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PREDICTING THE OPERABILITY OF THE TECHNOLOGICAL SYSTEM DURING PARTS MACHINING

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Abstract *The prediction of product behaviour during important phases of its life cycle is an urgent task of current mechanical engineering. A methodology for analysis of the influence of elements of the metal-working technological system on assurance of the regulated quality parameters of the product using Markov chains is developed. The impact of a metal-cutting machine, a clamping device, and a metal-cutting tool on ensuring the regulated quality parameters of the processed product is determined.*

Keywords*:* Reliability Engineering, Technological System, Technological Medium

The product life cycle which includes the development and production of the product and its future operation has an important role in scientific research in the mechanical engineering field. Product quality is formed not only by the design and technological preparation of production, different technological processes, and services, but also by the true sustainable capability of a company, ensuring economic, social, and environmental parts. So, support of sustainable manufacturing requires new paradigms including Digital Lean, Quality 4.0, and Zero-Defect Manufacturing in Quality Management [1].

Predicting the risks of machine failures at different phases and stages in their life cycles, taking into account environmental protection, economic criteria, and social aspects, are important tasks for sustainable machining of parts and sustainable manufacturing of products [2].

Reliability engineering is one of the fundamentals for the development of the Zero-Defect Manufacturing concept including physics, statistics, and engineering. The development of new approaches and methods of reliability engineering in the technological process planning for product manufacture, in particular, using Markov chains, is one of the priority areas for the development of modern manufacturing engineering [1].

Markov chains are mathematical models that use concepts from probability to describe how a system changes from one state to another [1]. This approach is difficult to realize in manufacturing engineering because typical elements of mechanical systems (shafts, gears, bearings, etc.) work in different machines with different operating loads. So, we need to find an approach (idea, technique, etc.) for calculating the failure rates of the elements of the technological systems for introducing the Markov chains technique for machining parts, assembly of machines, etc. [3].

The technological system, technological medium, and technological graph of the reliability for the i-th technological operation are presented in Fig. 1.

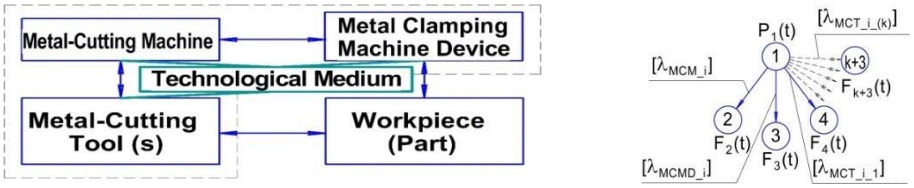
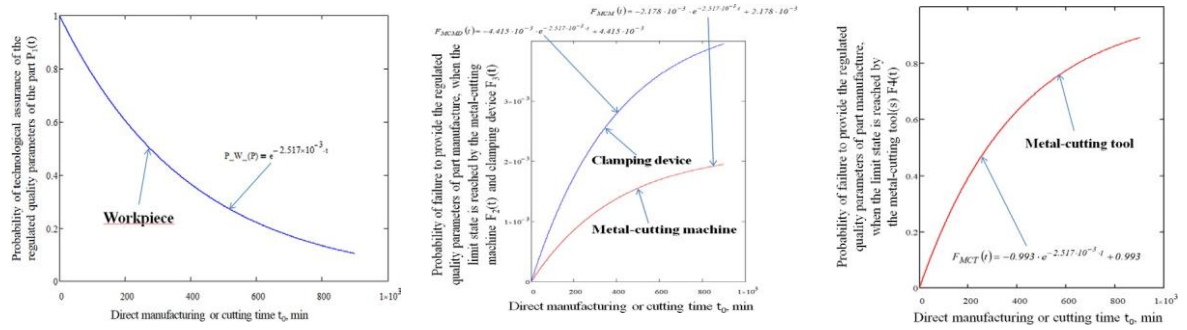


Fig. 1. Technological system /technological media a) and technological graph of the reliability for the i-th technological operation that is described by Markov chains to predict the probability of providing regulated quality parameters of the workpieces, taking into account the influence of the technological system elements b)

The probability of technological assurance of the regulated workpiece quality in the 005 technological operation (Vertical milling) of the technological process at machining of the base OSHPV 25.001 in case of failure to reach the limit state of the metal-cutting machine, fixture or clamping device located on the metal-cutting machine and metal-cutting tool (or tools) in general and their elements, in particular, $P_1(t)$; probabilities of failure to assure regulated quality parameters in the 005 technological operation (Vertical milling) of the technological process at machining of the base OSHPV 25.001 when the limit state is reached by the metal-cutting machine and metal-cutting tool (or tools) in general and their elements in particular, $F_2(t)$, $F_3(t)$, $F_4(t)$, respectively, are described by the

system of Chapman-Kolmogorov differential equations for the technological graph of reliability (see Fig. 1, b). Its solution allows us to find the relationship between the reliability metrics (Y axes) and direct manufacturing (cutting) time (see Fig. 2).



a) b) c)

Fig. 2. The probability of assurance the regulated parameters of the workpiece of the base OSHPV 25.001 at its machining at operation 005 if the limit states of the elements of the process media are not reached a); probabilities of failure to ensure the regulated quality parameters of the reduction-gear base at its machining at operation 005 when the limit state is reached: b) for metal-cutting machine and clamping device, c) for metal-cutting tool

The mathematical apparatus of Markov chains is proposed to be used at the stage of design and technological preparation of production for the analysis of the processes of parts machining. Further research in this direction will include the analysis of the reliability metrics with different operating times of the elements of certain technological mediums: metal-cutting machines, clamping devices (fixtures), and metal-cutting tools; realization of the experimental studies to check the theoretical and modelling results; comparison with the results using Bayesian networks, Monte Carlo simulations, AI-driven predictive maintenance, etc.; and adaptation the obtained mathematical dependencies to the operation stage of products life cycles.

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ПРОГНОЗУВАННЯ ПРАЦЕЗДАТНОСТІ ТЕХНОЛОГІЧНОЇ СИСТЕМИ ПІД ЧАС МЕХОБРОБКИ ДЕТАЛЕЙ

Анотація *Прогнозування поведінки виробу на важливих етапах його життєвого циклу є актуальним завданням сучасного машинобудування. Розроблено методику аналізу впливу елементів технологічної системи механічної обробки на забезпечення регламентованих параметрів якості продукції за допомогою ланцюгів Маркова. Визначено вплив металорізального верстата, верстатного пристрою, металорізального інструменту на забезпечення регламентованих параметрів якості оброблюваного виробу.*

Ключові слова*:* інженерія надійності, технологічна система, технологічне середовище

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