating on heavy machine tools based on the implementation of the «process approach» ISO 9000: 2000, which includes a set of processes: organizational, management of resources, maintenance of technological systems, set-informational and providing feedback to user (assessment, analysis, improvement) is developed.*
2) *The technique of theoretical researches of process quality level for tool operating is built on qualimetric approach and involves the development of a hierarchical system of properties, constituting the quality of the process of exploitation, on the basis of which the method of quantitative evaluation of the quality of the process, which is an additive convolution of multilevel evaluations, is designed.*
3) *For the first time the necessity of determining the reliability of heavy duty modular tools as system, not only in terms of its reliability, but also from the perspective of accounting complex indicators of reliability, is shown, for what, using the theory of Markov processes, mathematical model of the willingness function of cutting tool, which allows you to manage the stability of the tool, is developed, that particularly important when processing parts on heavy machine tools.*
4) *As a result of theoretical and experimental investigations of the cutting tool exploitation on heavy machine tools the scientific basis and a new solution of scientific and technical problem of increasing the efficiency of use of the cutting tool through the development of a quality management system of its exploitation, definition of rational regulations of this process and the establishment of general machine-building standards of cutting were created.*

REFERENCES

[1] Conde Hernad, J.M. and Gaya, C.G.: Methodology for implementing document management systems to support ISO 9001:2008 quality management systems. Procedia Engineering, Vol. 63 (2013), pp. 29-35. ISSN 1877-7058.
[2] Dašić, P.: Approximation of cutting tool wear function using polynomial regression equation. Journal of Research and Development in Mechanical Industry (JRaDMI), Vol. 3, Issue 3 (September 2011), pp. 171-180. ISSN 1821-3103.
[3] Dašić, P.: Comparative analysis of different regression models of the surface roughness in finishing turning of hardened steel with mixed ceramic cutting tools. Journal of Research and Development in Mechanical Industry (JRaDMI), Vol. 5, Issue 2 (June 2013), pp. 101-180. ISSN 1821-3103.
[4] Dašić, P.: Razvoj međunarodnih i nacionalnih standarda za sistem kvaliteta ISO 9000. Kvalitet, Vol. 15, br. 9-10 (2005), str. 89-95. ISSN 0354-2408.
[5] Dašić, P. and Stanojević, M.: Survey of international standards for quality management systems (QMS). Modelling and Optimization in the Machines Building Fields (MOCM), Vol. 16, No. 1 (March 2010), pp. 12-22. ISSN 1224-7480.
[6] ISO 9000:2000: Quality management systems. Geneva (Switzerland): International Organization for Standardizations (ISO), 2000. – 30 pp.
[7] Kovalev, V.; Klimenko, G.; Ostankova, L. and Vasilchenko, Y.: Evaluation of a level of quality of machining process. In: Proceedings of the 7th International Conference ICQM, 2012, pp. 51-61.
[8] Kovalev, V. and Vasilchenko, Y.: Optimization of cutting parameters considering the actual process state in real time environment in heavy engineering. In: Proceedings of the 12th International Conference RaDMI-2012, Sokobanja, Serbia, 13-17 September 2012, pp. 216-220.
[9] Kovalev, V. and Vasilchenko, Y.: Statistical researches of work of the enterprises of heavy mechanical engineering for a sub-station of technical characteristics of new machine tools/ 11th International Conference RaDMI 2011 from 15-18 September 2011, Sokobanja (Serbia). 2011. – p.359-364.
[10] Kovalev, V.D.; Vasilchenko, Y.V. and Dašić, P.: Adaptive optimal control of a heavy lathe operation. Journal of Mechanics Engineering and Automation (JMEA), Vol. 4, Issue 4 (April 2014), pp. 269-275. ISSN 2159-5275.
[11] Kovalev, V.; Vasilchenko, Y. and Makarkina, A.: Prospects of adaptive control of technological system on the base of heavy machine-tools. Mechanika. Z.77. Zeszyty naukowe Politechniki Rzeszowskiej.- Rzeszow, 2009, pp. 35-44.
[12] Kovalev, V.; Vasilchenko, Y. and Savelova, Y.: Procena kvaliteta proizvodnje. Kvalitet, Vol. 23, br. 7-8 (2013). 86-91. ISSN 0354-2408.
[13] McTeer, M.M. and Dale, B.G.: Are the ISO 9000 series of quality management system standards of value to small companies? European Journal of Purchasing & Supply Management, Vol. 1, Issue 4 (December 1994), pp. 227-235. ISSN 0969-7012.
[14] Mereuta, V.; Dašić, P.; Ciortan, S. and Palaghian, L.: Assessment of the influence of surface processing on fatigue damage using artificial neural networks. Journal of Research and Development in Mechanical Industry (JRaDMI), Vol. 4, Issue 1 (March 2012), pp. 11-20. ISSN 1821-3103.
[15] Rezaei, A.R.; Çelik, T. and Baalousha, Y.: Performance measurement in a quality management system. Scientia Iranica, Vol. 18, Issue 3 (June 2011), pp. 742-752. ISSN 1026-3098.
[16] Sroufe, R. and Curkovic, S.: An examination of ISO 9000:2000 and supply chain quality assurance. Journal of Operations Management, Vol. 26, Issue 4 (July 2008), pp. 503-520. ISSN 0272-6963.
[17] Thomas Ng, S.: Performance of engineering consultants in ISO 9000-based quality management systems implementation. Engineering, Construction and Architectural Management, Vol. 12, Issue 6 (2005), pp. 519-532. ISSN 0969-9988.
[18] Yeung, A.C.L.: Strategic supply management, quality initiatives and organizational performance. Journal of Operations Management, Vol. 26, Issue 4 (July 2008), pp. 490-502. ISSN 0272-6963.
[19] Yeung, C.L. and Chan, L.Y.: Quality management system development: Some implications from case studies. Computers & Industrial Engineering, Vol. 35, Issue 1-2 (October 1998), pp. 221-224. ISSN 0360-8352.
[20] Zaretzky, A.N.: Quality management systems from the perspective of organization of complex systems. Mathematical and Computer Modelling, Vol. 48, Issue 7-8 (October 2008), pp. 1170-1177. ISSN 0895-7177.