Lecture Notes in Mechanical Engineering

Vitalii Ivanov · Yiming Rong
Justyna Trojanowska · Joachim Venus
Oleksandr Liaposhchenko
Jozef Zajac · Ivan Pavlenko · Milan Edl
Dragan Perakovic *Editors*

Advances in Design, Simulation and Manufacturing

Proceedings of the International Conference on Design, Simulation, Manufacturing: The Innovation Exchange, DSMIE-2018, June 12–15, 2018, Sumy, Ukraine

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Lecture Notes in Mechanical Engineering

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Preface

This volume of Lecture Notes in Mechanical Engineering contains accepted papers presented at the International Conference on Design, Simulation, Manufacturing: The Innovation Exchange (DSMIE-2018), held in Sumy, Ukraine in June 12–15, 2018. The conference was organized by the Faculty of Technical Systems and Energy Efficient Technologies, Sumy State University, in partnership with Technical University of Kosice (Slovak Republic), Kielce University of Technology (Poland), University of West Bohemia (Czech Republic), Association for Promoting Innovative Technologies—Innovative FET (Croatia). The DSMIE-2018 was organized under the patronage of Prof. Anatoliy Vasylyev, Rector of Sumy State University and Dr. Oleksandr Gusak, Dean of the Faculty of Technical Systems and Energy Efficient Technologies.

DSMIE-2018 is the international forum for fundamental and applied research and industrial applications in manufacturing. The conference focuses on a broad range of research challenges in the fields of Manufacturing, Mechanical and Chemical Engineering, addressing current and future trends in design approaches, simulation techniques, computer-aided systems, software development, ICT tools and Industry 4.0 strategy implementation for solving engineering tasks. DSMIE-2018 brings together researchers from academic institutions, leading industrial companies, and government laboratories located around the world for promoting and popularization of the scientific fundamentals of manufacturing.

The book was organized into three parts, according to the main conference topics. Each part is devoted to research in design, simulation and manufacturing in the areas of Manufacturing and Materials Engineering, Mechanical Engineering and Chemical Engineering.

DSMIE-2018 received 91 contributions from 14 countries around the world. After a thorough peer-review process, the DSMIE-2018 Editorial Board accepted 55 papers, written by authors from 11 countries. Thank you very much to all authors for their contribution. These papers are published in present book, achieving an acceptance rate of about 60%. Extended versions of selected best papers will be published in journals: Management and Production Engineering

Review (indexed by ISI/ESCI, Scopus), Archives of Mechanical Technology and Materials (Poland) and Journal of Engineering Sciences (Ukraine).

We would like to take this opportunity to thank members of Program Committee and invited external reviewers for their efforts and expertise in contribution to reviewing, without which it would be impossible to maintain the high standards of peer-reviewed papers. Fifty-three Program Committee members and 14 invited external reviewers devoted their time and energy for peer-reviewing manuscripts. Our reviewers come from all over the world and represent 17 countries and affiliated with 41 institutions.

Thank you very much to all keynote speakers, who came from Poland, Slovak Republic, Czech Republic and Ukraine, and share their knowledge and experience.

We appreciate the partnership with Springer, Unicheck and EasyChair and our sponsors for their essential support during the preparation of DSMIE-2018.

Thank you very much to DSMIE-2018 Team. Their involvement and hard work were crucial to the success of the DSMIE-2018 conference.

DSMIE-2018's motto is "Together we can do more for science, technology, engineering and education."

June 2018

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Manufacturing and Materials Engineering

Implementation of CALS-Technologies in Quality Management of Product Life Cycle Processes

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Abstract. The aspects of the usage of CALS-technologies in support of the life cycle of products are considered in this research. The identification of problems and the main ways of creating a unified information space in the quality management system are focused on, due to the principles of ISO standards series 9000. Based on the analysis, a unified methodological approach to the construction of quality management systems for the application of CALS-technologies is introduced. As an example, a conceptual model of the information system for lifecycle management of instrumental production based on the process approach was suggested. The algorithm of construction and implementation of the introduced model with the consideration on the features of this system is developed. It is shown that observance of the recommendations set forth in the research work will allow to improve the quality of technological equipment as well as to facilitate the optimization of its processes, then it will lead to an increase in labor productivity, reducing resource dependence and costs.

Keywords: CALS-technologies · Implementation · Effectiveness · Life cycle

1 Introduction

At present stage of science and technology development, effective management of the products quality of the manufacturing plant (MP) in accordance with the requirements of the international standards of ISO 9000 series involves reducing uncertainty at all stages of the life cycle (LC) products primarily due to automation of measurements and evaluation of changing parameters of external and internal environment.

With the development of information technology (IT), models of quality management system (QMS), implemented with the help of various computer and software network complexes, automated design tools (CAD), information-analytical (IAS) and information management systems, automatic control systems (ACS), etc. [1, 2] are applied. It is IT, along with advanced production technologies, that can significantly increase productivity and product quality, and at the same time minimize costs during LC products and significantly reduce the timing of production of new products that meet the needs and expectations of consumers.

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2 Literature Review

From the experience and practice of many foreign companies, it can be concluded [2, 3], that the industrial management system is currently characterized by the use of various information technologies, based on modules that meet the standards of CALS-technologies.

At present Enterprise Resource Planning (ERP) modules and other CALS-based tools (PDM, CRSP, SRM, OLAP, DM, etc.) can be used effectively to manage material resources at the overwhelming majority of enterprises [4–6]. During the research, it was found out that today IT is used mainly to solve, as a rule, the individual tasks of the corresponding phase of the LC: design, development of technologies, preparation, and management of production, etc. However, the analysis of the toolkit of these systems in relation to each stage of the products LC shows that the modules of these systems partially perform the same functions [7].

The main problem here is the underestimation of the difficulties that arise in the process of shifting from the use of IT at individual stages of LC to work in a single information space (SIS), which would cover all the stages of LC products at the same time, including its after-sales support as well as utilization.

Analysis of the information sources showed that at present stage of development, Ukraine strives not to lag behind Western powers in the sphere of automation of all stages of LC. At present, a number of well-known authors [4, 8] of the mentioned issues in the field of introduction of CALS-technologies and their application in the process of development of products are the subject of the study of issues arising on the way of introduction of CALS-technologies and their use at domestic enterprises. At the same time, it has been established that theoretical developments and implementation methods being generalized in nature, are not detailed and cannot be applied in the practical implementation of SIS project.

Thus, an actual task, which is important for the domestic industry in the conditions of constant growth of competition in the world market of high-tech products, is the development of models and methods of formation of the SIS to support the development of product's LC. The use of CALS-technologies in the QMS will provide comprehensive information support for the adoption of sound management decisions on product quality based on the operational collection, processing, and analysis of the information in a single information environment of the enterprise.

3 Research Methodology

3.1 The Development of a Unified Methodological Approach to Building Quality Management Systems Based on the Use of CALS-Technologies

In the course of the research, the main directions in the implementation of information support of QMS based on CALS-technologies were determined. The main ones are [1]:

- definition of the general approach to automated support for QMS on the principles of CALS-technologies.

- modeling and description of the structure of information flows of the QMS, which are subject to management in the UIS of the enterprise.
- creation of a UIS and software for continuous analysis of information about the quality of products and processes of QMS.
- adapted application of technologies of business process re-engineering to the issues of analysis and reorganization of the QMS processes and product quality management within the framework of a modern approach to the implementation of integrated IT and control systems.
- creation of modern information infrastructure, which provides effective management of information resources of the QMS.

The basis of the development of a unified methodological approach to building of an IMS based on the application of CALS-technologies is grounded on the basic principles of quality management, based on the process approach (Fig. 1) [9].

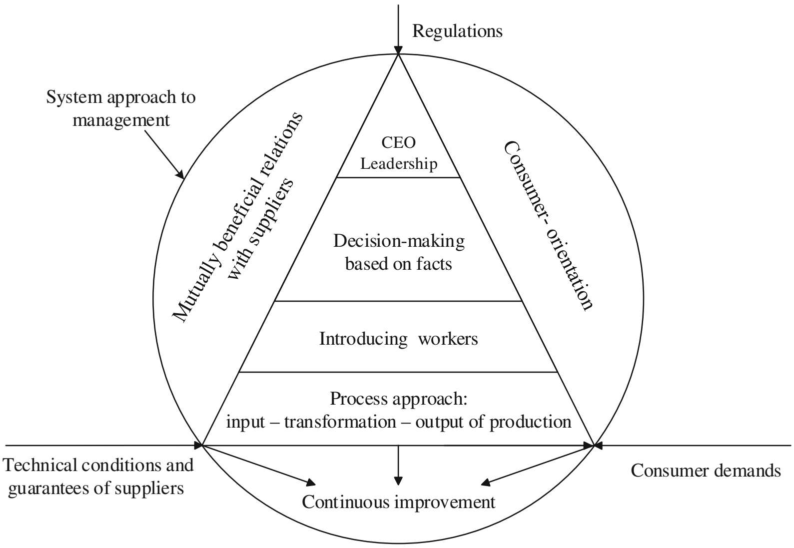

Fig. 1. Principles of quality management.

Realization of the implementation of CALS-technologies scheme consists of several basic stages (Fig. 2):

- organization and preparation;
- analysis and re-engineering of the processes of QMS and processes of the LC products;
- analysis and definition of approaches to the creation of a SIS at an enterprise;
- creation of a SIS in the industry, implementation of software applications for informational support of the processes of production of goods, regulation of the order of interaction of participants of the information exchange of data on the quality of products and processes.

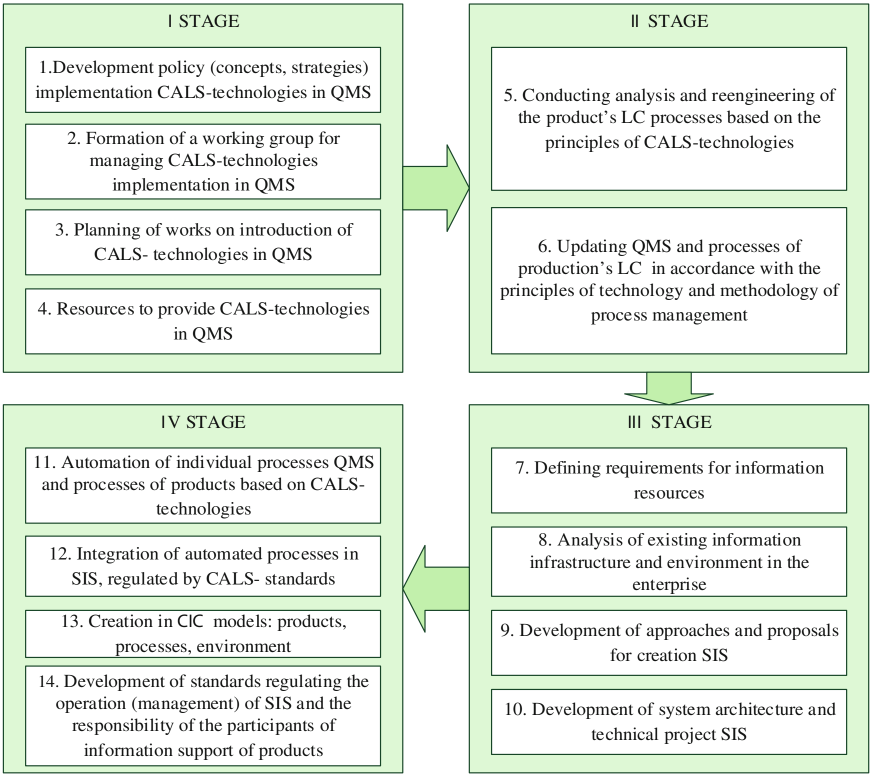

Fig. 2. Check stage-by-stage introduction of CALS-technologies for the support of LC products and QMS.

The process of production of machine-building products is complex and it is impossible to determine the exact cause of the occurrence of the lack of a real situation. Therefore, it is necessary to improve the QMS and implement statistical methods that make it possible to trace an entire technological process of production and to keep the most responsible stages under constant control.

Due to the application and automation of the use of statistical methods, ultimately, it is possible to improve the effectiveness of quality management at all stages of the production process and make objective managerial decisions regarding the conditions and results of processes and quality of products.

3.2 Introduction of Information Systems on the Example of Production Planning of Tools at the Machine-Building Enterprises

It was established [7], that due to the system of tool preparation for the production of machine-building industry, the modules of CALS-technologies practically do not take into account the specifications and features of the LC of technological equipment and tools. Therefore, the model of a process-oriented production planning of tools (PPT) management system in terms of information technology can be represented as three interrelated models: organizational model of the PPT, information model of the PPT system and PPT quality management system (Fig. 3).

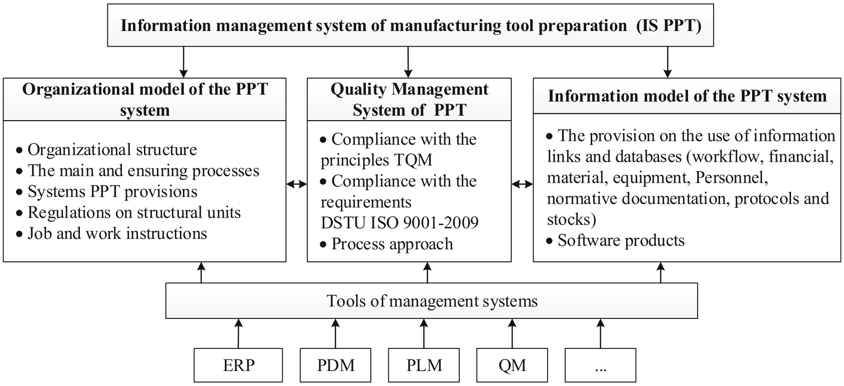

Fig. 3. Conceptual model of PPT control system under the conditions of information technologies.

Analysis of Fig. 3 shows the availability of a large number of different tools that can be applied in implementing the proposed conceptual model of the PPT management system. Implementation of this model is conditioned by the presence of problems connected, on the one hand, with the development and implementation of PPT quality management systems, on the other hand the implementation of software products and information tools.

The main problem here is the underestimation of the difficulties that arise in the process of shifting from the use of IT at individual stages of the LC to work in a unified information space (SIS), which would cover all the stages of the LC products at the same time, including its after-sales support and recycling. Therefore, in order to minimize the risks associated with the implementation of this model, an algorithm for its development and implementation is proposed (Fig. 4), taking into account those principles discussed in Sect. 2.

According to Fig. 4 the implementation of IS PPT consists of the following steps.

1. Decision-making by the management regarding the implementation of the IS PPT.

At this stage, the management should identify a team of specialists and the project implementation manager, identifying and documenting their functions and responsibilities, and ensuring the competence of the staff members of the team.

2. Formation of the requirements for IS PPT.

A team of experts generates a list of requirements that should correspond to the IS PPT. Based on the list of requirements for the IS PPT and the feasibility study on its implementation, it develops a draft of technical specification and submits it for the approval to the head of the enterprise.

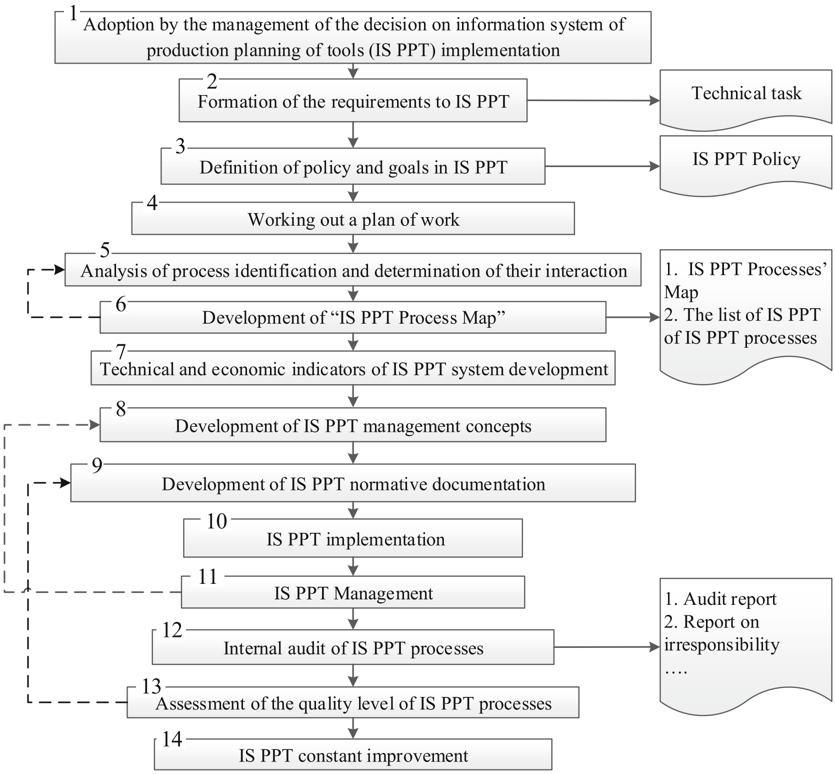

Fig. 4. Algorithm for the implementation of IS PPT.

3. Definition of the policy and goals in IS PPT.

The Working Group formulates the PPT policy and objectives. The project manager coordinates this project with the structural units that are participants in this process and submits it for the approval to the head of the enterprise.

4. Work out a plan of the work.

At this stage, the project manager develops a draft work plan, defines the main stages of the work, the terms of their implementation, and submits it for the approval to the head of the enterprise.

5. Identification, analysis, and identification of the processes acting in the PPT.

The working group defines a list of PPT processes and performs their analysis. Based on a detailed analysis of all the processes operating in the PPT, the working group identifies individual processes, that is owners, consumers and suppliers of each process; goals to be achieved in each of the processes under consideration; who measures (evaluates) the processes results; who initiates at the beginning of each process; input parameters of the processes, who and how to measure them; how and who (responsible persons) each process is realized by; the outputs of the relevant processes, (the result of their implementation); availability of a description of the of actions (model) algorithm for the transformation of known inputs into the outputs of each process; procedure of actions with changes in the course of its implementation; how (what criteria) each process is evaluated. The basis for the classification and grouping of the processes form the existing regulations on the structural units and job descriptions. The main processes, that is, the processes directly related to the creation of added value, supplemented by supporting processes and management processes. The main processes facilitates, the task of determining, the belonging of all processes of the enterprise to a certain group in the organization should be detected.

After obtaining a list of available PPTs, a project manager analyzes a detailed survey questionnaire to identify the processes required by DSTU ISO 9001: 2009, which are not included in the list. This list should also be agreed with the PPT staff and, if necessary, changes should be made to it. For each new process, it is necessary to carry out the work on its identification. Based on the requirements of the new system, the infrastructure is assessed and the role of the information systems department is determined.

6. Development of “IS PPT Process Map”.

Based on the information received about the existing and new processes, the working group is developing an “IS PPT Process Map” in the organization. “IS PPT Mapping” is agreed with the IS PPT staff and, if necessary, makes changes to it. Based on the “Process Maps”, the project manager develops the “List of IS PPT in the organization”. Then, the “IS PPT Map of Processes” and “IS PPT Processes List in Organization” are approved by the management.

7. Technical and economic indicators of IS PPT system development.

Based on the policy and objectives of the IS PPT, a common system of technical and economic indicators of IS PPT processes is developed, which is approved by the management afterwards.

8. Development of the IS PPT management concepts.

Based on the developed of IS PPT Mapping Cards and the technical specification, a working group together with the representatives of the software provider assesses the necessary resources to implement the IS PPT system, design the interface of the system and create a management concept.

9. Development of the normative documentation of the system IS PPT.

The working group together with the personnel of the IS PPT system carries out work on the development, registration and approval of documentation on the organizational model of IS PPT, information model of the IS PPT system and IS PPT quality management system (Fig. 3).

10. Implementation of IS PPT.

A working group with the representatives of the software provider are in charge of the following: personnel training, provision of technical equipment for workplaces, software implementation, system start-up, testing and experimental exploitation.

11. IS PPT management.

At this stage, IPO executives conduct surveys of the existing forms and methods of the production management, their assessment and benchmarking, identify bottlenecks in the management process, and factors that play the main role both in a positive and negative role in process management and in the search criteria for assessing the effectiveness of process management. Responsible for the process immediately after determining the value of a particular indicator and detecting its deviation transfers the information to the head of the regulatory entity and develops recommendations aimed at improving the process of management efficiency.

12. Internal audit of IS PPT.

The audit team conducts an internal audit of IS PPT procedures in accordance with the schedule of internal audits or management decisions of the PPT management. Auditors conduct data collection (survey methods, document studies, monitoring of activities, etc.), analyze them and record inconsistencies in the "Report on the inconsistency." After the audit, the team forms an "Audit Report", based on which the process managers carry out corrective and preventive actions.

13. Estimation of the quality of IS PPT processes.

The Department of Quality Control within a set period evaluates the level of quality of the processes of the IS PPT, determines the trends of the process changes and, if necessary, formulates recommendations for its correction.

14. Continuous improvement of IS PPT.

Top management of the PPT, in order to continuously improve the IS PPT, systematically reviews and updates PPT policies and objectives in terms of quality, controls the dissemination of information about the policy and objectives in the field of quality to raise awareness, motivation and involvement of staff at all levels of the enterprise, implement the principle of customer orientation (core production) in all units of the PPT, supports the functioning of an efficient and effective quality management system in accordance with DSTU ISO 9001:2009, provides IS PPT with the necessary resources, conducts Thematic analysis of IS PPT develops a system of measures to improve IS PPT.

4 Results

Development and implementation of a unified management information system is one of the ways to improve the effectiveness of the PPT. This system allows collecting and analyzing the sets of data on-time and efficiently planning the enterprise processes. In addition, one of the blocks of such a system is the evaluation of the PPT quality processes at step 13 of the proposed algorithm (Fig. 4). This stage provides for the formation of the quality indicators values process database used for further analysis and decision management aimed at improving the performance of PPT and forming an array of data for the further analysis.

For this stage, the interface of the program was developed to evaluate the generalized indicator of the effectiveness of quality management processes in the PPT (Fig. 5).

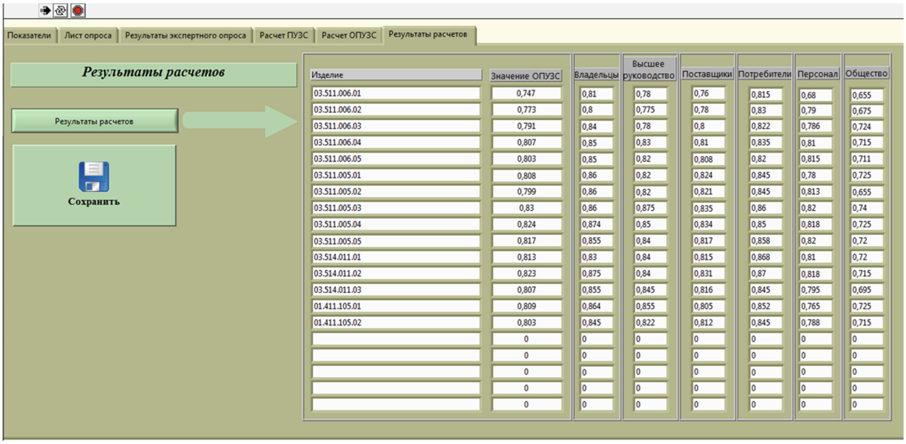

Fig. 5. The program interface for calculating the index of processes efficiency of PPT at stage 13 (in Russian).

The program was created using a highly effective LabVIEW software environment (a product of the National Instruments Company), it is a platform for executing programs, created in the graphical programming language "G". LabVIEW is used in collection and data processing systems, as well as for the technical objects and technological processes management.

5 Conclusions

1. Thus, the integrated application of CALS-technologies for automated and informational support of the QMS will allow for the purposeful management of various information resources of the QMS due to their integration into a unified information system and to create a modern information infrastructure that ensures the effective management of product quality at all stages of its JC. Thus, the introduction of CALS-technologies at the MP for informational support of all stages of the production of products is an important task in the QMS.
2. The introduced algorithm of IS PPT implementation is universal. It allows developing IS PPT quality management system taking into account the specific aspects of the enterprise, the totality of technological processes, the nature of the technological equipment being manufactured, and other production features at each machine-building enterprise.
3. Based on the considered principles of creating the information system of a machine-building enterprise, the information support of the PPT effectiveness assessment processes was developed. The main objective of the developed information support is to create conditions that ensure rational processing and timely providsion with the

necessary information about the results of the performance assessment of the quality management system.

4. In the future, normative documentation is planned to be developed, which will allow providing with an information management system for PPT quality at each machine-building enterprise, taking into account the specific aspects of the enterprise, the totality of technological processes, the nature of the technological equipment being produced, and other production features.

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Variation Coefficient and Some Distribution Laws in the Context of Cutting Tools and Other Technical Objects Reliability Modeling

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Abstract. In the paper some practice of the usage of three distribution laws: Gauss, Gamma, and Weibull for reliability modeling of technical objects in general and metal cutting tools in particular are analyzed and arranged. Selection of distribution law and estimation of its parameters based on empirical data are the main tasks in reliability simulation. It is stressed that selection of the above-mentioned laws should be made taking into account the process mechanism; otherwise, it leads to some false conclusions such as equivalence of Gamma and Weibull distribution. Mentioned distribution laws and their usage are analyzed from the position of physical interpretation. The conditions are shown when the above-mentioned distribution laws are similar. The simplified dependence that connects the shape parameter of Weibull distribution and variation coefficient is obtained and confirmed statistically. The variation coefficient defines the shape parameters for both Gamma and Weibull distributions uniquely and reflects the mechanism of the process. The variation coefficient and failure rate in addition to formal criteria are shown to be the main indicators for the distribution law selection.

Keywords: Failure rate · Weibull distribution · Gamma distribution
Shape parameter · Scale parameter · Gauss distribution · Metal cutting tool
Reliability modeling · Empirical data · Object failure

1 Introduction

To simulate the reliability of any technical object and the metal-cutting tool in particular, including: prediction of the failure probability or that of the no-failure operation during certain time; prediction of the no-failure time; determination of the mean time between failures or time to failure; planning of the test programs etc., it is necessary to establish what kind of theoretical distribution law describes available empirical (selective) data referring to the operation time to failure. In other words, it is necessary to establish a correspondence between the empirical and the theoretical distribution laws. From the formal point of view, this correspondence can be established by the Pearson's chi-square, Kolmogorov–Smirnov type, and other criteria. But it is not only the formal side that is important – namely how close the form of the theoretical distribution law to the available

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empirical data is, but also the physical interpretation, connecting type of theoretical distribution law and its parameters with the process mechanism [1].

2 Literature Review

Metal cutting tools are wearable and non-repairable though fully restorable objects - for example, the replaceable-insert tools. In this case, one of the reliability parameters is the time to failure - an equivalent parameter, which is the mean time between two failures (MTTF) [2, 3]. In reliability analysis and modeling, it is very important to take into account the period of life cycle at which the object operates: wear-in, normal operation or wear-out, which affects, first, at the nature of the dependence between time and failure rate.

Different theoretical distribution laws can be used to describe the same empirical data [1]; in addition, one distribution law can be a particular case of another. A considerable number of works are devoted to methods for determining the parameters of some theoretical distribution laws, based on empirical data and comparing these methods [4–7]. However, the distribution laws themselves, taking into account their physical interpretation, are not compared, which sometimes leads to some incorrect conclusions. There are also no clear practical criteria and recommendations regarding the application of any particular theoretical distribution laws in reliability analysis. Taking into account the foregoing, the purpose of this paper is as follows: to analyze and compare three most common theoretical distributions (Gauss or Normal, Gamma and Weibull) for the reliability modeling. The laws should be analyzed by arranging available information, from the following positions: object failures; possibility of transition from one law to another; identifying conditions under which a certain law can be applied.

3 Research Methodology

Research methodology, chosen for the purposes of this article, includes general and statistical analysis of the published cutting tools reliability data (including tool life) and theoretical approaches to it as well as simulation experiments based on generating of selections, following the given distribution laws with predetermined parameters, and their further statistical analysis. All selections with defined theoretical parameters have been generated by means of Microsoft Excel program using its inbuilt functions:

– Gamma distribution: GAMMAINV((1-RAND()); <alfa>; <betta>))
– Weibull distribution: <*Cell containing β*>*(-LN(RAND()))^(1/<*Cell containing α*>.

4 Results

4.1 Failure Rate and Variation Coefficient

One of the main indicators describing technical objects reliability is the failure rate $\lambda(t)$, as the conditional instantaneous failure probability at time t, referred to the number of objects that are in good condition at that moment. It can also be defined as the failure probability at a time t, per one object, from those “survived” until that time. Moreover, any integral distribution law can be represented as an exponential function of the failure rate [2]. The nature of the failure rate function determines the phase of the object life cycle:

– Decreasing type - for the wear-in or “child mortality” phase, when failures indicate defects of the object assembly process and/or that of its individual elements caused by violation of production processes;
– Constant - for the phase of normal operation under the conditions of wearing, aging and fatigue absence, when failures occur suddenly because of the reasons not related to the object itself, in accordance with the exponential distribution law. Sometimes it is used for the cutting tools failures analyses [1], but there are no periods without wearing and in general, it is unacceptable to use exponential distribution for the objects that are subject to wear [3]. The only exception for the usage of distribution law similar to exponential is a complete and almost instantaneous restoration of the object after failure [3]. So, for the cutting tools this period could be taken contingently as one of insignificant increase of failure rate
– Increasing – wear-out phase. For the metal cutting tools, it starts just after wear-in due to the distinguishable processes of wearing aging, fatigue, etc. Only for some period, as mentioned above, it is taken as a normal operation. As soon as the tool reaches the certain limiting state, wear rate and thus failure rate will increase sharply and it will be a catastrophic wear period that normally should be avoided for the cutting tools.

Another significant indicator specifying stability or the variable volatility degree, and hence, the time to failure is the variation coefficient:

$$V = \frac{S}{\bar{T}} \tag{1}$$

where S is the standard deviation of the time between failures and $\bar{T}$ is MTTF.

From the viewpoint of the sample homogeneity and therefore the stability of the results obtained, including the objects quality uniformity, certain boundary values of the variation coefficient can be distinguished [8] (see Table 1).

Table 1. Boundary values of the variation coefficient in terms of results stability.

Variation coefficient	Sample characteristics – results stability
Less than 0.17	Sample is absolutely homogenous – the results are stable
From 0.17 to 0.35	Homogeneity is sufficient – the results are stable enough
From 0.35 to 0.40	Homogeneity is not sufficient – the results are not stable enough
Higher then 0.4	Sample is inhomogeneous – the results are not stable