# DEVELOPMENT OF TECHNOLOGY FOR PROCESSING HARDOX STEEL PARTS BASED ON THERMAL FRICTION CUTTING

## ANNOTATION

**dissertation work of doctoral student Kuanov Isa Serikovich for obtaining the Doctor of Philosophy (PhD) degree in the educational program 8D07105 –«Mechanical Engineering»**

**1. Relevance of the dissertation work**. Under modern conditions of mechanical engineering development in the Republic of Kazakhstan, increasing the efficiency of machining hard-to-process materials used in heavily loaded and wear-resistant machine parts has become especially important. Due to the rapid development of mining, metallurgical, construction, transport, and processing industries, the demand for materials with high strength, hardness, and wear resistance is continuously increasing. One of such materials is HARDOX steel produced by SSAB (Sweden), which is widely used because of its excellent operational characteristics.

HARDOX steels are used in excavator buckets, dump truck bodies, crushing equipment, liners, cutting elements, conveyors, bunkers, and road-construction machinery operating under severe abrasive wear conditions. The main advantages of HARDOX steel include high hardness, impact toughness, wear resistance, and long service life. However, these properties significantly complicate machining processes.

Traditional machining of HARDOX steel causes intensive tool wear, excessive heat generation in the cutting zone, deterioration of surface quality, and increased production costs. These problems are especially significant during milling and cutting operations.

Analysis of domestic and foreign studies showed that existing HARDOX machining technologies mainly rely on expensive imported tools, hard alloys, plasma, laser, or waterjet processing technologies. However, such technologies require expensive equipment and high operating costs. Therefore, there is a need to develop more economical and efficient machining technologies suitable for domestic mechanical engineering enterprises.

One of the promising directions is thermofriction cutting based on local heating of the workpiece due to friction between a high-speed tool and the workpiece surface. The use of thermofriction effects makes it possible to reduce cutting resistance, decrease tool loads, and increase machining productivity. Of particular interest is thermofriction milling with pulse cooling, which allows localization of thermal and deformation processes in the "tool–workpiece" contact zone.

Therefore, the development of machining technology for HARDOX steel parts based on thermofriction cutting is an important scientific and technical task.

**2. Research Objects:** Machining processes of HARDOX 450 steel using thermofriction cutting with pulse cooling.

**3. The aim of the dissertation work.** Development of a machining technology for HARDOX steel parts based on thermofriction cutting with pulse cooling to improve machining efficiency, reduce tool wear, and enhance surface quality.

The following tasks were set to achieve the aim:

- to analyze existing HARDOX machining technologies;
- to study thermofriction machining methods for hard-to-machine materials;
- to develop a special friction milling cutter for HARDOX 450 machining with pulse cooling;
- to conduct experimental studies of thermofriction milling;

- to determine the influence of cutting modes on roughness and hardness;
- to develop mathematical models for surface quality evaluation;
- to perform thermal simulation using ANSYS WB and DEFORM-3D software;
- to evaluate the economic efficiency of the proposed technology.

**4. Research methods and methodology.** The following methods were used in the dissertation:

- analysis of scientific and technical literature;
- experimental machining methods;
- mathematical statistics and regression analysis;
- metallographic research methods;
- roughness and hardness measurements;
- finite element modeling;
- ANSYS Workbench, DEFORM-3D, and STATISTICA 10 software packages.

**5**. **Scientific novelty of the research.** The scientific novelty of the dissertation includes:

- development of a new thermofriction machining method with pulse cooling for HARDOX steel;
- development of a special friction milling cutter design;
- determination of the influence of cutting parameters on surface quality;
- obtaining mathematical equations for roughness and hardness evaluation;
- development of a nomogram for selecting cutting modes;
- first-time simulation of thermal and deformation states during thermofriction milling using ANSYS WB and DEFORM-3D;
- determination that the cutting-zone temperature does not exceed the recrystallization temperature of HARDOX 450 steel.

**6**. **Application Field**. The developed technology of thermofrictional processing of HARDOX steel parts can be used at machine-building, mining, metallurgical, repair-mechanical, and metalworking enterprises engaged in the manufacturing and restoration of parts operating under conditions of intensive abrasive wear and impact loads.

**7. Practical significance of the work.** The practical significance of the research lies in:

- development of an efficient HARDOX machining technology;
- creation of special friction milling cutters;
- reduction of tool wear;
- increase in machining productivity;
- reduction in manufacturing costs;
- possibility of implementation at mechanical engineering enterprises of Kazakhstan.

The developed technology was implemented at and ООО «Нестандартные машиностроительные изделия».

**8. Personal Contribution of the author.** The research personal contribution consists in formulating the research objectives and developing the research methodology; designing and manufacturing special friction milling cutters and cutting discs, as well as technological and tooling equipment; determining optimal processing parameters; organizing and conducting experimental studies of thermofrictional milling with pulse cooling, thermofrictional cutting-off with pulse cooling, and thermofrictional machining of open and closed keyways in HARDOX steel.

**9. Work Approbation.** The main results of the dissertation were presented at:

- the international scientific-practical conference “Saginov Readings” (Karaganda, 2021);
- “Seifullin Readings” international conferences (Astana, 2021–2022);
- department meetings;
- technical councils of industrial enterprises.

**10. Publications.** A total of 12 scientific papers were published on the dissertation topic, including:

- 2 papers indexed in Scopus and Clarivate databases;
- 4 papers in journals recommended by the Committee for Quality Assurance in Science and Higher Education of Kazakhstan;
- 5 conference proceedings;
- 2 patents of the Republic of Kazakhstan for utility models;
- a copyright certificate.

**11. Structure and scope of the dissertation.** The dissertation consists of an introduction, five chapters, conclusion, references, and appendices. The work contains 119 pages, 66 figures, 18 tables, and 110 references.

**12. Conclusions of the dissertation.**

During the dissertation research, comprehensive scientific studies aimed at solving the urgent problem of machining HARDOX steel parts were carried out, and the following results were obtained:

- A new method for machining HARDOX steel parts based on thermofriction cutting with impulse cooling was developed. This method provides a reduction in cutting resistance, decreases the thermal load on the tool, and increases the efficiency of machining difficult-to-machine materials.
- Special thermofriction tools, technological equipment, and tooling necessary for implementing the thermofriction machining process of HARDOX steel parts were developed and manufactured. The proposed designs ensure the stability of the cutting process and the possibility of machining high-hardness materials.
- It was experimentally established that thermofriction milling ensures the surface roughness of the machined surface within the following range:

$$Ra=1.0\text{–}7.5\ \mu m$$

which corresponds to surface roughness grades 5–7.

- It was also established that the initial hardness of HARDOX 450 steel does not decrease during machining, while changing the cutting conditions makes it possible to control the hardness of the machined surface within the required limits.
- The following possibilities were experimentally proven:
  - the application of the thermofriction cutting method using cutting tools made of non-tool materials (HARDOX 450 steel, Steel 20, and gray cast iron SCH15) for machining HARDOX steel parts;
  - performing various technological operations, in particular:
    - face milling;
    - cutting of workpieces;
    - machining of open and closed keyways.
- Mathematical equations for evaluating the quality indicators of the machined surface after thermofriction milling with impulse cooling were obtained, and a nomogram for selecting cutting modes to achieve optimal roughness and hardness values of the machined

surface was constructed.

- As a result of thermal process simulation in the cutting zone during thermofriction milling with impulse cooling of HARDOX 450 steel using ANSYS WB and DEFORM-3D software packages, it was established that the temperature in the subsurface layer of the cutting zone does not exceed the recrystallization temperature of HARDOX 450 steel:

$$T_{rec} \approx 600°C$$

which ensures the preservation of the material’s operational properties and prevents structural changes in the surface layer.

- The research results were implemented at Steel Manufacturing and LLC “Non-standard Machine-Building Products” (Saratov, Russia). The annual economic effect from the use of the developed friction milling cutter amounts to:

6,711,282.48 tenge

- The developed technology makes it possible to increase machining productivity, reduce tool wear, lower the manufacturing cost of parts, and improve the efficiency of machining difficult-to-machine materials under machine-building enterprise conditions.
- The obtained results possess scientific novelty and practical significance and can be used in the further development of highly efficient technologies for machining high-strength and wear-resistant materials.