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RESOURCE MANAGEMENT AND INNOVATIVE OPTIMISATION OF MACHINING MODES IN THE PRODUCTION OF COMPLEX-SHAPED COMPONENTS

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Background. A pressing challenge in mechanical engineering is increasing labour productivity during the “cutting” operation. This topic is highly relevant because cutting tool capabilities continue to lag behind the technical potential of modern automated turning equipment. The solution is to apply innovative methods and software in production management and mechanical engineering.

Purpose. The aim is to analyse and optimise the processing modes of complex parts and manage the implementation of innovations in mechanical engineering to achieve higher efficiency.

Findings. A comparable tendency was identified in the second classification category of the probabilistic neural network model, characterised by improved performance indicators. For the model with comparatively lower classification performance, both the first and second output categories achieved the same accuracy of 90.0%. An assessment of the structural and technological characteristics of components with intricate profile geometries indicates that machining efficiency is strongly influenced by the complexity of part geometry and the diversity of manufacturing procedures when automated multifunctional equipment is applied. The final values of the “weight coefficients W” and “bases B” were determined, and the resulting matrix structures support compliance with the minimum Mean-Squared Error (MSE) criterion while increasing the reliability of predictive outcomes in evaluating production risk for mechanically engineered components and systems.

Implications. The evaluation of machining-mode selection demonstrates that identifying optimal manufacturing conditions for components with sophisticated profile surfaces processed on automated systems remains a major engineering and economic challenge. Existing approaches for parametric optimisation insufficiently incorporate technological constraints. As the application of materials with specific physical and mechanical characteristics expands, along with the increasing geometric complexity of components and the wider implementation of multifunctional automated systems, technological production planning increasingly depends on the effective determination of cutting parameters and tool geometry, thereby contributing to improved manufacturing performance.

Keywords: Manufacturing Efficiency, Mechanical Engineering, Optimisation, Production, Risk Assessment.

1. Introduction.

Innovation obsolescence occurs due to ongoing changes driven by continuous technological improvements, as innovations serving identical production functions become obsolete. There are certain interrelations and interdependencies (a constellation) between innovation development and obsolescence that characterise the process of innovation obsolescence.

The sustained trends of economic globalisation drive the rapid adoption of advanced technologies and automated manufacturing systems to improve productivity, enhance product quality, increase process flexibility and sustainability, and reduce the time required to bring products from concept to market.

Worldwide industrial development demonstrates that manufactured products are becoming more sophisticated in both structural design and functional performance requirements (Dahmani et al., 2021; Demirova, 2019). Contemporary production concepts, therefore, require a substantially different approach to industrial manufacturing systems (Aleksandrova et al., 2025a; Petrova et al., 2025).

Currently, mechanical processing is the most common method for producing various types of parts, including those with complex profiled surfaces. Despite the development and widespread implementation of methods for obtaining accurate blanks using concentrated energy flows for shaping (electrochemical, electrophysical, electron-beam processing, etc.), the proportion of surfaces subjected to mechanical processing remains sufficiently high.

The analysis of the literature and production data (Aleksandrova et al., 2025b; Dahmani et al., 2021) indicates that 80-85% of component blanks are processed by cutting, and the labour intensity of these operations accounts for approximately 60% or more of the total labour intensity of component manufacturing. Therefore, determining the appropriate modes of operation for the instruments is an important technical and economic task.

Its importance increases with the introduction of wide-scale automation of machine-building production, the application of multi-operation automated Computer Numerical Control Machines (CNC) lathes, and the use of new materials characterised by poor machinability during cutting (Marinov, 2024).

Cutting is the most effective dimensional processing method across productivity, cost, energy consumption, environmental friendliness, processing accuracy, and quality. In the coming decades, cutting will remain the primary technological method for dimensional processing (Mitev, 2024). The following factors can explain this:

- The increasing use of materials with special physical and mechanical properties, characterised by low machinability, increases the cost of producing the part.
- Complicated configuration of the components, with simultaneous strict requirements for accuracy and quality of the processed surfaces.
- Multi-purpose automated CNC lathes are used to process complex profile surfaces, which require a special approach to selecting mechanical processing modes.

In the production of components combining complex surfaces (disks, shafts, rings, vanes, etc.), mechanical processing operations predominate, particularly turning. Machining operations constitute more than 50% of the labour intensity of aircraft engines. The final mechanical dimensional processing of parts is a perspective on a foreseeable period of development in mechanical engineering technology (Aleksandrova et al., 2025a). An actual problem in machining production is increasing the labour productivity of the "cutting" operation. This topic is highly relevant because cutting tool capabilities continue to lag behind the technical potential of modern automated lathes. When the allowance is removed or when a constant shear layer section is used, cutting speed is the primary factor affecting productivity. However, changing this parameter alters the nature and intensity of wear on the cutting tool, temperature in the cutting zone, processing accuracy, properties of the surface layer material, and other indicators (Liao, 2023; Tapie et al. 2012).

Therefore, from a technical perspective, increasing the efficiency of the machining process through cutting should be considered a complex management measure, with all main factors ensured using mathematical methods of calculation and optimisation.

A significant part of the developments in cutting mode optimisation is based on determining the variables influencing the cutting process using empirical methods under conditions aligned with the main goals of increasing productivity and reducing the cost of cutting tools, with set requirements for accuracy and surface roughness.

Vachev (1998) noted that considerable attention has been paid to the development of empirical formulas to facilitate optimisation processes. In addition, the cutting modes were optimised using the developed empirical formulas that account for various variables influencing the cutting process (Velchev et al., 2014). A review of the literature shows that there are currently no universal analytical dependencies that reflect the relationships among all factors affecting the cutting process (Salapateva & Lengerov, 2025). It is important to note that, given the parameters of the cutting modes, it is not possible to establish the relationships between many influencing factors using empirical formulas. In this regard, enterprises used simplified metal-cutting machines and a limited range of materials for cutting tools and workpieces.

With the development of mechanical engineering, especially the automation of metalworking equipment, it is necessary to consider a much larger number of variables than those used in existing empirical formulas when calculating the cutting modes. This necessitates the development of new methods for determining cutting modes and is a prerequisite for creating complex dependencies that can be presented as a table or nomogram.

The analysis shows that determining the cutting modes using tables and nomograms is analogous to using formulas, but is simpler and thus feasible. However, it should be noted that general mechanical engineering regulations serve only as prerequisites for establishing load norms and do not guarantee the necessary flexibility.

These shortcomings can also be noted in relation to the recommendations for companies producing cutting tools.

The creation and implementation of automated systems for the design of technological processes for the component manufacturing, as well as for the automation of these processes, pose complex challenges for the theory of cutting. They concluded by formalising the basis for deep physical research into all the interrelationships of the cutting process, determining its performance, accuracy, quality, and, most importantly, its reliability.

The calculation task for determining the processing conditions is complicated by the need to comprehensively assess input parameters when selecting a cutting mode combination, including the tool's durability, required accuracy, surface quality, and mode-specific factors. All of these are affected differently by temperature and cutting forces, which together determine the tool longevity, processing accuracy, and surface-layer characteristics. It is necessary to choose the depth, feed, and cutting speed in a complex manner, ensuring compliance with the requirements for the workpiece and tool, as well as the operating conditions of the equipment used.

2. Methodology.

The solution to this complex technological task is possible through advanced mathematical models that account for the interrelationships among the main parameters of the machining process. The created mathematical models must be distinguished by sufficient accuracy and universality to yield solutions on computing equipment of a different class, and the emphasis in the development of mechanical processing technologies will be on solving technical tasks related to the automation of processing (Petrova et al., 2025).

When choosing a variant of a technological process, including a variant for preserving a specific operation, the principle of optimality or the principle of ensuring the most advantageous conditions under the set technological limitations must be observed.

For a precise selection of a technological procedure applied in machining operations of parts, it is necessary to determine the value of the sought-after technological parameter, which will ensure the greatest efficiency of the process at the specified quality of the produced output, productivity, costs of working capital, and technological and organisational-technical capabilities for fixed assets. With such a solution to a given task, it is necessary to perform it considering the relationship between the specified requirements for the part (surface roughness, depth and degree of overlap, residual stresses, dimensional accuracy, etc.) and processing modes (tool geometry, brand of the tool material, cutting modes, etc.).

Calculations of the relationship between technological processing conditions are carried out, in particular, the cutting modes, the physical and mechanical properties of the workpiece and tool materials and other parameters, and the initial characteristics of the cutting process, such as wear resistance of the tool, productivity, cost of processing, and characteristics of the quality of the treated surface (Metev et al., 2025).

Many models have been derived from experimental data. However, they only allow the determination of the optimal cutting speed and the corresponding relative magnitude of the tool surface wear. Under certain requirements, the resulting models may be related to the physical basis of a process. That is, these models in their entirety cannot be used to solve technological tasks.

2.1. Innovative Development on Technology.

The dependencies are obtained based on the analysis of the results of a theoretical study of the method according to the theory of similarity and also sufficiently reliably evaluate the physical phenomenon associated with the chip separation process, on the one hand, and on the other hand, with the formation of the material of the surface layer of the processed part (Petrova et al., 2025).

The influence of technological innovation is reflected in improvements to existing machines and equipment and in the construction of fundamentally new machines.

Recent industrial practice shows a growing tendency toward modular standardisation and unification of machine components. This approach supports the rapid configuration of machines for different technological applications while maintaining common functional characteristics, reflecting the concept of mechatronic manufacturing systems.

Research into the patterns of technological progress and enhancement enables identification of the time interval during which a particular machine generation provides maximum efficiency for a manufacturing process, as well as the transition period required to introduce new machine types into production (Petrova et al., 2025).

This is also the place to focus on the management and optimisation of the processing modes of complex parts, as well as on implementing innovations in mechanical engineering to achieve higher efficiencies.

It has been established that the extraordinary variety of options for performing operations in the mechanical processing of parts requires general solutions to the problem of selecting mode conditions when using process technology (Demirova, 2019). The proposed options cannot be determined solely using experimental research methods. The methodology and program for calculating the technological conditions of processing, as well as the parameters of the surface layer quality and the processing accuracy, do not account for cutting tool wear, the technological cost of processing, and the performance of the operation in the considered modes. The proposed models are general, as they were obtained through theoretical studies.

2.2. Technical Standardisation of Cutting Modes.

Another argument is that the calculation of the cutting modes is basically technical standardisation, and that is why the determined speed, feed, depth of cut, wear resistance of the tool, intermediate allowances, and tolerances providing a minimum or a maximum of the optimality criterion, taking into account all the restrictions, are reported within the technical standardisation.

Thus, the developed methodology and optimisation algorithms address the task of improving technical norming and determining basic time norms. The development of technological processes for manufactured parts within a given enterprise is a complex task, with corresponding requirements that must be met as a semi-finished product is transformed into a finished product that meets all requirements for its purpose. Before comparing the different variants of the technological process, internal optimisation for each variant must be performed (Metev et al., 2024).

Currently, a significant number of methods for choosing cutting modes for individual mathematical treatments have been developed, and they can be divided into three groups depending on the way they are solved to find a conditional maximum (a classic example is determining the optimal cutting speed), to use mathematical programming and for optimal management. The analysis of these methods shows that all of them have certain shortcomings. The task of determining the cutting modes should be understood precisely as an optimal design and management problem.

Models can be used with exponents, such as in the system setup size part, the tool wear rate, and the cutting power. For example, the parameters of the cutting process affect the changes in physicochemical phenomena accompanying processing, as well as their intensity. Technological optimisation is structural (intended to optimise the sequencing of transitions and operations during mechanical processing) and parametric (to optimise process parameters for individual operations).

2.3. Technological Optimisation and Production Management.

The main features of technological optimisation, reflecting the goals in the production of engineering products, are as follows (Skorkin et al., 2019):

– Technological solutions, starting from the choice of the initial workpiece, the sequence of processing, the choice of the cutting tool, and the cutting modes.

– The structure of any technological solution is determined by the large number of its constituent elements and their connections.

– Choosing an optimal technological solution at the intermediate stages is an undefined task.

Despite the noted complexity, sufficiently complex mathematical models can be developed to assess the durability of cutting tools for heat-resistant alloys, titanium alloys, and high-strength steels.

Analysing the content of these model dependencies, we should note that:

– By offering these models for the different groups of processed materials, the physico-mechanical properties of the materials within each group are not considered.

– The proposed models are first-order dependencies, where the range of change of the variable parameters is not given; the dependence of durability on the elements of the cutting mode is a non-monotonic function.

– The offered models are not sufficiently complex and do not allow solving tasks in external and internal technological optimisation when processing complex profile parts.

As already noted, optimising the technological parameters is a complex optimisation task due to the multivariate nature of the technological processes, the complexity of the configurations of the processed parts, etc. In real production conditions, this task is also complicated by the fact that, during processing, the cutting mode parameters and the geometry of the cutting tool change (Velchev et al., 2014).

Therefore, the best option for mechanical processing should be selected, considering the accepted optimality criteria and integrating it into the variable control of the cutting process. It has been proven that spatial and temporal variability related to the geometric shape of the processed surface, variable-depth processing, allowance fluctuations, and changes in the cutting process geometry are important during processing.

However, it should be noted that stationary cutting processes do not exist, especially when machining difficult-to-machine special steels and alloys.

This is because tool wear occurs rapidly, and the temperature-load conditions that determine tool reliability and surface-layer material quality change sharply during the processing of even a single part.

An attempt can be made to develop and use complex mathematical dependencies for tool life based on a large number of factors, considering not only the tool geometry and cutting modes, but also the tool and processed material properties. Mathematical dependencies for the tool life and quality characteristics of the machined surface can be obtained in the form of first-degree polynomials as follows:

- Turning of heat-resistant alloys.
- Milling of titanium alloys.

To evaluate the characteristics of the machined surface during turning, dependencies have been established. Despite the many factors affecting the cutting process and the variable quality of the cutting mode, the proposed models do not consider productivity or technological costs, nor do they address issues related to accuracy when processing components with complex shapes.

The components of modern machines operating at high temperatures, high pressure, and cyclic load changes are essential not only for the parameters the roughness of the processed surface but also for the physical, mechanical, chemical, and structural-phase characteristics of the surface layer of the material. Therefore, the issues of prediction and development of mathematical dependencies that reflect the relationships among the characteristics of the machined surface of the material, cutting modes, and tool geometry have been considered.

The analysis of the results shows that the obtained mathematical dependencies are related to the quality characteristics of one or several parameters characterising the technological conditions for performing the operations and cannot be used for complex evaluation or to solve issues related to technological optimisation.

Most developments convincingly demonstrate the feasibility and necessity of applying a mathematical description (theoretical or experimental) of the nature of the change and the magnitude of the indicators of the quality of the processed surface under different mechanical processing conditions.

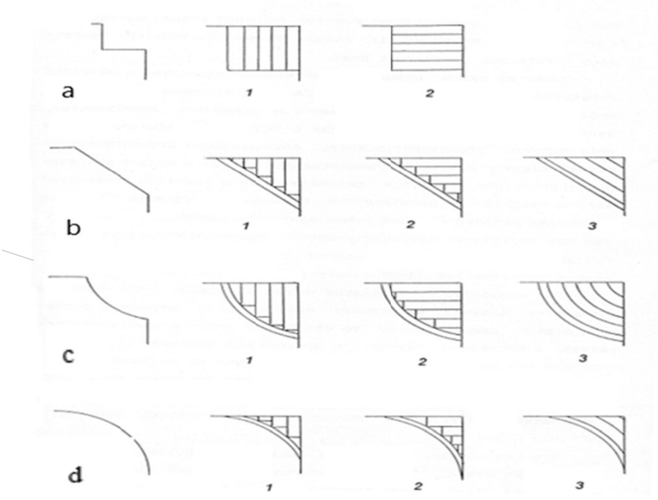


Fig. 1. Tool Movement Schemes for Machining Elementary Surfaces: (a) cylindrical and face; (b) conical; (c) concave spherical; (d) convex spherical; 1 – perpendicular to the workpiece axis; 2 – parallel to the workpiece axis; 3 – equidistant to the profile.

The main methods for processing parts with a complex rotational shape on lathes are:

- Turning with standard knives without a copier.
- Processing with profile knives.
- Processing with standardised knives using a circular feed device.
- Processing with special round profile knives.
- Turning with standardised knives using a copying device and enables the precise reproduction of complex profiles.
- Turning with standardised knives on CNC lathes.

Each method has its area of application, and components can be processed in two ways:

− The first is based on the movement of the cutting edge of the tool along a curvilinear trajectory (track method); and

− The second is through a straight-line working stroke of the tool; that is, the cutting edge has a curvilinear contour identical to the contour of the machined surface (copying method).

In the first method, considerable time and resources are spent repeatedly to reproduce the part's complex shape on the machine. Moreover, in the second method, a significant amount of time and money is spent once, which is then necessary for the machine to reproduce the tool's complex path repeatedly. The schemes of movement of the tool when removing the main allowance are as follows:

− Parallel to axes OY or OX (Fig. 1 b, a1, a2);

− Equidistant to the contour of the processed part (Fig.1b, b3, c3, d3);

Parallel to the OY or OX for the rough passes and equidistant to the contour of the workpiece for the finishing passes (Fig. 1b, b1, b2, c1, d1, d2) (the scheme combines the two previous schemes).

One way to increase productivity and quality when processing complex profile surfaces is to use CNC machines in a partially automated production environment. These machines combine the high productivity of automated equipment with the flexibility of universal equipment, making them a basic technical means of automation in single- and small-scale production. The use of CNC machines for machining parts with complex shapes is the most efficient, as it automates the metalworking process without the need to manufacture specialised, time-consuming equipment or tools.

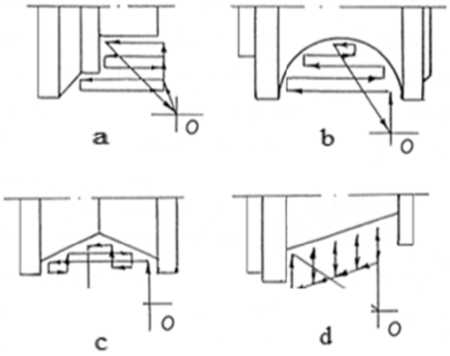


Fig. 2. Typical Toolpath Schemes for CNC lathe Machining: (a) loop pattern; (b) zig-zag pattern; (c) curved path; (d) drop-type path.

When machining step shafts on CNC lathes, roughing can be performed in two ways: if the difference in neck diameters is greater than the shaft length, a transverse feed is used; otherwise, a longitudinal feed is used. Modern CNC systems allow these types of machining to be performed continuously. Variants with a longitudinal feed for the rough passes and equidistant feeds on the contour for the clean or equidistant feeds for the rough and clean passes are also possible. Standard toolpath diagrams are used when developing toolpaths for CNC machines. The "loop" scheme (Fig. 2a) is used to process workpieces with knives that operate in one direction.

The "zig-zag" scheme is mainly used when processing deep grooves with cup-shaped knives in both directions. The spiral pattern (Fig. 2c) differs slightly from the zig-zag pattern but offers advantages for machining deep grooves composed of conical surfaces with cup-shaped knives. The "drop" scheme (Fig. 2d) is intended for the channel knife operation.

Machining of components with complex shapes is a non-stationary process. Stationary means cutting in which the mean values (mathematical expectation) and dispersion field (dispersion) of external influences (cutting depth, feed, cutting speed, etc.) do not change during the lifetime of the cutting tool.

An example of non-stationary cutting is the scraping of a stepped shaft, where the processing of each step is performed with different but constant cutting modes.

With the use of CNC machines and adaptive control systems, it becomes possible to change the processing modes when one or more cutting parameters change continuously during a single working stroke of the tool (a particular case of non-stationary cutting).

Variable cutting is widely used for turning complex-shaped workpieces at variable cutting speeds, with the knife moving along the workpiece contour while the machine spindle rotation frequency remains constant. Thanks to the variable cutting mode, it is possible to increase productivity and reduce processing costs while maintaining the desired quality of the processed surfaces. For example, in many cases, it is desirable to machine complex-shaped workpieces with a variable depth of cut to remove all allowances in a minimum number of passes.

The variable cutting mode is used to better utilise the machine's capabilities, with systems that ensure a constant cross-sectional area of the sheared metal layer at the expense of controlling the feed and cutting depth. The management of the processing mode is applied to ensure consistency in technological parameters (cutting force and power, processing accuracy, deformations, roughness of the processed surface, etc.) and to increase productivity and reduce operational costs.

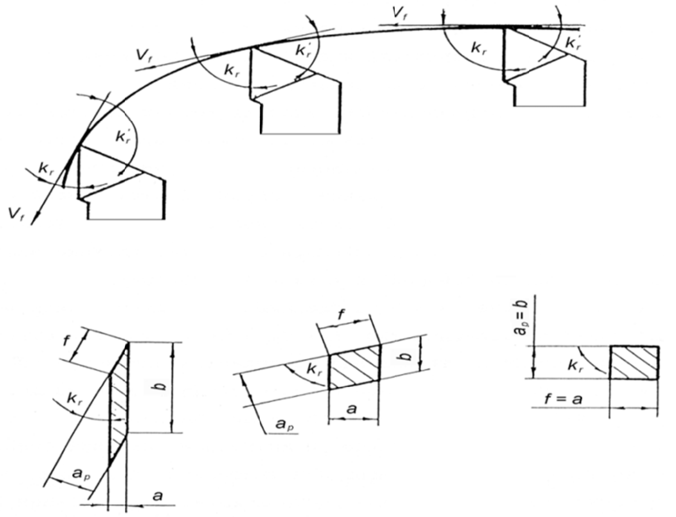


Fig. 3. Determination of Angles and Cross-Sectional Parameters of the Metal Shear Layer during Machining of Curvilinear Surfaces.

When machining curved sections of workpieces on CNC machines, the feed direction f $(v_f = f \cdot n)$ is constantly changing, the main setting angle k_r decreases, and the auxiliary k_r' increases. When the angle decreases, the width of the metal shear layer b increases, and the thickness a decreases, whereas the nominal area of the metal shear layer remains constant (Fig. 3):

$$K = a_p \cdot f = a \cdot b \tag{1}$$

When the knife moves along a curvilinear trajectory, a change in the cutting forces is observed owing to the influence of *a* and *b* on the main component of the cutting force (F).

Changes in the installation angle affect the roughness of the machined surface and the direction of chip movement, which is perpendicular to the diagonal of the sheared metal section.

The actual front angle of the knife and the ratio of the components of the cutting forces F_x and F_y depend on the angle of movement of the chip. In this way, processed workpieces with complex shapes on lathes with non-stationary cutting, a special case of which is the variable cutting mode, is a promising direction that requires the solution of such issues as cutting time, wear and durability of knives, cutting forces, etc.

3. Results and Discussion.

Modern economic reality is strongly influenced by changes in production activity, driven by the explosive development of information and communication technologies and by the transition of entire societies to market-economy conditions and strong market competition. Both markets and the time required to develop new competitive products and services have been significantly reduced. This requires organisations to adopt new management approaches and organisational solutions to respond flexibly to a rapidly changing environment and maintain or expand their competitive advantage, that is, to apply reengineering in management and manage risk.

Risk management analysis is important for resource optimisation and the application of innovative methods for processing complex parts. Risk analysis is a fundamental process that ensures the quality, efficiency, and profitability of the production of complex parts. It integrates the assessment of technological hazards and the effective allocation of production resources with innovations to minimise scrap.

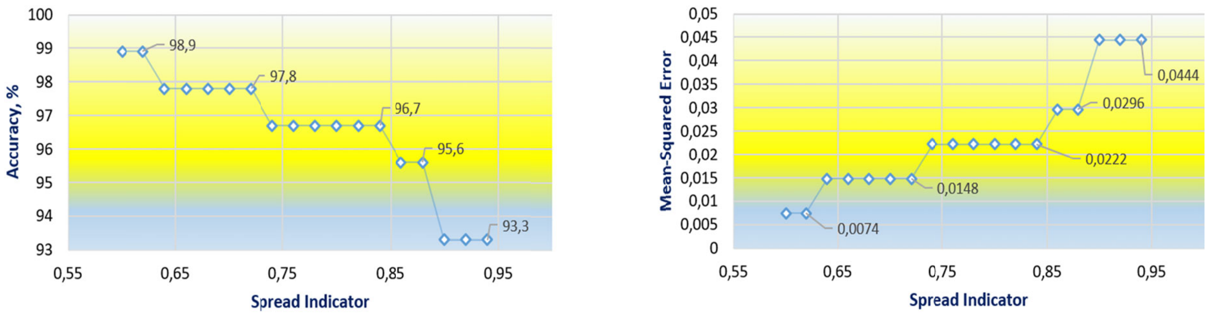
The main aspects of the analysis include identifying risks, applying innovations to prevent and optimise, and resource management.

An approach for predicting risk levels in the production of complex mechanical parts based on Artificial Intelligence is proposed. In particular, a probabilistic neural network (PNNs) apparatus was integrated. The specificity of the approach provides the following input variables and risk categories:

1. *Input Variables:*
   - Market Volatility Index
   - Inflation Rate.
   - Stock Index Change.
2. *Risk Classes:*
   - № 1: Risk Level 0;
   - № 2: Risk Level 1.
   - № 3: Risk Level 2.

The methodology for training and synthesising models based on the defined mathematical apparatus includes an assessment of two basic indicators:

- Classification Accuracy.
- Mean-Squared Error.



a) b)

Fig. 4. Change of a) accuracy and b) MSE metrics in PNNs Investigation for Risk Level Assessment.

Source: based on MATLAB software R2022a (9.12).

A sequential assessment of the behaviour of the created four-layer PNN structures in the experimentally established range of “0.6 to 0.9” of the spread matrix, satisfying the condition for the highest levels of the set quality indicators (Fig. 4), was carried out. Spread is a specific metric for radial basis layers in the studied neural models, varying within the permissible interval of “0 to 1”.

Based on the studies conducted, classification accuracy ranged from 93.3% to 98.9% for the initial and final values of the spread indicator. The achieved respective lowest and highest thresholds of the mean squared error criterion are quantitatively expressed with the order of “0.0074” at Spread = 0.6, 0.62 and “0.0444” at Spread equivalents 0.9, 0.92 and 0.94.

According to the analysed results, a four-layer PNN architecture was synthesised with 90 computing units in the second radial basis structural layer at a minimum value of the spread metric, as shown in Fig. 5.

In connection with the indicated architecture, matrices of correct and incorrect classifications in the production risk assessment procedures were constructed, as shown in Fig. 6.

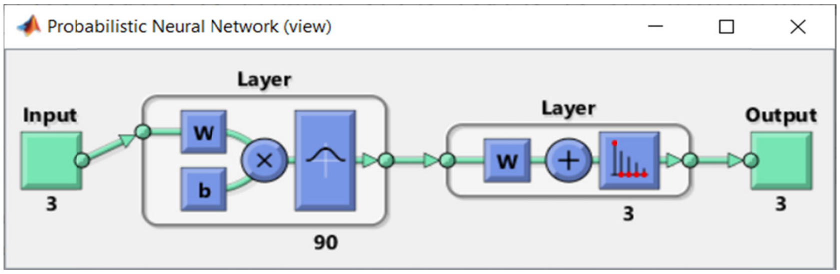
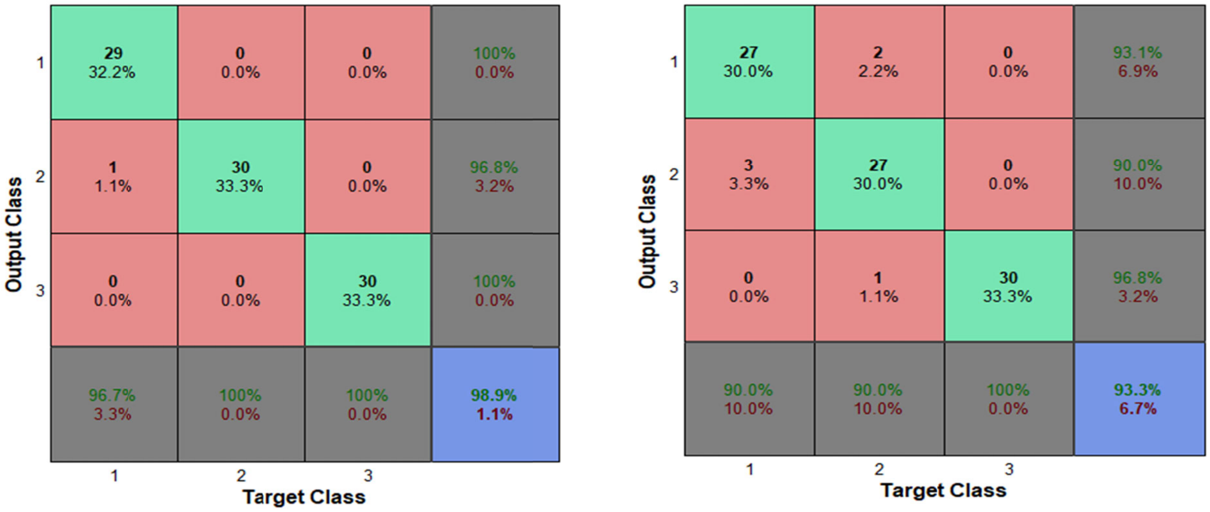


Fig. 5. PNN Architecture for Risk Level Prediction.

Source: based on MATLAB software R2022a (9.12).



a)

Output Class \ Target Class	1	2	3	
1	29 32.2%	0 0.0%	0 0.0%	100% 0.0%
2	1 1.1%	30 33.3%	0 0.0%	96.8% 3.2%
3	0 0.0%	0 0.0%	30 33.3%	100% 0.0%
	96.7% 3.3%	100% 0.0%	100% 0.0%	98.9% 1.1%

b)

Output Class \ Target Class	1	2	3	
1	27 30.0%	2 2.2%	0 0.0%	93.1% 6.9%
2	3 3.3%	27 30.0%	0 0.0%	90.0% 10.0%
3	0 0.0%	1 1.1%	30 33.3%	96.8% 3.2%
	90.0% 10.0%	90.0% 10.0%	100% 0.0%	93.3% 6.7%

Fig. 6. Confusion Matrices for Risk Level Assessment under Conditions of (a) Highest and (b) Lowest Classification Accuracy.

Source: based on MATLAB software R2022a (9.12).

The confusion matrices show the distribution of test standards during PNN model verification, grouped by the highest and lowest classification accuracies.

The standards for the third output group were correctly determined using both models. Regarding the PNN structure with higher-quality indicators (Fig. 6a), a similar result was observed for the second classification group. Identical accuracy levels of 90.0% were obtained for the first and second output groups in the model, with a lower established classification quality, as shown in Fig. 6b.

$$\begin{bmatrix} 28.80 & \cdots & 0.43 \\ \vdots & \ddots & \vdots \\ 24.06 & \cdots & -1.48 \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} 1.3876 \\ \ldots\ldots \\ 1.3876 \end{bmatrix} \tag{3}$$

The derived matrices (2) and (3) show the calculated final “weight coefficients W” and “bases B”. The indicated matrix objects ensure that the minimum MSE criterion is met and that the predictive results are most reliable when analysing the level of production risk for complex parts and structures.

4. Conclusions.

Based on the research and analysis conducted above, we can summarize the following conclusions.

From a geometric perspective, the classification of surfaces based on the variety of "their forms and ways of obtaining" cannot be scientifically justified. However, systematising the approach to surface formation will enable the correct solution of tasks related to modelling complex profiled surfaces and the technological methods for their production.

The class of parts with complex rotational shapes includes cylindrical parts (smooth and stepped). Therefore, all methods for processing cylindrical parts can be considered as technologies for processing rotary profile surfaces. Components characterised by complex rotational geometry consist of combinations of basic surfaces formed by straight and curved elements, including one or several geometric configurations such as cylindrical, frontal, conical, spherical, elliptical, or parabolic surfaces. Each elementary rotational surface can be represented mathematically for theoretical evaluation, while the coordinated motions of the generating and guiding mechanisms support the effective implementation of appropriate manufacturing methods.

Different technological strategies are available for rough machining of complex-shaped components without additional allowances, allowing efficient operation in partially automated production environments.

In most cases, processing workpieces with a complex rotational shape is a multipass process, with work moves performed parallel or perpendicular to the workpiece axis and equidistant from the workpiece contour. Cutting modes when turning parts with complex rotational shapes are non-stationary. When using CNC lathes and adaptive control systems, the cutting conditions vary from one working stroke to the next.

Analysis of design and manufacturing characteristics of parts with complex-shaped components shows that the complexity of their geometry, together with the diversity of manufacturing procedures, strongly influences the effectiveness of machining operations performed on multifunctional automated equipment equipped with digital-program-controlled (DPC) systems.

Given the quantity of materials with specific physical-mechanical properties, the complex configuration of parts, and the use of automated multifunctional equipment, the primary objective of technological production planning is to select cutting modes and tool geometry, thereby optimising the task and increasing production efficiency.

The investigation of machining-mode selection issues indicates that defining optimal production conditions for components with complex profile surfaces on automated equipment remains a major technical and economic challenge. At present, there is still a shortage of parametric optimisation methodologies that adequately incorporate technological constraints.

The final “weight coefficients W” and “bases B” were calculated. The indicated matrix objects ensure that the minimum MSE criterion is met and that the forecast results are the most reliable when analysing the level of production risk for complex mechanical engineering parts and structures.

Conflict of Interest Statement.

The authors declare no conflict of interest.

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Data Availability.

Data are available from the authors upon reasonable request.

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