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Engineering Consulting Technology in Production Engineering Intelligent Mobile Machines

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Abstract

The article features layout tools with parallel structure. It also developed dynamic simulation model that allows the simulation of a given law of motion of platform parallel mechanism and obtained such valued characteristics as speed, acceleration platform, changing the torque on the front crank, reactionary force kinematics of interaction mechanism of nodes. It allows you to make a decision of direct and inverse problems of dynamics by interactive visualization of spatial states of all moving parts of the implementation of precision movements programmed by many systems of coordination of movement. The article also provides the classification and analysis of prospects for the use of automated manufacturing equipment based on industrial platforms with mechanisms of parallel structure. It is established that the use of machines-robots based on these mechanisms can significantly increase the productivity and precision in machining geometrically complex engineering products.

Keywords: *Parallel kinematics machines, neural networks, control, precision, neuron computers.*

1. INTRODUCTION

A growing number of engineering companies that deal with improving the efficiency of processing hard core surfaces of machine parts, are interested in advancements in high-speed processing. The attempts of its implementation are hampered by several limitations caused by imperfect machines of traditional layout based on the principles serial kinematics. A classic example of such an arrangement may be the machine 500V/5 (Sterlitamak M.T.E.). The feature configurations of this type is that, given the trajectory of movement of the spindle axis defined serial displacement sled moving relative to each other.

Such arrangement has several drawbacks. First of all – it is not high enough rigidity machine that triggers the possibility of vibration during the cutting process, which reduces the quality of surface finish and tool stability.

The second important limiting factor is high inertia of mobile nodes. To disperse large mass of moving parts of the machine, which is typical for classic layout tools, required long periods of time. High-speed processing is associated with the use of high feed speed, maximum acceleration and special treatment strategies that are characterized by a very large number of reversing drives. In the analysis of stable CNC processing program evaluates the expected acceleration and if they exceed a certain limit, the control system automatically lowers the value of supply not to disturb the trajectory. There is a drop in productivity and a violation of the cutting.

An effective solution to the problem that has arisen is to create tools based on parallel kinematic structure that provide consistent change in the lengths of rods, which hold executive body (the spindle hub). This principle has application and further development of machine-tool in the development of many companies, including rods with a length constant [1].

An example of this type of cutting equipment is the machine V100 by the firm INDEX (Germany), Fig. 1. The trajectory of movement of the spindle hub (1) is given in consistent movement sled (2) on the guide (3) [2].

Figure 1. The layout of the machine events V100

1 - spindle hub; 2 - sled; 3 - guides; 4 - bar constant length

Cutting equipment of this type is called "machine - a robot", because the rod functions as the robot arm, which determines the trajectory of the executive body.
Machine tools kinematics, based on the principles of parallel kinematics [3], in theory, have the following advantages:

- high rigidity that is provided by the emergence of a carrier system only in tensile stress (compression) and parallel distribution efforts working in a closed kinematic structure, unlike open-loop kinematic structure of classic layout tools;
- high dynamic performance due to low weight and distribution efforts in parallel motors;
- simplicity of design with the same type of parts, low metal content, and thus - a lot.

However, with the advantages of machine tools with parallel kinematic structure there are also the inherent disadvantages:

- nonlinear kinematic and dynamic characteristics of machines that require nonlinear control systems;
- dependence of static stiffness, gear ratios for effort and acceleration and dynamic properties of the actual position of the spindle;
- complex form of working space and the reduction in comparison with traditional machines, the ratio of the working area and the area occupied by the machine;
- the analysis of the work of foreign researchers devoted to assessing stiffness of the machines with parallel kinematics, concluded that the rigidity of the existing machines with similar kinematics, depending on the design features, ranges from 5 to 200 N/m and is inferior in this to the characteristic tools of classical layout.

Scientific problem of handling industrial platforms (IP) uniqueness and special changes leaving significant impact on the performance of machines - robots and related technology systems, is relevant and solved, for example, through the development of industrial platforms with kinematic interchange (Figure 2).
According to the company Siemens, which takes an active part in the development of machines with industrial platforms (IP), individual modules and control systems, the greatest consumer demand machine - work type Tricept (60%), is based on linapod (20%) and hexapod (5%) (Fig. 2). It is expected that soon the total annual production of such machines will reach 3,300 units. Superiority in the creation and production of mechatronic systems currently owned highly in the "Hi-Tech" technology in countries such as Japan, Germany, USA, Sweden, France, Austria. Positioning accuracy of mass-produced machine tools, robots with MPS reaches 1 ... 5 micron frequency spindle up to 30,000 min^{-1}, the speed of movement PE to 90 m/min, maximum speed up to 10 m/s^2, and when tested up to 50 m/s^2.

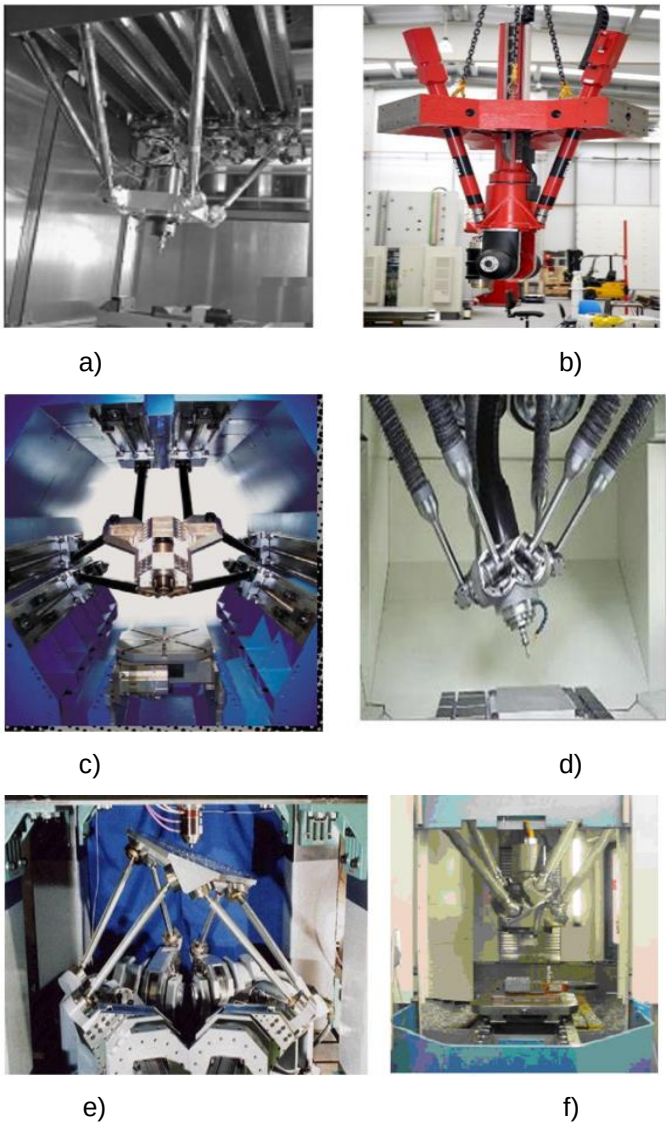

Figure 2. Examples of application of the industrial platforms in machine tools

a) milling machine of the company IWF ETH (Sweden) based on hexahlide; b) milling machine T805 (Tricept) of the company MIKROMAT; c) milling machine of the company PARAUS (France) from hexapod; d) machining center OKUMA PM-600 (Japan); e, f) six coordinate private schemes of rothopod and linapod.

Despite the rapid development of unconventional machine hardware-based industrial platforms (IP), problems of kinematics and dynamics of software, including the conditions of their operation in the positional and contour management, have not been

researched enough. There mathematical formulas do not provide the opportunity to explore the many links between the kinematic parameters platform when mining the same path at different times and the ability to smoothly adjust the speed of the parts of the light gradient acceleration. Also another unsolved problem of modeling the aggregate trajectories platform for different load units with common or consistent the engines do not set conditions for the possible closure of spatial mechanism.
Example of adaptive optimal control of heavy machine tools is given in papers [4-6].

2. MATERIALS AND METHODOLOGY

Structural and functional features of industrial platforms (IP) technology equipment offered are classified according to the number of links leading (Fig. 3).
No less relevant and still usufficiently investigated problem of forecasting reliability indices industrial platforms for the period of estimated lifetime. Industrial platforms reliability analysis during the design and refinement of prototypes are impossible without computer simulation modeling, the bulk of which is to assess the efficiency of "weak element" in the industrial platforms (IP) criteria for disorders of functioning as a separate element, and the entire system in general. For similar systems usually it is not possible to establish the laws of distribution of integrated load characteristics, accuracy, durability, etc., because these tasks are advisable to decide on the method of statistical simulation (Monte Carlo), which provides a reliable assessment of disability in the absence or analytical solutions difficulty. Adequate accuracy in predicting performance and reliability in terms of their operation was established during the project to research and bringing in the prototypes is almost impossible without computer simulation [7,8]. In this case, the least developed and most difficult is the question of stability Lewis pole positioning and its orientation when in the resonant modes, as well as in critical overload in an unfavorable combination of functional and structural parameters. Previous of simulation modeling include functional, settlement and design analysis. Depending on the functionality of the module assembly unit, part or element set the criteria of efficiency and prescribe treatment with a further burden simulation modeling [8].

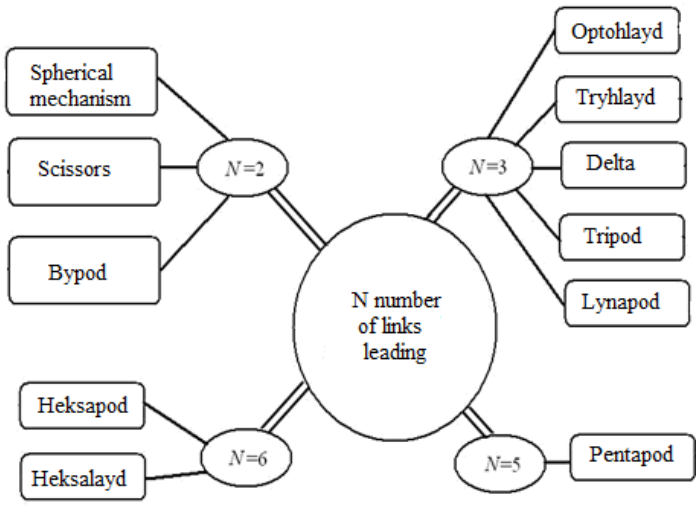

Figure 3. Classification of process equipment based on industrial platforms (IP)

For gears, bearings, seals and other heavy elements of the mechanical subsystem the extreme level statistical tests eliminate the need to identify all areas of existence of each critical parameter of disability weak element in the scattering spectrum loads and other actively influencing factors. For certain low set element extreme test conditions set the following groups of factors:

- in operation (speed, load, temperature, dust, etc.);
- the conditions of work (taking into account the possibility of contamination of surface friction, aging rubber seals and loss of lubrication, mechanical elastic vibrations, resonance phenomena, etc.);
- for the initial state of the object (precision manufacture and assembly, gaps in the joints of probabilistic estimation of extreme values within the tolerance stiffness related items at possible values, etc.).

In the initial data for modeling efficiency gears included statistical distributions of random variables (parameters) that are tested in practice through design verification techniques of deterministic calculation capacity and ISO standards. Calculations include fatigue schematization exercise regimes. Statistical tests of the extreme end of the definition of disability weak elements, while not identifying a possible implementation of emergency and extreme set of implementations and the law of their distribution in time, provided the ability to predict resource.
For the calculation of efficiency and reliability of statistical modeling by PE one should generate extreme pressures of weak level elements and perform simulation efficiency of weak elements. The criteria violations pursuant to the flowchart cyclical payments (Fig.4) [8].

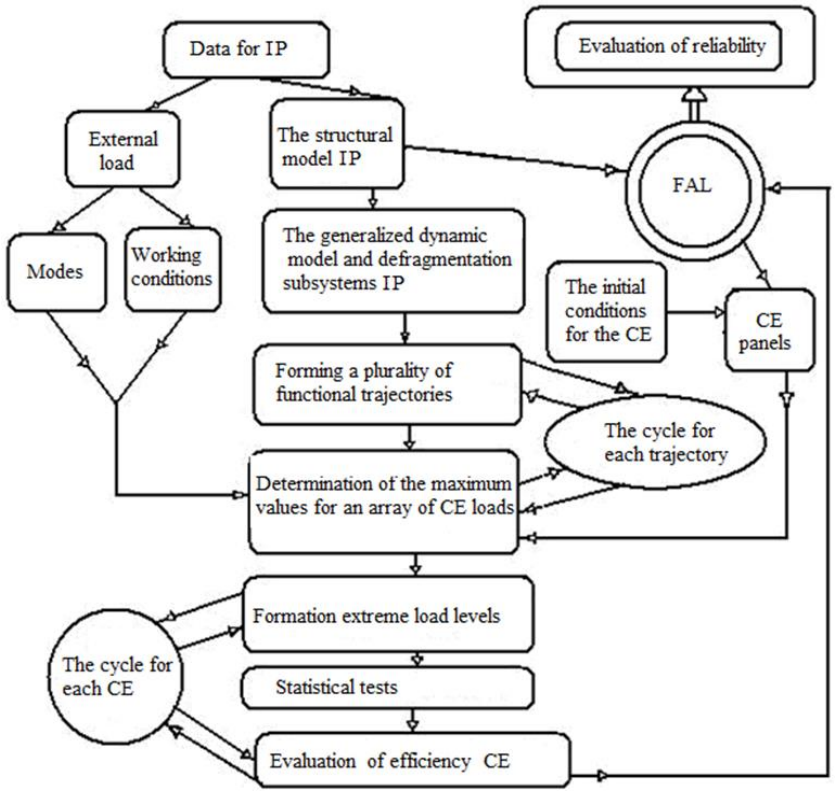

Figure 4. Block diagram of assessing the reliability of industrial platforms (IP)

For most designs electromechanical industrial platforms (IP) in the calculation of the probability of failure of the system cannot be represented as a series-parallel connection of elements and functions used to solve algebraic logic (FAL) [8]. Based on a linear model of the process in the joints wear parts and the method of statistical tests (Monte Carlo), performed parametric forecasting reliability IPU, established with a certain probability value positioning accuracy during a given lifetime [8].

3. RESULTS AND DISCUSSION

Construction of the coordinate system for the implementation of complex spatial displacement with high accuracy and dynamic performance requires a dynamic analysis of executive-level system, which refers to the actuator parallel kinematics, which has manufacturing operations moving, processing or measurement. During the dynamic analysis of actuator displacement coordinate system solved the problem of designing and implementing direct mathematical model that describes the dynamic state and behavior of the mechanism in motion and balance of power in the presence of external influences; built on the basis of a dynamic model of the actuator solve direct and inverse problems of dynamics, modeling is conducted in an environment of dynamic simulation models for specific cases testing actuator movement specified [9,10]. Based on the results obtained during dynamic analysis, you can determine the requirements and recommendations to the Governing engine displacement coordinate system as output characteristics such as the torque change, velocity, acceleration, peak loads needed to implement a given law of motion of the actuator. The built dynamic model serves best way as the configuration controller and verification management system, as well as taking into account both dynamic and kinematic features of the actuator.

Consider the example of dynamic analysis of optopod, whose structure is shown in Fig. 5.

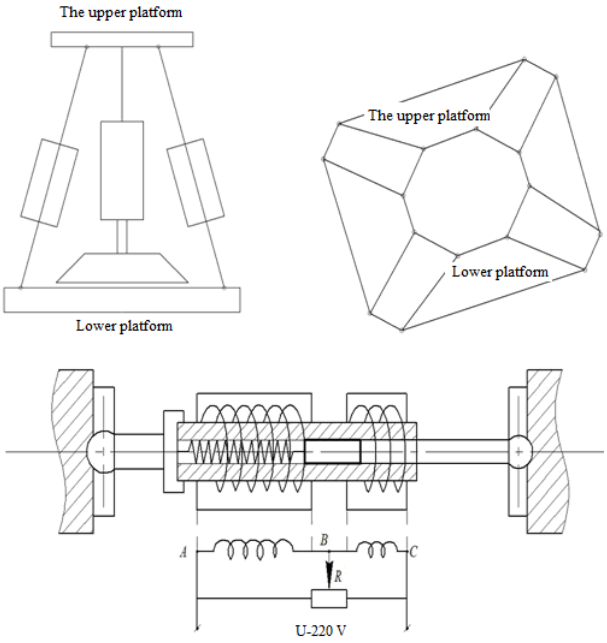

Figure 5. Block diagram of optopod

This parallel mechanism is the most common case of structural performance of the above mechanisms of parallel kinematics.

Within the dynamic analysis the solution was made for direct and inverse problems of the dynamics of the actuator [10]. Direct problem of dynamics is to determine the law of motion platform based on a given change in torque applied to the input crank actuator. Inverse dynamics is to determine the functional dependence of change of torque applied to the input crank actuator to implement a given law of motion platform. Fig. 6 clearly shows the solution of direct and inverse problems of dynamics, based on a dynamic model of the actuator.

To move the platform mechanism we proposed dynamic simulation model of management of the structural scheme presented in Fig. 7.

Immediate implementation of dynamic simulation models of parallel control mechanism in MATLAB Simulink environment is presented in Fig. 8.

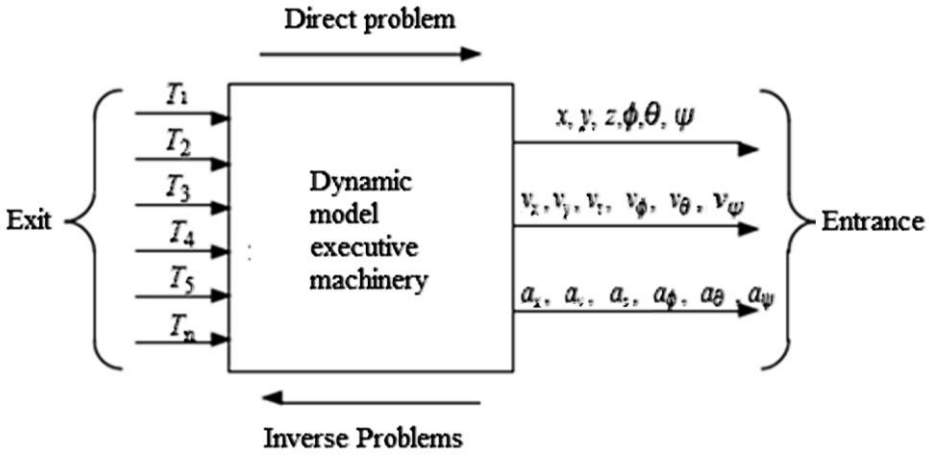

Figure 6. Diagram solution of direct and inverse problems of dynamics

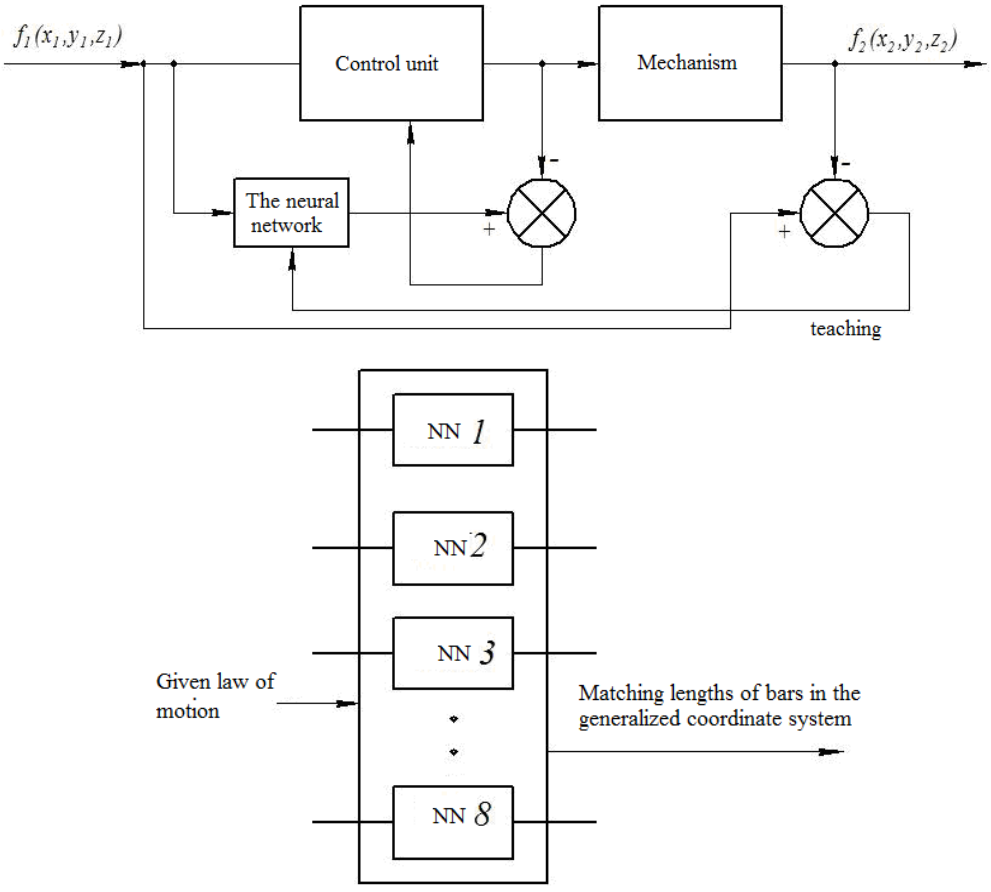

Figure 7. Scheme of dynamic simulation models of parallel control mechanism

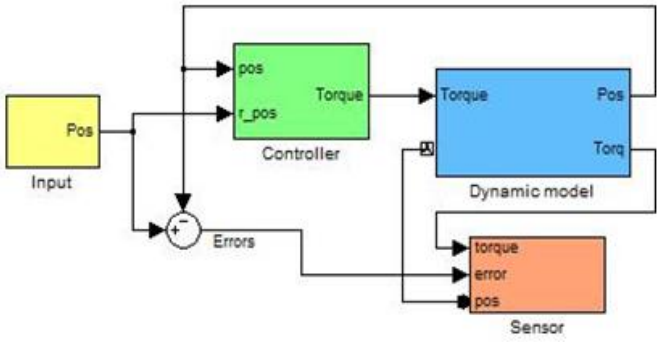

Figure 8. A dynamic simulation model of parallel control mechanism in the environment MATLAB / Simulink

4. CONCLUSION

The developed simulation dynamic model allows the simulation of a given law of motion platform parallel mechanism and receives such valued characteristics regarding speed, acceleration platform, changing the torque on the front crank, reactionary force kinematics interaction mechanism of nodes. It allows you to make a decision of direct and inverse problems of dynamics interactive visualization of spatial states of all moving parts of the implementation of precision movements programmed by many systems of movement coordination.

The obtained classification and analysis of prospects for the use of automated manufacturing equipment is based on industrial platforms with industrial platforms. It is established that the use of machines - robots based on industrial platforms can significantly increase the productivity and precision in machining geometrically complex engineering products. Also clearly expressed is the tendency to use machine tools, the layout of which is based on the principles of parallel and hybrid kinematics so as to reduce the size & weight which are of potentially large specific rigidity, increased dynamic performance, ease of manufacturability and design.

According to Fig. 8 Input function block sets the law of motion platforms and calculates the generalized angular coordinates input crank mechanism by solving the inverse problem of kinematics, the unit acts as a regulator of controller, dynamic model - a dynamic model of parallel mechanism, the Sensor gives a conclusion and performance of dynamic models.

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Tehnologije konsalting inženjeringa u proizvodnom mašinstvu inteligentnih mobilnih mašina

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Abstrakt

U radu je prikazana šema alata sa paralelnom strukturom. Takođe ovaj rad razvija dinamički simulacioni model koji omogućava simulaciju datog zakona kretanja paralelnog mehanizma platforme i daje takve vrednosne karakteristike kao što su brzina, platforma za ubrzanje, promena obrtnog momenta na prednjoj pedali, kinematiku reakcione sile mehanizma interakcije čvorova. To omogućava da odlučite o neposrednim i inverznim problemima dinamike primenom interaktivne vizualizacije prostornih stanja svih pokretnih delova koristeći precizna kretanja programirana od strane brojnih sistema koordinacije kretanja. Članak takođe daje klasifikaciju i analizu perspektive za korišćenje automatizovane proizvodne opreme bazirane na industrijskim platformama sa mehanizmima paralelne strukture. Utvrđeno je da korišćenje mašina - robota zasnovanih na ovim mehanizmima može znatno povećati produktivnost i preciznost u mašinskoj obradi geometrijski kompleksnih mašinskih proizvoda.

Ključne reči: *Paralelna kinematika mašina, neuronske mreže, kontrola, tačnost, neuronski računari.*