ANNOTATION

of the thesis on for the degree of Doctor of Philosophy (PhD)
in the specialty 6D071200 Mechanical Engineering

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Research and Development of a Method for Ensuring Wear Resistance, Rigidity and Strength of Thermofriction Cutting Tools

Relevance of the research. Currently, significant work is being carried out on the further development of the machine-building industry in the Republic of Kazakhstan, one of which is the approval of a roadmap (comprehensive plan) for the development of machine-building for 2019-2024.

The main goal of the roadmap is to increase the competitiveness of domestic machine-building enterprises, introduce new technologies and increase the export potential of the industry.

The efficiency of machine-building production depends on many factors, among which metal-cutting tools occupy an important place. Tool failure most often occurs due to wear of the cutting edges (up to 75%). This is especially noticeable when processing difficult-to-machine materials, which are widely used in all industries, since the complexity of processing the workpiece for these materials corresponds to the service life of the tool.

In the context of global development, the solution to these problems is the development of a method of machining and design of metal-cutting tools that meets such requirements as high quality, productivity, resource conservation, availability, etc.

One of such methods of mechanical processing is thermofriction methods of processing with impulse cooling, developed at the Department of Technological Equipment, Mechanical Engineering and Standardization (TEMEandS) of Karaganda Technical University (KTU).

The essence of the cutting mechanism lies in the localization of the thermal and deformation fields in the workpiece, which makes it possible to transfer the external friction between the tool and the cut material into the internal one. In this case, friction occurs between the layers of the cut material. This technology makes it possible to carry out the process of cutting metal blanks on conventional machines with a spindle assembly with a rotational speed of n = 2000-3500 rpm. This ensures the quality of the treated surface and significantly reduces the cost of processing. The main difference between the traditional and the proposed thermofriction treatment is a significant reduction in the required number of revolutions, which in turn leads to a significant reduction in electricity consumption.

However, despite the decrease in cutting speeds, there is wear on the cutting friction discs, which has a negative effect on the quality indicators of thermal friction treatment.

In this connection, the thesis aimed at increasing the wear resistance, strength and rigidity of thermofriction cutting tools **is relevant**.

Purpose of work: increase the wear resistance, rigidity and strength of thermal friction cutting tools.

Research problem:

- research and analysis of the problem of wear resistance, rigidity and strength of thermofriction tools;
- research of existing methods and methods for improving the wear resistance, rigidity and strength of thermofriction tools;
- research of existing wear-resistant surfacing materials and methods of surfacing;
- experimental study of the process of surfacing of thermofriction tools made of various materials, as well as structural and metallographic study of the quality of the deposited layers
- disclosure of the relationship between the surfacing modes, the surfacing material, the number and thickness of the deposited layers while ensuring quality, depending on the material of thermofriction tools;
- a pilot study to test the weld thermofriction tools;
- modeling of the thermal state, the rigidity and strength of thermofriction instruments using special computer programs;
- development of recommendations for implementation in production.

Object of research: ways to increase the wear resistance, stiffness and strength of thermofriction cutting tools.

Subject of research: laws governing the process of surfacing the working surfaces thermofriction tools.

Research methodology. The tasks set in the work were solved by practical and theoretical methods. The theoretical studies considered: the design of metal-cutting tools, the technology of stamping worn surfaces, the theory of cutting materials, mechanical engineering technology, metal technology, and the foundations of materials science. The experimental studies were carried out in the conditions of the scientific laboratory base of the Department of TEMEandS, KTU. The surfacing process was carried out on the basis of the laboratory of the Kazakhstan Institute of Welding at KTU**.**

Metallographic studies of the hardness and structural quality of the molten layers were carried out using the equipment of the engineering testing laboratory “Integrated development of mineral resources” on the basis of KTU. Non-destructive testing of thermofrictional cutting tools with surfacing was carried out under the conditions of the private institution of “Certification Center for Non-Destructive Testing”, testing laboratory of “Independent Non-Destructive Testing and Diagnostics” (Karaganda).

The planning of experiments and the processing of the results were carried out using well-known techniques. The study of thermal processes and heat transfer during melt processing by thermofrictional means was carried out using the

Explicit-Dynamic ANSYS program and modeling using finite elements in the DEFORM-3D program.

The scientific novelty of the work consists in:

- in the scientific justification and development of a method for improving the wear resistance, stiffness and strength of thermofriction tools, which includes:
  - method selection of the brand of surfacing materials, method of welding and of optimum modes of welding;
  - determination of the optimal thickness and number of layers to be deposited for each design of the thermofriction tool;
  - determination of the pattern of the relationship of modes of surfacing, surfacing material, thickness and number of deposited layers, providing quality welding depending on the material thermofriction tool.
- for the first time a mathematical model is proposed for determining the thickness of the deposited layer depending on the material of the thermofriction tool;
- performed for the first time:
  - modeling the thermal state, stiffness, and strength of thermofriction tools with surfacing using the Explicit-Dynamic PC (ANSYS);
  - analytical calculation of the strength thermofriction tool.

The main provisions submitted for protection:

- method of increasing the wear resistance, stiffness and strength of thermofriction media-surfacing;
- results of an experimental study of the process of surfacing thermofriction tools made of various materials, as well as structural and metallographic studies of the quality of the deposited layers;
- surfacing modes, surfacing material, the number of deposited layers and the relationship between their thicknesses in ensuring the quality of surfacing, depending on the material of thermofriction means;
- mathematical model for determining the thickness of the deposited layer depending on the surfacing mode;
- a method for modeling the thermal state, stiffness, and strength of deposited thermofriction tools using the Explicit-Dynamic (ANSYS) program.

Practical significance and application of research results:

- designs of heat-friction tools covered with wear-resistant surfacing, such as rotary-friction cutters, friction cutters, circular saws and cone friction cutters;
- surfacing of thermofriction tools with surfacing materials (STOODY M7-G, STOODY 102-G and OK TUBRODUR 58 O/G M) increased their wear resistance, rigidity and strength in comparison with traditional thermofriction tools by 1.5-2 times;
- developed methods for determining thermal processes, as well as the stress-strain state of the tool structure during processing with thermofriction tools with surfacing;
- developed recommendations for production.

The research was carried out as part of the implementation of the roadmap (comprehensive plan) for the development of mechanical engineering in the Republic of Kazakhstan for 2019-2024. The results of the dissertation work were introduced into the production of MEGA GROUPKZ LLP, as well as into the educational process of Toraighyrov University in the training of bachelors and masters in mechanical engineering.

Approbation of work. The main provisions of the dissertation work are described and discussed:

- international scientific-practical conference Saginov reading (Karaganda, 2018-2020);
- international scientific and technical conference of young scientists "New Materials, Equipment and Technologies in Industry"(Mogilev, Belarus, 2018);
- international scientific and practical conference "Modern Technologies in Mechanical Engineering and Foundry Production"(Cheboksary, Russia, 2018);
- scientific seminars of the Department "Technological Equipment, Mechanical Engineering and Standardization"(2017-2020);
- scientific seminars of the dissertation Council for the defense of doctoral dissertations in the specialties 6D071200 "Mechanical Engineering", 6D071300 "Transport, Transport Equipment and Technology"(2018-2020);
- at scientific seminars of the Department of Mechanical Engineering Technology of the Saratov state Technical University named after Yu. a. Gagarin and its branch of the Department of materials processing Technologies of the Engels Institute of Technology (Engels, Russia, 2018);
- at the expanded scientific and technical seminar of the Energy and Mechanical faculty of the Navoi State Mining Institute (Navoi, Uzbekistan, 2019);
- at the scientific seminar of the Department "Production of Building Materials, Products and Structures" of the Samarkand State Institute of Architecture and Construction (Samarkand, Uzbekistan, 2019.);
- at the technical meeting of INTECHCOM LLP (Saratov, Russia, 2018).

The author's personal contribution consists in the analysis of scientific, technical and patent literature on this problem, the formulation and development of research tasks for methods of increasing the wear resistance, rigidity and strength of thermofriction cutting tools; design and manufacture of constructions of thermofriction tools with surfacing, having a special composition, organization and performance of experimental research, generalization of the results of research work at scientific seminars of the departments of related domestic and foreign higher educational institutions, as well as approbation at domestic and international scientific and practical conferences.

Information about publications. The main provisions and the results of the thesis were published in 17 journals, including 3 in the journal list of SCOPUS publishers, 5 – in journals recommended KKSON MES RK, 1 – in international scientific journals and 5 in proceedings of international conferences, including 2 in foreign international conferences, 2 patents for inventions and utility models, 1 – the certificate of state registration of copyright on intellectual property.

CONCLUSION

As a result of research and analysis of the issue of wear resistance, strength and rigidity of thermofriction tools, it was revealed that, despite the decrease in cutting speeds, there is wear of thermofriction cutting tools, which has a negative effect on the quality of processing. In order to solve this problem, a research was carried out and the following results were achieved:

1. A method has been developed to increase the wear resistance, strength and rigidity of thermofriction tools, which includes:

- surfacing materials of STOODY M7-G, STOODY 102-G and OK TUBRODUR 58 O/G M, which have high hardness, wear resistance and temperature resistance, have been identified;
- it has been found that for surfacing of the cutting part of thermofriction tools, it is sufficient to perform a two-layer surfacing. In this case, the thickness of the first and second layers should be 4 and 2 mm, respectively;
- designs of thermofriction tools coated with wear-resistant surfacing have been created, such as rotary frictional cutters, friction cutter for thermo-friction milling, circular saw and cone friction cutter;
- thermofriction tools deposited with materials of STOODY M7-G, STOODY 102-G and OK TUBRODUR 58 O/G M showed that wear resistance, stiffness and strength have been increased by 1.5 ÷ 2 times compared to traditional thermofriction tools.

2. A mathematical model has been developed to determine the thickness of the deposited layer depending on the surfacing modes:

$$y = 13{,}867 - 0{,}0385 \cdot z_1 - 0{,}01612 \cdot z_2 - 0{,}1934 \cdot z_3 + 0{,}00144 \cdot z_1 \cdot z_3$$

3. A technique has been developed for modeling the thermal state, rigidity and strength of thermofriction tools with surfacing using the Explicit-Dynamic (ANSYS) PC, and an analytical calculation of the strength of a thermofriction tool has been performed.

4. The results of the thesis have been introduced into the production of MEGA GROUPKZ LLP, which allows to reduce the cost of processing the outer cylindrical surfaces by 2-3 times, by reducing the transitions of the turning operation and reducing the cost of cutting tool material. The expected economic effect is ~ 1.6 million tenge per year.