ANNOTATION

dissertation for the degree of Doctor of Philosophy (PhD) in the field of preparation 8D071 - “Engineering and practice of engineering”, in the educational program 8D07101 - “Mechanical Engineering”.

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RESEARCH AND DEVELOPMENT OF TECHNOLOGICAL EQUIPMENT FOR PROCESSING LONG CYLINDRICAL SURFACES

Relevance of the dissertation work. The dissertation was carried out within the framework of the state program for the development of mechanical engineering in the Republic of Kazakhstan (2010-2014) and within the framework of investment projects included in the “Industrialization Map” of Kazakhstan for 2010-2014, the State Program for Industrial-Innovative Development of the Republic of Kazakhstan (RK) for 2015 -2019 and 2020-2025, as well as the “Project to Strengthen Industrial Safety in Central Asia”, for the degree of Doctor of Philosophy PhD in the field of study 8D071 - “Engineering and Engineering”, in the educational program 8D07101 - “Mechanical Engineering”.

The issue directly related to ensuring the required technical level, as well as the economic efficiency of machine tool production, is part of the general problem of mechanical engineering. Today, due to the large-scale development of the engineering industry in Kazakhstan and the high demands placed on long cylindrical parts, the question of the need to obtain increasingly accurate and high-quality products has become acute. All this is because the accuracy of processing parts directly depends on the performance of the machine, its vibration resistance, the rigidity of its structure, and the deflection that occurs in it. When the machine is operating, individual elements of the machine - bed, base, supports - are subject to heavy loads. In this regard, the need for new technologies and materials for the manufacture of machine tool elements has increased.

There are various ways to combat the insufficient rigidity of metal-cutting machine structures. The structural forms of connecting the guides to the walls of the frame can significantly affect the balance of elastic movements of the machine, as well as the intrinsic stresses in the castings due to uneven cooling of the walls of the frame and the guides. Also, to solve existing problems, structural reinforcement is used. In such structures, the reinforcement absorbs tensile forces. For such reinforcement, high-strength steel is used; then, using calculation, a decision is made on the amount of reinforcement. Transverse rods, or stirrups, carry the lateral load of the beam. Welded reinforcement cages are also used when the reinforcement bars are connected with knitting wire. Currently, the main type of reinforcement for

reinforced concrete structures is welded reinforcement frames and meshes, which are made on special welding machines.

The disadvantages of such methods include the fact that when using standard technology for the manufacture of metal-cutting machines from cast iron and steel, the production time of the machine is extended due to the need to pre-make models and core boxes, as well as to withstand the casting before machining and after grinding for quite a long time to relieve internal stress. Possible casting defects and some defects are discovered only during machining, the need to leave fairly large allowances on the processed surfaces of the casting which entails a large consumption of metal and, consequently, an increase in costs. When castings are kept for a long time, the turnover of the enterprise's working capital slows down and the cost of unfinished products increases. Manufacturing machines from steel and aluminum also has several disadvantages, namely, when using the materials there is a large consumption of material since it is not possible to maintain sufficient structural rigidity and reduce weight.

The supporting systems of machine tools must ensure and maintain, during the required service life, the correct location and the possibility of accurate and smooth mutual movements of the tool and products when idle and during cutting.

To meet these requirements, the design of frames and body parts is currently subject to the criteria of rigidity and wear resistance of guides, as well as manufacturability conditions. As a rule, the strength conditions for these parts are automatically satisfied when choosing their dimensions and material according to the specified criteria. Calculations and design of load-bearing systems for vibration resistance have not yet been developed.

In this regard, work aimed at researching and improving the design of a long bed of a metal-cutting machine with optimized geometry and the technology of its manufacture from polymer concrete is relevant.

The research hypothesis is an assumption about the possibility of increasing the structural rigidity of a long metal-cutting machine and reducing deflection through the use of polymer concrete material, optimized geometry in the form of stiffeners with variable pitch, and increasing the wear resistance of the machine guides by applying thermal spraying.

The purpose of the study is to establish parameters and dependencies for the development of technological equipment made of polymer concrete for processing long cylindrical surfaces.

To achieve the goal, the following tasks were solved:

– Analysis of the features of existing equipment;

– Analysis of previous studies on the study of polymer concrete and identifying the features of this type of composite in the manufacture of long parts;

– Study of the characteristics of polymer concrete as the main component for the manufacture of long parts;

– Development of an optimized geometry of a metal-cutting machine bed with increased strength and rigidity without using metal;

– Ensure the possibility of manufacturing long beds and increase the wear resistance of guides;

– Reducing the cost and material consumption of long beds.

Research methods. The complex method of scientific research was the basis for the dissertation research. Theoretical research was based on the use of methods from the theory of numerical solutions of mathematical problems using computer technology and simulation, as well as scientific principles of theoretical mechanics and physical modeling.

Experimental studies consisted of conducting a passive multivariate experiment using simulation results and experimental results of small samples and data analysis in Excel.

In the process of conducting dissertation research, the following application packages were used: AutoCAD, KOMPAS-3D Viewer, EXCEL, Autodesk Inventor, BETA CAE System, ABAQUS, and META/ANSA.

The scientific novelty of the study is as follows:

– Establishment of dependencies that determine the optimal geometry of the bed of a metal-cutting machine based on curved stiffeners with variable pitch for processing long parts;

– Establishing the dependence of the influence of geometric parameters of curved ribs on the rigidity of the frame;

– Establishing the dependence of the influence of the mixing time of the components of the polymer concrete mixture, the rotation speed of the mixer working body on the geometry of the long bed of a metal-cutting machine;

– Establishment of technological dependencies when applying wear-resistant coatings on polymer concrete surfaces.

Scientific provisions submitted for defense:

– Results of an experimental study of the strength properties of various polymer concrete compositions for the manufacture of a long bed of a metal-cutting machine.

– Results of an experimental study of a statically indeterminate long bed of a metal-cutting machine in compression.

– Technological process of applying thermal spraying to the guides of a long metal-cutting machine.

– Dependence of the optimal geometry of a metal-cutting machine on the geometric parameters of the stiffeners, the mixing time of the components of the polymer concrete mixture, and the rotation speed of the mixer's working body.

– Results of modeling of various designs of long frames of metal-cutting machines using the BETA CAE System, ABAQUS software package, using the finite element method.

The author defends:

1. Constructive decisions
2. Mathematical model
3. Experimental results
4. Spraying technique

The object of study serves as the bed of a metal-cutting machine for processing long surfaces.

Subject of study - optimal geometry of a metal-cutting machine bed for processing long surfaces.

Practical significance research is:

– The use of a new frame design made of polymer concrete will make it possible to manufacture long products;

– To obtain the opportunity to manufacture technological equipment in the conditions of interested enterprises that cannot manufacture metal frames;

– Thermal spraying will improve the wear resistance of the guides of the metal-cutting machine bed.

The research results are formalized using the appropriate method and implemented into the work process of HansaFlex – Gidravlik LLP.

Summary.

In the first chapter, an analysis of the state of the problem of technological equipment for processing long cylindrical surfaces is carried out. The geometries of metal-cutting machine bed structures used for processing long cylindrical surfaces have been studied. The problems that arise when processing long parts are studied. An analysis of the use of various materials and manufacturing technologies for metal-cutting machine beds was carried out.

In the second chapter, the optimal geometry of the bed of a long metal-cutting machine was designed and rational compositions of polymer concrete and thermal spraying were found. The selection of geometry optimization parameters and the selection of the optimal design of the bed of a long metal-cutting machine were made. The influence of internal force factors was calculated and the dangerous sections of a long metal-cutting machine bed were determined. A technology has been developed for designing the bed of a long metal-cutting machine with optimized geometry. A rational composition of polymer concrete for the manufacture of a long frame of a metal-cutting machine was found, and the strength properties of the samples were studied using the finite element method. The selection of the compositions of powder mixtures, experimental experiments on the application of coatings and studies of the properties of the resulting layers of gas-thermal spraying on the guides of a long metal-cutting machine were carried out.

In the third chapter, mathematical modeling of a long bed of a metal-cutting machine made of polymer concrete with optimized geometry is carried out. A modal analysis of metal-cutting machine bed housings made of polymer concrete and gray cast iron was carried out. A static analysis of a long bed of a metal-cutting machine was carried out using the finite element method using the BETA CAE System,

ABAQUS software package. During the modeling, the maximum deformations were determined, and local stresses of the models were identified, and the results were compared with each other for different geometries of metal-cutting machine beds.

The fourth chapter presents the methodology and results of experimental studies. The planning of a full factorial experiment was carried out, the influence of the spiral pitch, the rotation speed of the mixer working body and the time of mixing the mixture on the strength of the structure on the deflection of a long frame of a metal-cutting machine was considered.

In the fifth chapter, a technical and economic calculation was made for the manufacture of a long frame of a metal-cutting machine made of polymer concrete with optimized geometry in the form of stiffeners with variable pitch. The total cost of the product was calculated, the profit of the enterprise and the payback period for the product were determined.

Personal contribution of the dissertation candidate. The work was carried out by the author personally, the author performed a patent analysis of known designs, a review of theoretical research in the field of metal-cutting machines. The task was set and a research methodology was developed, the geometry of a long bed of a metal-cutting machine was designed and modeled, the optimal compositions of polymer concrete and thermal spraying were determined, experimental studies were organized and carried out to determine the strength properties of a long bed of a metal-cutting machine made of polymer concrete with optimized geometry.

Publication and testing of the work. The main provisions of the dissertation were published in 11 scientific papers in Russian and English, including 2 articles in an international scientific publication, according to the Clarivate database or included in the Scopus database (Applied Sciences (Switzerland) 75% (Q1), Coatings 64% (Q2)), 2 articles in publications recommended by the Committee for Quality Assurance in Education and Science of the Republic of Kazakhstan. The reports of the presented work were reviewed at 5 international conferences and received 1 patent of the Republic of Kazakhstan for a utility model and 1 certificate of state registration of rights to an object of copyright. All publications present materials and results of theoretical and experimental studies of manufacturing a long bed of a metal-cutting machine made of polymer concrete. Additionally, the dissertation materials are presented in 6 theses of international scientific-practical and scientific-methodological conferences. The research results were reported and discussed at international scientific conferences: XIX International scientific and practical conference “International innovation research”, (Penza, 2019), International scientific and practical conference “Integration of science, education and production - the basis for the implementation of the Nation’s Plan” (Saginovsky readings No. 11), (Karaganda, 2019), International scientific and practical conference “Integration of science, education and production - the basis for the implementation of the Nation’s Plan” (Saginovsky readings No. 12), (Karaganda, 2020), International Scientific and Practical Conference “Integration of Science,

Education and Production - the Basis for the Implementation of the Nation's Plan" (Saginov Readings No. 13), (Karaganda, 2021), X International Scientific and Practical Conference "Mechanical Engineering Engineering and Technologies" (Omsk, 2021), International scientific and practical conference "Integration of science, education and production - the basis for the implementation of the Nation's Plan" (Saginov Readings No. 15), (Karaganda, 2023).

Structure and scope of the dissertation. The dissertation work is presented on set out on 152 pages of typewritten text, consists of symbols and abbreviations, an introduction, 5 sections and a conclusion, which are explained by 64 drawings, 34 tables, a list of references of 128 titles.

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Research results and main conclusions. The dissertation contains new scientifically substantiated results, the use of which provides a solution to the important applied problem of developing an optimal design for a long bed of a metal-cutting machine:

1) The available types of designs of long frames of metal-cutting machines have been studied. The optimal design was chosen with optimized geometry in the form of stiffeners with variable pitch.

2) The possibilities of replacing the material of a long bed of a metal-cutting machine have been studied. Polymer concrete with composition No. 2 was chosen as the optimal material.

3) The possibilities of using thermal spraying to increase wear resistance and reduce stress on the guides of long metal-cutting machines have been studied. The composition chosen as the optimal composition is Ni-7Cr-3Fe + 60%WC.

4) An empirical multiple regression equation was obtained for determining the deflection depending on the spiral pitch, the rotation speed of the mixer working body and the mixture mixing time and has the form: $Y= -0.029 + 0.002X_1+ 2.468X_2 - 0.0001X_3$.

5) The design of a long lathe with optimized geometry in the form of stiffening ribs with variable pitch made of polymer concrete was designed, the design at the junction of the beam support on the pedestals was changed to reduce stress. Thanks to optimization, stresses that arose due to insufficient rigidity of cast iron structures were reduced.

6) An optimal technology for manufacturing a long metal-cutting machine with optimized geometry from polymer concrete has been developed.

7) An optimal technology for applying thermal spraying to the guides of a long metal-cutting machine has been developed.

8) The annual economic effect of using the proposed manufacturing method is 4,524,008 tenge. The payback period was 2 years.