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PROBABILISTIC ESTIMATION OF THE RELIABILITY OF THE PLAN OF MECHANICAL SURFACE PROCESSING

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Abstract

Consideration routing technology of machining, as a sequence of independent stochastic processes of the formation of the necessary parameters of the quality and accuracy of products allows to forecast the probability of a given quality at the stage of technological preparation of production. The value of probability can be used as a quantitative estimation of reliability of technological project in terms of persistence properties of a technical system.

Keywords: technological design, consistency of machining, reliability, quality, statistical criterion, variations factor.

Introduction

The term "reliability" with respect to any technical systems suggests: "property of the object to save time within the established values of all the parameters, characterizing the ability to perform required functions ...". Technological reliability, considered as a special case of the general notions, has a meaning "... property technological equipment ..., ensuring the save for a given level of output parameters of quality of the produced products ...". As a rule, the issues of estimation of reliability and failure safety of technological processes are considered from the point of view of capacity of technological systems, processes and operations to ensure production of the products quality indicators which correspond to the pre-installed by the requirements. Thus, the concept of reliability is used as an indicator of stability and sustainability [3] the technological process.

As a possible assessment of the reliability can serve [3] the relative frequency of failures or conditional density of the failure probability of the technological system. The most likely causes of failures and, therefore, the loss of stability properties of a product, usually called an increased wear and violation of thermal conditions processing due to changes in the modes of cutting or failure of equipment. This characteristic reliability holds true for the commercial use of the technology. Before the start of commercial operation at a stage of technological designing, assess the reliability of the process, you can largest probability of the expected outcome of a process running under certain conditions, i.e., the probability of obtaining the required quality of the elements being processed products.

With regard to mechanical treatment, it can be argued:

– for elementary surface treatment, performed on a single technological transition, as conditions should considered the combined, first of all modes of treatment and physical and mechanical properties of the tool and the workpiece materials;

– in case of correct realization of technology, i.e., subject to the conditions of the implementation process, should expect to receive the results of processing, and the appropriate technological tolerances; summaries of which are given, for example, in tables accuracy;

– a variation of the conditions of processing at a single technological transition in the acceptable range is displayed in tables accuracy in the non-zero intervals values for each of the indicators of quality products. It is obvious that the limit values of indices-border technological tolerances are relevant to the highest attainable quality can be achieved with the least intensive treatment conditions. Toughening of conditions of processing in accordance with the limits for a specific processing method, results, as a rule, to reduce the performance of the quality and accura-

cy. Suppose that the values of indicators of the quality and accuracy of processing, corresponding to the lower limit values intervals tables accuracy are achieved with the probability equal to 100 %. Then the results are based on the upper limits of intervals is possible with a probability of less than 100 %, and this probability is smaller, the more pronounced the stochastic process of the process;

– when considering a multistage treatment it is necessary to take into account the reliability of each technological transfer.

Consider a single technological transition in terms of assessing the reliability of the projected results of processing. Based on the above arguments, we believe that the process can be considered secure in that case when the accuracy of the resulting value is estimated to be significantly lower than the actual result. The scattering field values of the random variable unstable [1, 2] process substantially [5, 6] – more than 5.5 times – exceeds the range of possible values of this indicator reliable process.

Comparing the laws of distribution, discussed [5, 6] when technological calculations, can make a conclusion about-to-one correspondence of values of the technological tolerance and the coefficient of variation with cumulative probability (1), which determines the possibility of obtaining the maximum possible, for the technological transition, the quality of processing. The value of Φ(V) is defined as the minimum possible for any point within the interval defined by the boundaries of technological tolerance. Such value of the integral of the probability of (1), calculated depending on the coefficient of variation, corresponds to the most pessimistic forecast of results of processing.

$$\Phi(V)=\begin{cases}\dfrac{1}{\sqrt{2\cdot\pi}}\cdot\displaystyle\int_{-\infty}^{1/V}V^{-2}\cdot e^{-0{,}5\cdot V^{-2}}dV, & V<0{,}564\\ 0{,}5+\dfrac{1}{V\cdot\sqrt{6}}+\dfrac{1}{12\cdot V^{2}}, & 0{,}564\le V<0{,}697\\ 0{,}5+\dfrac{1}{2\cdot V\cdot\sqrt{3}}, & V\ge 0{,}697\end{cases} \quad (1)$$

We consider as the characteristic of a random variable, namely the coefficient of variation, because its value is determined by the value of the mean and the width of the technological tolerance and not dependent [1] from the law of distribution.

Analysis of data on the reliability of the processing methods, presented in our papers [1, 2 and others] and mapping with the laws of distribution allows making the following conclusions:

– machining process can be considered as absolutely reliable – with a probability of more than 99.9(9) %, – if the value of the coefficient of variation of the method is $V < 0{,}17$;

– the process can be considered reliable enough – is not likely to below 99,86 %, – if the value of the coefficient of variation of this method of processing is within $V \in [0{,}17; 0{,}33]$;

– value of the coefficient of variation $V > 0{,}33$ determines the low process reliability is the probability of getting the expected result is less than traditionally (in accordance with the «rule of six standard deviations») valid values 99,73 % for bilateral confidence probability.

Thus, the value of the integral probability (1) of the expected completion can be considered as an evaluation of stability (reliability) of a stochastic process, and a stability criterion for the coefficient of variation is the numerical estimates of reliability.

The sequence of process steps, implemented for each surface details in accordance with the routing technology must ensure that the specified parameters of the quality and accuracy of processing products.

Reliability and, more specifically, persistence [3, 4], the technical system, which we consider a plan of processing of a single surface of the product can be determined from the condition of compliance with technical requirements of the values of indicators of quality and accuracy obtained in the result of processing, as the probability of attaining, as a result of the technological process, the required accuracy's parameters.

Depending on the number of assessed the accuracy of the indicators, a treatment plan can be considered as a serial (Fig. 1, a), or of a mixed (Fig. 1, b) structure.

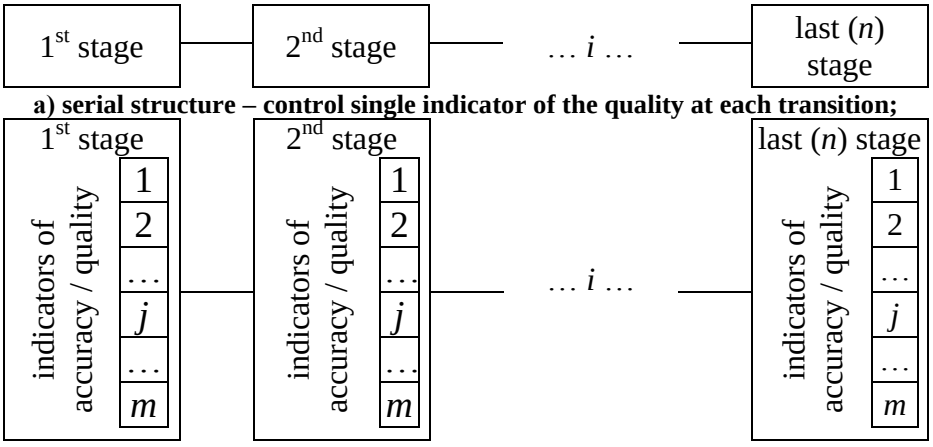

Figure 1. Structural scheme for calculation of reliability of a processing plan

Consistent (Fig. 1, a) the structure of the production plan acceptable to consider, if controlled by only single indicator of quality, which is the result of execution of the functions of the corresponding element of the technological system. Each result is formed under the influence unique to the respective transition conditions, so all results are mutually independent. Reliable operation of the technical system, consisting only of cells connected in series possible, while ensuring reliability of each individual element. As an element we consider the technological transition, the reliability that we rely on as a cumulative probability of (1) hit the index values of the boundaries of technological tolerance. Probability consistent technical system [6], i.e., reliability plan of processing (P_Σ) is determined in the following way:

$$P_\Sigma = \prod_{i=1}^{n} \Phi(V_i), \qquad (2)$$

where n – total number of stages of processing route;

V_i – coefficient of variation of single indicator of the quality at the i-stage.

In the real practice of technological design is controlled by at least two groups of indicators of the quality of the machining - accuracy specifications size (for example, errors of processing or workmanship) and quality (settings micro-surface profile, the depth of the defect layer, etc) the treated surface. In this case, the serial structure of a technical system does not reflect the peculiarities of the formation of the reliability of the technological route. For complex structures is recommended [6] make the decomposition scheme for the purpose of segregating several series-connected blocks (Fig. 1, b). We regard the separated technological transitions as insulated blocks, each of which is provided by several (more than one) of the indices of quality of processing. Each block can be regarded as an independent subsystem with parallel structure. Thus, the whole system consisting of individual blocks, has a serial structure. To determine the reliability of the whole serial (2) technical system it is necessary to define the indicators of reliability for each block.

Each of the indices of quality of processing is a random value, which is characterized by its own set of parameters. The correct estimation of the reliability of the process of being evaluated several random variables is possible, only if we confirmed the mutual dependence or independence of quantities and corresponding random processes. Mutual dependence of events, namely the formation of the values of precision parameters of the product is determined by physical and chemical, temperature, deformation and other peculiarities of the processes of machining.

The majority of studies conducted in the field of the theory of cutting metals, confirms the assumption that different physical nature of the indicators of the quality of the machined surface and geometrical precision dimensions. Therefore, random variables corresponding to such indicators of quality should be seen as mutually independent. Total reliability of several, joint mutually independent processes is determined by the size of probability of the expected completion of these processes [5, 6].

$$P_{\Sigma i} = \prod_{j=1}^{m} \Phi\left(V_{ij}\right), \quad (3)$$

где m – the total number of indices of the quality, which at the i-stage;
V_{ij} – coefficient of variation of each (j) indicator of the quality at the i-th stage.

While overseeing several indicators of the quality of a specific classification group, we are dealing with random variables depending on the conditions of one of the physical process. The fact of measurement values to each of the random variables a random event. The events are joint, because it is possible to measure any of the values. Events are independent, because the fact of any measurement of quantities not means an obligatory control to another value and the numerical value of a random variable does not affect the values of the other random variables.

Total reliability of the i-th element in the present case, is defined as the probability of occurrence of several independent events, in accordance with the (3). Taking into account the (2), reliability of elementary technological route, which includes more than one transition, subject to the control of an arbitrary number of parameters of accuracy or quality of treatment will be determined as follows:

$$P_{\Sigma} = \prod_{i=1}^{n} \prod_{j=1}^{m} \Phi\left(V_{ij}\right). \quad (4)$$

Thus, reliability of the elementary technological route is estimated forecasted (4) the probability of receiving the product of a given quality, calculated depending on the value of changes in the coefficient of variation of the normalized indicators of quality in a multistage treatment.

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