ABSTRACT

Thesis on the topic: **"Study and development of the construction of a thermodynamical working organ for surface processing of blocks made of strong rocks"** submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D071200 - "Mechanical Engineering"

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Relevance of research. Currently in Kazakhstan there are a number of trends requiring development and modernization infrastructure. In the transition period of Kazakhstan from planned to a market economy, its mineral resources are acquired extremely important. In the face of tough international Competition The President of the Republic of Kazakhstan has been tasked with diversifying the domestic economy.

Despite the fact that granite reserves in the Commonwealth countries are significantly higher than in foreign countries, their extraction and processing lags 3–4 times behind compared with Italy, Belgium, the United States, and Great Britain.

Natural stone occupies a special place among the extensive range of building materials. Over the past 70 years, world production of natural stone has increased almost 25 times, while over the past twenty years, the annual increase in production and consumption of stone averaged 7.4%. According to forecasts for the coming decades, this growth will continue, and the world's stone output will increase more than 4 times. Granite is surprisingly durable, uncomplicated in processing and, most importantly, incredibly beautiful, and has a huge variety of colors.

The Kazakhstan market of natural stone also shows a steady upward trend in the consumption of this material. Since 1999, the consumption of natural stone in Kazakhstan has increased by an average of 10...12% per year. Taking into account the planned rates of economic development of the country, suggesting a significant growth in GDP over 10 years, it can be expected that by 2020 the consumption of natural stone in Kazakhstan will increase by almost 2 times and will be at least 1.2 million m^2 per year.

However, due to the low technical level of enterprises in the industry, - collected by the lack of effective means of extracting and processing hard rock, these natural resources are underutilized. Needs on Commonwealth countries in natural stone products only 10...15% are baked, and export requests are 5...10%. The development of stone processing industries is considered as one of the promising tasks, the solution of which is possible through the introduction of advanced technology and high-performance equipment.

The current GOST 23342-91 allows for granite slabs to differ from each other in length by ± 2 mm, in thickness: ± 3 mm. The requirements of European standards are even tougher, the tolerance is only ± 2 mm. That is why Chinese granite, unlike the domestic one, is actively imported into the European market (especially Germany), with the volume of supplies growing annually by 5...7%.

However, such a rapid growth in demand for natural stone does not mean a similar rate of development of domestic stone mining and stone processing. In order to resist the competition of imported stone products, it is necessary to introduce high-performance tools, machines and technological lines into the domestic industry that are not inferior to their foreign counterparts.

Thermal tools for processing rocks have high durability and reliability due to the lack of contact with the surface being destroyed, but when implementing the method in the form of hand-held thermal tools, the working and surrounding environment is exposed to powerful aerodynamic noise of the burner. The creation of thermal tools with increased power while maintaining the design parameters is an important structural and technological challenge, and when equipped with these tools, manipulation devices will completely mechanize manual labor, protect the worker and the environment from noise, improve productivity and work culture, and ensure work safety.

However, there are unsolved problems in the theory of destruction and in the practice of designing mechanized thermoaggregates, the development of which requires their solution. Namely, the refinement of the mechanism of destruction of rocks with different methods of orientation of gas jets and physical and mechanical properties of the rocks being destroyed; determination of rational technological parameters of processing and design parameters of thermal tools; the development of effective working bodies of thermal tools that implement new methods of combustion of the fuel mixture; ensuring the normal sanitary and hygienic working conditions of workers.

Consequently, the task of studying the process of destruction of strong rocks, the development on this basis of an engineering method for calculating the parameters of thermal tools, improving the technology of mechanized mining and processing of block stone are relevant, the solution of which improves the efficiency of the thermal method of destruction.

The work was carried out in the Kazakh National Research Technical University named after K.I. Satpayev, at the stone-working stone processing enterprise IC "Titushin" (Almaty).

The aim of the work is to study and development of the construction of a thermodynamical working organ for surface processing of blocks made of strong rocks, allowing you to create a design of increased power and economical to use.

The idea of the work is to select and justify the parameters of thermotools for the surface treatment of rocks, allowing them to increase their productivity of destruction during the processing of blocks, rocks and cutting slotted openings.

In connection with the goal, the following **research** objectives are formulated:

- analysis of the current state of the stone mining industry of mining and processing of block stone from strong rocks;
- justification of the use of high-speed fire jets in technological processes and production;

- research of processes, technologies and equipment for the extraction and processing of block stone from strong rocks using fire-jet burners;

- justification of the design parameters of the petrol-air termotool body with a combustion intensifier for the destruction of strong rocks;

- experimental studies of the new design of petrol-air termotool for processing granite blocks;

- justification of the use of industrial robot with fire-jet working body for the surface treatment of large blocks of strong rocks.

Object of study: the processing of blocks of strong rocks thermotools increased power.

Subject of research: tools for fire-jet processing of strong rocks.

Research methods. The results of the study were obtained on the basis of theoretical and practical principles of the theory of gas dynamics, thermal conductivity and the theory of combustion of hydrocarbon fuels, as well as the theory of experimental design and statistical data processing. Experimental studies were carried out in bench conditions on existing equipment using original techniques and modern measuring equipment, methods of mathematical and physical modeling and planning experiments.

The scientific novelty of the work is as follows:

- modeling of the process of destruction of rocks by thermal tools with combustion intensifiers using a multifactor experiment, which allows to obtain regression equations to determine their operating parameters;

- it was found that in a supersonic gas flow flowing from a burner Laval nozzle into a cylindrical perforated nozzle chamber, friction against the inner walls of the nozzle and contact with cold atmospheric air, a powerful stationary shock wave is formed - a shock wave fed by oxygen from the ejected through the perforation nozzle, atmospheric air, which ensures the intensive burning of the fuel in the jet;

- the analytical dependences of the heat flux of the thermal tool, the temperature of the gas at the nozzle exit, the temperature in the combustion chamber and the flow rate of the plume on the oxidizer oxidation coefficient at various fuel consumption have been established to justify the structural and operating parameters of the new thermotool design with an ejector nozzle: determine the temperature of the mixed flow the parameters of the output section of the nozzle ejection nozzle, the diameter of the free jet and its length;

- the effective zone of rock destruction along the length of the jet of the torch, which is 0.05...0.35 m, has been experimentally established, which is provided by a gas-air burner with a nozzle - an intensifier of combustion, with the consumption of fuel components: gasoline - 0.0035...0.0077 kg/c; air - 0.1057...0.228 kg/s, with the coefficient of excess oxidant α_T = 0.7...1.1.

The reliability of scientific statements, conclusions and recommendations is confirmed by the results of experiments on experimental designs of thermal tools, as well as the use of proven engineering calculation methods, methods of mathematical statistics in data processing using computers. The convergence of

experimental data and theoretical calculations is confirmed by acts of implementation.

The following basic scientific statements are put forward for defense:

- the constructed model of the process of rock destruction by thermal tools with combustion intensifiers, using a multifactor experiment, allows us to obtain regression equations to determine their operating parameters;
- intensive burning out of fuel in a supersonic gas flow flowing out of a burner nozzle into a cylindrical perforated nozzle is enhanced by an increase in the thermal power of the stream due to friction against the inner walls of the nozzle and contact with cold atmospheric air and the newly formed powerful stationary shock wave - a shock wave, feeding on oxygen from the ejected, through the perforation of the nozzle, atmospheric air;
- the method of calculating the design and operating parameters of the new design of a thermal tool with an ejection nozzle, includes calculating the heat flow of the burner of the basic thermotool, the gas temperature at the cut of the Laval nozzle, the temperature in the combustion chamber and the flow rate of the torch from the oxidizer excess ratio at various fuel components;
- experimentally determined the effective zone of destruction of rock along the length of the jet of the torch, which is provided by petrol-air termotool with a nozzle - an intensifier of combustion, with a set consumption of fuel components - gasoline and air, as well as an oxidizer excess ratio.

The theoretical significance of the work lies in the scientific substantiation of the main parameters of the process of fire-destruction of rocks by the method of large cleavage; in the development of a new design of a thermotool that implements a new type of combustion of a fuel mixture in a jet of a burner flowing from a Laval nozzle into a cylindrical cavity of an ejection nozzle, in shock waves.

The practical significance of the work is as follows:

- substantiation and calculation of the geometrical parameters of a new design of a gasoline-powered instrument with an ejection nozzle was performed, the main pressure parameters in the inlet section of the mixing chamber were determined, as well as the main geometrical dimensions of the gas-jet ejector with a diffuser, a prototype burner with a gas-dynamic nozzle was manufactured;
- a method has been developed for determining the technological parameters of fire-jet processing (destruction) of the surface of blocks of hard rock, including: the thickness of the detachable particle; the time of separation of particles from the array; linear rate of destruction; required heat flux; volumetric efficiency of destruction; the longitudinal velocity of the treated rock block; failure performance at gross failure; overall performance destruction;
- a block diagram of the industrial four-link robot of the type PPTP was proposed, described as a uniform transformation matrix by the Denavit-Hartenberg method and analytical dependencies of the four-link manipulator were established taking into account the acting forces and moments (inertial, centrifugal, coriolis and gravitational).

- on the basis of thermotool TRV-12M, a new design of petrol-air termotool of increased power has been developed, with an ejection nozzle, which has passed production tests and is recommended for implementation;

- the expected annual economic efficiency of the introduction of thermal tools with combustion intensifiers for processing large blocks of strong rocks will be more than 2 million 760 thousand tenge per year.

Individual devices have been transferred for introduction into stone-processing enterprises of Almaty and Almaty region. The methodological basis for calculating the kinematic and dynamic parameters of robotic manipulators can be used to teach courses on the mechanics of robotic technical colleges.

The validity and reliability of scientific statements, conclusions and recommendations is confirmed:

- analysis of a large amount of production data and empirical materials at the mining enterprises of Kazakhstan and the CIS countries on fire-treatment (passaging) of granite blocks from strong rocks;

- using the basic principles and methods of engineering technology, theoretical mechanics, the theory of elasticity and plasticity, the theory of gas dynamics and thermo elasticity, solving problems on a computer;

- conducting mathematical modeling and experimental laboratory studies of technological parameters of thermal tools for processing granite blocks;

- establishing the convergence of the results of theoretical and experimental studies.

The implementation of the results. The results of the research were transferred to the IC «Titushin» (Almaty) for introduction into the production of stone processing enterprise for stone processing and were used in the educational process in preparing bachelors in the specialty 5B071200 - "Mechanical Engineering" in KazNRTU named after K.I. Satpayev.

Approbation of work. The main provisions of the thesis and the results of the research were reported and discussed at the International Scientific and Technical Conference "Exploration and Oil and Gas Business in the 21st Century: Technology, Science, Education" dedicated to the 50th anniversary of the Department "Technology and Drilling Technology" (Almaty, 2016); XII international correspondence scientific-practical conference: "The development of science in the XXI century" (Kharkiv, 2016); the 22-nd International conference on Vibroengineering "Dynamics of Strong Nonlinear Systems" (Moscow, 2016), the 24-th International Conference on Vibroengineering "Theories, Technologies and Applications in Vibration Engineering" (Shanghai, 2016), International scientific and technical conference of Satpayev readings "Scientific heritage of Shakhmardan Esenova" (Almaty, 2017); XXIII International Scientific and Technical Conference "Engineering and Technosphere of the XXI Century" (Sevastopol, 2016), XXIV International Scientific and Technical Conference "Engineering and Technosphere of the XXI Century" (Sevastopol, 2017).

Publications. The main results of the thesis were published in 18 publications, including 5 articles in journals recommended by the ESCC MES RK; 3 articles in scientific journals of the Republic of Kazakhstan and the Russian

Federation, 9 publications at international conferences, 7 of which are foreign, including 2 articles in the Scopus database; 1 article in a scientific journal in the Scopus database; 3 registered applications in the RSE "National Institute of Intellectual Property" of the Ministry of Justice of the Republic of Kazakhstan for obtaining patents for an invention.

Structure and scope of work. The thesis consists of an introduction, four sections and a conclusion set out on 137 pages, contains 61 figures, 16 tables, 132 sources used and 7 appendices.