SUMMARY

to the dissertation for the degree of Doctor of Philosophy (PhD)
in the training area 8D071 – Engineering,
in educational program 8D07101– Mechanical Engineering

Karsakova Nurgul Zholayevna

INCREASING ACCURACY AND QUALITY OF MANUFACTURING LARGE-SIZED PARTS

Statement of the problem and relevance of the study. The main trend of mechanical engineering development, in particular heavy mechanical engineering, are considered in the state program of the mechanical engineering development in the Republic of Kazakhstan (2010-2014) and within the framework of investment projects included in the "Industrialization Map" of Kazakhstan for 2010-2014, as well as the State Industrialization Program: innovative development of the Republic of Kazakhstan (RK) for 2015-2019 and 2020-2025. In the Comprehensive Plan of the Engineering Industry Development in the Republic of Kazakhstan for 2024 - 2028, special attention is paid and support is provided from the state to further increasing the competitiveness of the domestic engineering industry.

The development of advanced industries of the Republic of Kazakhstan, such as chemical, oil, geological exploration, metallurgy, etc. directly depends on the quality of manufacturing machine parts and technological equipment.

At present, manufacturing and repairing large-sized parts of technological equipment are mainly carried out by heavy engineering plants, in particular by the Petropavlovsk Heavy Engineering Plant JSC (Petropavlovsk), the Almaty Heavy Engineering Plant JSC (Almaty) and the Maker LLP – KLMZ (Karaganda).

The analysis of the state of domestic machine-building plants has shown that there are problems in manufacturing large-sized parts of technological equipment associated with ensuring the required accuracy and quality of machining and control of critical surfaces.

Such parts include the frame of submersible pumps. The NP8 frame of a submersible pump is its supporting part, on which the components and parts of the pump are mounted and to which particularly high demands are placed in terms of its strength, rigidity and manufacturability.

The main manufacturer of submersible pump frames in the Karaganda region is the Maker LLP - KLMZ and the QazKarbon LLP. The technological process of machining the frame of a submersible pump is developed in different ways, depending on the level of technological support of a particular machine-building enterprise. High requirements for ensuring the quality of machining and the accuracy of surface location are imposed on stepped hole surfaces. Ensuring the required quality of machining and the accuracy of location of these surfaces is complicated and sometimes completely difficult to ensure. This can be caused by

the appearance of vibrations, errors in positioning the part and securing technological and tool equipment, wear of the cutting tool, control accuracy, etc.

It has also been revealed that there is insufficient research in the field of establishing relationships between the quality of machining large-sized parts and vibrations of the cutting tool, errors in positioning the part and securing technological and tool equipment, wear of the cutting tool, and control accuracy.

In this regard, studies aimed at solving the problem of ensuring the quality of machining and the accuracy of the location of stepped surfaces of holes in large parts are an urgent task.

The purpose of the work is to improve the accuracy and quality of manufacturing large-sized parts by developing and using special designs of cutting tools and instrumentation.

The object of the study. Methods of machining and methods of monitoring stepped holes of large parts.

The subject of the study. Regularities of the process of boring stepped holes of large parts.

Research methods. To conduct the research, the following methods were used: analyzing the manufacturing technology of large-sized parts of technological equipment, experimental research, planning and processing the results, controlling stepped holes, computer modeling of a special boring bar design and a combined boring tool.

The study objectives

1. Analyzing the problem of ensuring the accuracy and quality of manufacturing large-sized parts in the conditions of domestic engineering production.

2. Studying the existing machining and control methods, as well as the design of cutting tools and control and measuring equipment used in the manufacturing of large parts.

3. Developing a boring tool design for simultaneous machining of stepped holes in large parts.

4. Optimizing and calculating the design of a boring tool for static rigidity and strength, as well as studying the effect of amplitude-frequency characteristics of the tool on the machining accuracy by modeling in the ANSYS Workbench computer program.

5. Experimental studying the process of simultaneous boring stepped holes with a special boring tool;

6. Testing a prototype of a special bore gauge for monitoring the holes of large parts.

7. Calculating the economic efficiency of the developed technology and developing recommendations for implementation in the production conditions.

Scientific novelty of the work consists in the following:

1. It has been experimentally established that with the simultaneous machining of stepped holes, the effect of cutting conditions on the quality indicators of the machined surface is ambiguous:

- increasing the spindle speed and the depth of cut has a positive effect on the roughness of the machined surface but has a negative effect on hardness;

- increasing the feed has a negative effect on roughness, while it has a positive effect on the hardness of the machined surface.

2. It has been established that with simultaneous machining stepped holes at optimal values of the cutting mode (S=0.26 mm/rev; *n*= 1250 rpm/min; *t=1.0 mm)* there is provided: *Ra≤1.25 μm; HB kgf/mm*^{2}.

3. As a result of experimental studies, the following dependences were established:

– to assess the machined surface roughness

$Ra = 2.6 \cdot \lg(X_1) + 1.35 \cdot e^{2,34X2} + 9.42e^{-1,16 \cdot 10\text{-}3 \cdot X3} - 3.868;$

– to assess the machined surface hardness

$HB = 50.344 \cdot X_1^2 - 66.81 \cdot X_1 + (X_2/(2.2 \cdot 10^{-4} + 4.31 \cdot 10^{-3} \cdot X_2)) - 3.2 \cdot 10^{-5} \cdot X_3^2 + +3.56 \cdot 10^{-2} \cdot X_3 + 416.58.$

4. For the first time, using the ANSYS Workbench computer program, the design of a special boring bar was calculated for static rigidity and strength, and the influence of the amplitude-frequency characteristics of a combined boring tool on machining accuracy was studied. As a result, it was found that:

- the deformation value at the tip of the cutting insert is 23.8 μm in the axial direction and 36.2 μm in the radial direction;

- at values of cantilever overhang of boring cutters of 95 mm and 108 mm, the conditions for static rigidity of the boring tool are met;

- radial movement in the boring tool cutter at the optimal frequency (v = *20.83 Hz*) is 9.9 μm and at the resonant frequency (v_p = *1167.1* Hz) 67.2 μm, that is 7 times higher.

Provisions submitted for defense

1. A method of simultaneous machining stepped holes and the design of a special combined boring tool.

2. A method of monitoring large diameter holes and the design of a special bore gauge.

3. The results of an experimental study of the process of simultaneous boring stepped holes with a special combined boring tool.

4. Equations for the surface roughness and hardness dependence on the cutting conditions after machining with a special combined boring tool.

5. The results of calculating the design of a boring tool and studying the effect of the amplitude-frequency characteristics of the tool on the machining accuracy using the ANSYS Workbench program.

The validity and reliability of scientific propositions, conclusions and results is confirmed by the correctness of the problem statement and the adequacy of theoretical and experimental research. There was received a Republic of Kazakhstan patent for the design of a special boring bar. The method of studying the effect of the amplitude-frequency characteristics of a combined boring tool on the accuracy of machining stepped holes, calculating the design of a boring bar for static rigidity and strength, as well as the method of optimizing the design of a special boring bar for machining stepped holes, received a certificate of the

Republic of Kazakhstan on state registration of rights to the copyright object for intellectual property.

Practical significance consists in the development of a method of simultaneous machining stepped holes, designs of a special boring bar, a combined boring tool and a special bore gauge, as well as a methodology of studying the effect of the amplitude-frequency characteristics of a combined boring tool on the accuracy of machining stepped holes, calculating the design of a boring bar on static rigidity and strength, optimizing the design of a special boring bar for machining stepped holes and recommendations for production.

The author's personal contribution consists in setting problems and developing research methods, developing the design of a special boring bar, developing the design and manufacturing of a special combined boring tool and bore gauge for monitoring holes, determining optimal machining modes, organizing and conducting experimental studies of simultaneous machining stepped holes.

The dissertation work is aimed at fulfilling the main objectives of the State Program for Industrial and Innovative Development of the Republic of Kazakhstan for 2015-2019 and 2020-2025 and has been executed within the framework of the initiative theme of the Technological Equipment, Mechanical Engineering and Standardization" (TEMES) Department "Developing resource-saving technologies of machining large-sized parts". The main results of the dissertation were introduced into the production of the Maker LLP - KLMZ and into the educational process of A. Saginov Karaganda Technical University NPJSC (A. Saginov KTU) in training bachelor and master students in the Mechanical Engineering specialty.

Approbation of the work. The main provisions of the doctoral dissertation were reported and discussed at the meetings of the TEMES Department of A. Saginov Karaganda Technical University NPJSC (2019-2022), at the meeting of the Mechanical Engineering Technology Department of Saratov State Technical University (2021), at the meeting of a scientific seminar of the DC at A. Saginov KTU, as well as at international conferences and workshops of machine-building enterprises:

- an international scientific and practical conference on integrated innovative development of the Zarafshan region: achievements, problems and prospects (Navoi, 2024);
- an international multidisciplinary conference "The latest scientific research" (USA, 2024);
- an All-Russian scientific and technical conference with international participation "Mechanics for the 21st century" (Bratsk, 2024)
- at the technical meeting of Maker LLP - KLMZ, Karaganda, 2020.

Publications

Based on the results of the doctoral dissertation, 15 works were published in Russian, Kazakh and English, including 4 articles in the international scientific editions, according to the Clarivate database or included in the Scopus database, 3 articles in the editions recommended by the Committee for Quality Assurance in Education and Science of the Republic of Kazakhstan, 1 article in another edition.

The reports of the presented work were reviewed at 3 international conferences. A patent of the Republic of Kazakhstan for a utility model and 3 certificates of state registration of rights to an object of copyright were received.

Scope and structure of work. The doctoral dissertation consists of an introduction, 5 chapters and a conclusion, set out on 154 pages of typewritten text, is explained with 69 figures, 16 tables, a list of references of 113 titles, 9 appendices.

Conclusion

The scientific study carried out in domestic engineering production has shown that there is a problem in manufacturing of large-sized parts. It has been revealed that the most labor-intensive task is to ensure the accuracy and quality of machining stepped holes of large diameters. When carrying out research work aimed at solving this problem, the following results were obtained.

1. A method of the simultaneous machining of stepped holes has been developed, designs of a special boring bar and a combined boring tool have been developed, and a prototype of a combined boring tool has been manufactured.

2. A method of monitoring large diameter holes and the design of a special bore gauge have been developed, and a prototype has been manufactured.

3. When designing the boring tools using the ANSYS Workbench computer program, the design of a special boring bar was calculated for static rigidity and strength, and the effect of the amplitude-frequency characteristics of a combined boring tool on the machining accuracy has been studied.

4. For simultaneous machining stepped holes, the optimal values of cutting modes have been determined: S = 0.26 mm/rev; n= 1250 rpm; t=1.0 mm.

5. As a result of experimental studies, the following dependences were established:

– to assess the roughness of the machined surface

$Ra = 2.6 \cdot \lg(X_1) + 1.35 \cdot e^{2,34X2} + 9.42e^{-1,16 \cdot 10\text{-}3 \cdot X3} - 3.868;$

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$HB = 50.344 \cdot X_1^2 - 66.81 \cdot X_1 + (X_2/(2.2 \cdot 10^{-4} + 4.31 \cdot 10^{-3} \cdot X_2)) - 3.2 \cdot 10^{-5} \cdot X_3^2 + +3.56 \cdot 10^{-2} \cdot X_3 + 416.58.$

6. The annual economic effect from using the proposed technological process of manufacturing one part “frame” of a submersible pump is 26,375.325 tenge. At the same time, the economic effect on the annual production program of the “frame” part is 1,055,013 tenge.

7. The results of the dissertation work have been introduced into the production of the Maker LLP - KLMZ. The expected economic efficiency is ~ 1.2 million tenge per year.