ABSTRACT
of the dissertation for the doctor of philosophy (PhD) degree in the specialty 6D071200 - "Mechanical engineering"

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Optimization of cutting modes for heat-friction processing of hard-to-process materials based on the study of physical and mechanical properties of the surface layer

Statement of the problem and the relevance of the study. To improve the quality of engineering products is the problem of obtaining high-quality surfaces of machinery, part of which are the roughness portion of the workpieces during cutting. The quality of product planes is determined by their geometry, the stresses that remain after the load is removed, structure and service characteristics. The depth and surface quality depend on the base material, the type of processing, geometry of tool, machining modes and properties of cutting fluid. It is especially difficult to cut materials with high hardness and viscosity, which will lead to rapid premature wear and salting of the tool teeth. These materials include materials based on tungsten, nickel, molybdenum, complex alloy steels, titanium alloys, and low-carbon steels.

To solve the problem of processing such materials at the "Technological equipment, mechanical engineering and standardization" department of Karaganda technical university, a promising method of thermo-friction cutting (TFC) with pulse cooling was developed, which is implemented at low speeds and is resource-saving. The implementation of this method allows you to reduce costs: for electricity (no more than 7-10 kW), for tools (the cutting disc is made of St.45, St.50, etc.) and, which in turn, can be the only possible solution for processing such materials. However, the research has shown that the physical and mechanical properties of the processed material have an ambiguous effect on the choice and purpose of cutting modes and tool geometry.

Formation of the surface layer of the part during thermal friction processing by the stress-strain state of the cutting zone, optimization of cutting modes during thermal friction processing by studying the physical and mechanical properties of the processed material, including studies of the influence of cutting modes, tool geometry, the number of frequency cycles "heating-cooling", temperature distribution deep into the workpiece from the "disk-workpiece" contact of the treated surface **is relevant**.

The aim of this work is to increase the efficiency of thermal friction processing by optimizing cutting modes based on the study of the physical and mechanical properties of the surface layer.

Object of research: Method of heat-friction cutting of hard-to-process materials with pulse cooling.

Subject of research: the status of the surface layer and thermal processes in thermal friction segment with pulsed cooling at different cutting conditions and geometry of the tool.

Research objectives:

1. Study the state of the problem and analyze the factors that determine the quality of the surface layer.

2. Investigation of the physical and mechanical properties of the surface layer and thermal phenomena in the "tool-workpiece" contact zone.

3. Investigation and refinement of the cutting mechanism and the time of establishing the process of TFC with PC. Determination of optimal cutting modes and tool geometry for cutting difficult-to-process materials and materials that are difficult to cut due to computer modeling.

4. Investigation of the state of the surface layer (distance of stress dispersion, hardening) in the TFC with PC.

5. Experimental studies of the influence of cutting modes and the geometry of a circular saw on the quality indicators for TFC with PC of various materials. Optimization of cutting modes and tool geometry.

6. Calculation of the economic efficiency of the proposed technology and development of recommendations for production.

The scientific novelty of the work is as follows:

- optimal processing modes and geometric parameters of the circular saw for cutting various materials are established;

-regularities of temperature distribution and its influence on the physical and mechanical properties of the processed material are established;

- empirical dependences for determining the surface roughness and hardness when cutting different materials are revealed;

- for the first time in a pulse-cooled TFC, depending on the cutting modes and geometry of the circular saw, a DEFORM-3D software was used to obtain:

* confirmation of the hypothesis about the mechanism of cutting TFO with pulse cooling and the time of setting the processing process 0.0024÷0.0250 seconds;

• the value of the distance of the temperature distribution deep into the workpiece from the "tool-workpiece" contact is 0.74÷1.02 mm and the thickness of the contact layer is 0.0112÷0.076 mm.

Provisions for protection:

- results of experimental research and computer modeling to optimize cutting modes and tool geometry for thermal friction cutting of hard-to-process materials with pulse cooling;

- regularities of temperature distribution and its influence on the physical and mechanical properties of the processed material;

- empirical dependences for determining the surface roughness and hardness when cutting different materials;

- a method for determining the influence of cutting modes and the geometry of a circular saw on the temperature distribution deep into the workpiece during a thermal friction cutting with pulse cooling.

The validity and reliability of scientific statements, conclusions and results is confirmed by the correctness of the problem statement, the adequacy of theoretical and experimental research. Patents of the Republic of Kazakhstan (RK) were obtained for the design of a circular saw and a device for pulse-cooled TFC. A certificate of the Republic of Kazakhstan on state registration of intellectual property rights to the object of copyright was obtained for the method of determining the influence of cutting modes and the geometry of a circular saw on the temperature distribution deep into the workpiece in the TFC process with pulse cooling.

The practical significance is to develop a special design of circular saw blades and methods of determining the influence of cutting conditions and geometry of circular saws on the temperature distribution into the workpiece in the TFC process with pulse cooling, as well as creating devices that allow the flow of pulsed cooling in the process of parting and recommendations for production.

The author's personal contribution consists in setting tasks and developing research methods; developing and manufacturing special designs of circular saws and creating a device that allows pulse cooling during cutting; obtaining regression models for determining optimal cutting modes; organizing and conducting experimental studies of the TFC of hard-to-process materials.

The thesis work aims at performing the basic tasks of the State program of industrial-innovative development of Kazakhstan for 2015-2019 and is designed in the framework of the initiative themes of the TEME&S department "Development of technology of thermal friction processing of difficult materials with pulsed cooling, allowing the replacement of carbide tool material on structural steel". As well as the main results of the dissertation are implemented in the production of LLP “Inkar-1”, in the educational process of the NPJSC "Karaganda industrial university" for training bachelors and masters in Mechanical engineering and Technology of materials processing by pressure.

Testing the work. The main provisions of the dissertation were discussed at meetings and scientific and technical councils of the departments: "Technological equipment, mechanical engineering and standardization" of Karaganda technical university, "Metal forming" of Karaganda industrial university, "Equipment and materials processing technologies" of Engels technological Institute of Saratov state technical University named after Yu.A. Gagarin; at the expanded scientific and technical seminar of the Energy and mechanical faculty of the Navoi state mining institute, as well as at international conferences and workshops of machine-building enterprises of “Intechcom” LLC and “Inkar-1” LLP.

Publications. According to the results of the doctoral dissertation, 16 papers were published in Russian, Kazakh and English, including: 1 article in an international scientific publication, according to the Web of Science database or included in the Scopus database, 1 article in journals included in the RSCI database, 6 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, including 3 foreign ones. 2 patents of the Republic of Kazakhstan for a utility model and 1 certificate of state registration of rights to the object of copyright were obtained.

Conclusion. 1. Factors that determine the quality of the surface layer that have a different character depending on the processed material and processing conditions are studied.

2. Regularities of temperature distribution and its influence on the physical and mechanical properties of the processed material are established.

3. Hypothesis of the mechanism of thermal friction cutting with pulse cooling is confirmed, the dimensions of the molten, heated and hardened layer are determined using the computer program DEFORM and the time of setting the processing process in the range of 0.0024÷0.0250 seconds;

4. Based on the results of the study of the surface layer, the optimal processing modes and geometric parameters of the circular saw for cutting various materials are established;

5. Based on the results of the experiment, empirical dependences are calculated for determining the surface roughness and hardness when cutting various materials;

6. Annual economic effect of the implementation will be 22.216 million tenge.

Conclusion. In the dissertation, the study of the state of the domestic machine-building enterprises revealed that there is a problem ensuring the quality and productivity for cutting operations, from which performance depends on the quality and effectiveness of further mechanical operations of the technological process. It is established that the most exposed to the operation of the segment are bar blanks. Also, if the cutting operation is final, it may be subject to high requirements regarding structural changes deep from the end surface, which in turn may lead to changes in the distribution of hardness in the deformed surface layer.

The quality of the cutting operation is also affected by the physical and mechanical properties of the workpiece material. It is difficult to cut materials with high hardness and viscosity, which will lead to rapid premature wear and salting of the tool teeth.

To solve this problem, research work was carried out and the following results were achieved:

1. Factors that determine the quality of the surface layer (hardness, stress-strain state, roughness, slope), which have a different character depending on the processed material and processing conditions, are studied. As a result, a classification of processed steels was proposed depending on the amount of carbon and the complexity of processing.

2. Regularities of temperature distribution and its influence on the physical and mechanical properties of the processed material are established.

3. As a result of studying the process of thermal friction cutting of various materials with pulse cooling using the computer program Deform3D, the following was obtained:

- confirmation of the hypothesis of the mechanism of thermal friction cutting with pulse cooling;

- determination of the dimensions of the molten, heated and hardened layer, which are respectively: for steel 08 – 0.046 mm; 0.087 mm; 0.15 mm; for steel 20 – 0.042 mm; 0.095 mm; 0.17 mm; for steel 50 – 0.031 mm; 0.117 mm; 0.195 mm; for Hardox450 – 0.046 mm; 0.066 mm; 0.089 mm; for Ti5553 – 0.01 mm; 0.037 mm; 0.0637 mm.

- time to establish the processing process is in the range of 0.0024÷0.0250 seconds.

4. Optimal processing modes and geometric parameters of the circular saw for cutting various materials (St.08, St.20, St. 50, HARDOX450, Ti5553) are established.

5. Empirical dependences for determining the surface roughness and hardness when cutting various materials are revealed.

Volume and structure of work. The doctoral dissertation consists of an introduction, 5 chapters and a conclusion set out on 166 pages of typewritten text, which are explained by 69 figures, 24 tables, references list of 152 titles, and 12 appendices.