ЖОЛ, ҚҰРЫЛЫС ЖӘНЕ КӨТЕРГІШ-КӨЛІК МАШИНАЛАРЫ ЖӘНЕ АВТОМОБИЛЬ ТРАНСПОРТЫ
ДОРОЖНЫЕ, СТРОИТЕЛЬНЫЕ И ПОДЪЕМНО-ТРАНСПОРТНЫЕ МАШИНЫ И АВТОМОБИЛЬНЫЙ ТРАНСПОРТ
ROAD, CONSTRUCTION AND LIFTING AND TRANSPORT VEHICLES AND ROAD TRANSPORT

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IMPROVING THE DESIGN OF THERMAL TOOLS FOR ROCK FRACTURING

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IMPROVING THE DESIGN OF THERMAL TOOLS FOR ROCK FRACTURING

Abstract: The article deals with the main parameters of the thermodynamic working device for rock destruction due to the implementation of a new method of fuel mixture combustion in shock waves initiated by a high-speed torch burner in gas-dynamic combustion intensifiers. A device for thermal destruction of rocks has been developed, which belongs to the mining industry and can be used for directed impact on rocks when they are destroyed by hot gas jets in mining, stone processing and construction industries. Also, installed coaxial to the nozzle, with increasing inside diameter, a cylindrical nozzle, with two cascades of ejection holes - the first cascade is made at a distance from the Laval nozzle, equal to the distance to complete expansion of the jet of the torch, then, the accelerating section of the nozzle and the new, formed by burning the unburned fuel, jet of the burner. It is found that the cross sectional area of the inner hole of the cylindrical nozzle, is made with an excess of the area of the critical cross section of the nozzle Laval burner 2.5-3 times, in which, because of the rapid expansion of the gas flow in the nozzle, there is turbulization, with the formation of a powerful zone of heating of the gas flow and the appearance of a standing detonation wave in it. The drilling angle of the ejection holes of the first stage is 45-50º to the axis of the nozzle, which serves for ejection of atmospheric air, the oxygen of which reacts with the surplus of combustible in the main jet of the burner and the formation of a more powerful jet.

Key words: thermotool, rock, detonation burning, fuel components (gasoline, kerosene, air).

The Republic of Kazakhstan has large reserves of building stone of strong rocks, suitable for production of facing and industrial products. Significant reserves of these rocks in the Eastern, Central and Southern Kazakhstan are represented by granites of various composition and different colors. They include already developed unique bluish-greenish color amazonite granite deposits Maikul, red granite Kurdai and Akbakai deposits, granodiorite deposits Kayrakty, granite deposits Kurty, Arasan-Kapal, Alatagyl, Zheltau and others [1].

Scientists from several foreign universities in Moscow, Leningrad, Almaty, Kharkov and other cities of the former Union, have developed a fire-jet method of mining and processing block stone from hard rocks with the use of gas-jet burners (thermal tools), which worked on the basis of combustion of hydrocarbon fuels in oxygen or air [2-4].

The thermal tools developed have been used in the vast majority of blockstone mining and surface treatment facilities.

However, there is a huge reserve for increasing the thermal capacity of flame burners using new combustion processes of fuel components. To solve this issue, there is a modern theoretical basis for studying hydrocarbon combustion processes in oxygen medium, while creating conditions for formation of shock waves in a high-speed supersonic jet of burners [5-7].

Ongoing studies on the intensification of combustion of fuel components show the promising application of the detonation combustion phenomenon. A qualitative assessment of detonation combustion was carried out on a gas-air burner with a combustion intensifier in the form of a cylindrical nozzle on part of the burner jet, and by ejecting air through the nozzle perforation, made at a certain distance from the burner nozzle cut [6,7].

Intensification of combustion in the nozzle occurs due to control of the combustion process, after the jet exits from the Laval nozzle into the nozzle cavity, which has a cross-sectional area 2.0÷2.5 times greater than the critical sectional area of the Laval nozzle. In this cross section, the burner jet expands sharply, resulting in a zone of turbulent flow of the gas stream and, as a consequence, a sharp increase in the temperature of the gas stream [8].

The authors of the article developed a new design of a thermal tool at the level of invention [9].

The invention belongs to the mining industry and can be used for directed impact on rocks during their destruction by red-hot gas jets in mining, stone processing and construction industries, as well as in cleaning and spraying of materials.

It is known that the device for thermal destruction of rocks [10], which we took as an analogue, consists of a combustion chamber, a nozzle, a reflecting screen having the form of a parabolic rotation and an opening for supplying the missing component. The process of continuous generation of detonation pulses occurs as follows. To the base of the flare, expiring from the combustion chamber, a combustible component enters through the holes in the wall of the screen, instantly entering into a chemical reaction. This creates a shock wave and a high-pressure region that stops the ingress of the component from the holes. Once the pressure is reduced, the missing component is reintroduced to the base of the flare and the process repeats. The disadvantage is its low efficiency, i.e. the process is somewhat intensified, but it is not possible to obtain a qualitative jump in productivity.

Also known, the device for thermal destruction of rocks [11] taken by us as a prototype, which includes a flame-jet burner with a combustion chamber and a Laval nozzle for forming a flowing jet of gas, which is different in that coaxial to the nozzle are made with increasing diameters sequentially several cylindrical nozzles with ejector windows, and the joint places of nozzles form channels for the supply of additional fuel. The disadvantage of which is the complexity of starting, newly formed cylindrical nozzle, and high metal intensity. The task of the invention is to increase the power of the burner flame by more complete use of its energy characteristics.

The problem solution is achieved by the fact that the sealing jumps are excited along the formed jet of burner flame after its introduction into a special cylindrical nozzle, the cross-sectional area of the inner hole of which, exceeds the critical cross-sectional area of the burner nozzle Laval in 2.5... 3,0 times, and the nozzle is made two-stage with ejection cylindrical holes, located at an angle of 45-50° to the axis of the nozzle, in the first stage of which, to eject atmospheric air and use its oxygen for burning in the main jet of burner inside the nozzle the high-temperature unburned fuel and forming a new jet of high temperature and speed.

Execution of ejection holes in the second stage of the nozzle is designed to cool the outlet nozzle of the nozzle, the area of the orifice exceeds the area of the inner nozzle opening by 30-32%, and its length is equal to its diameter.

The burner gas jet exiting the burner's Laval nozzle is directed to the inner orifice of the nozzle, in which, due to the sharp expansion of the gas jet, turbulence is formed and, as a consequence, a sharp increase in the temperature of the gas flow. Execution of ejection holes in the second stage of the nozzle is designed to cool the outlet nozzle of the nozzle, the area of the orifice exceeds the area of the inner nozzle opening by 30-32%, and its length is equal to its diameter.

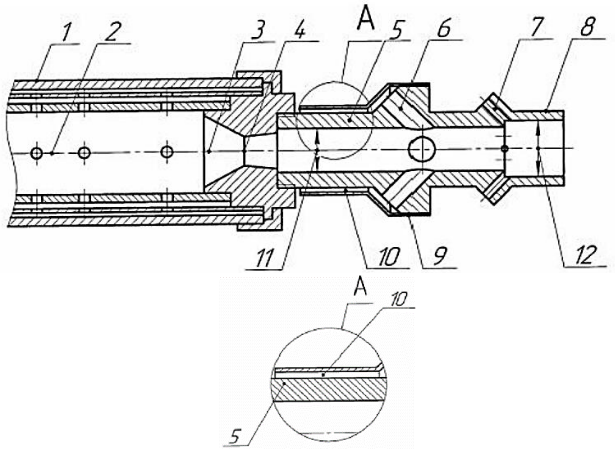
The burner gas jet exiting the burner's Laval nozzle is directed to the inner orifice of the nozzle, in which, due to the sharp expansion of the gas jet, turbulence is formed and, as a consequence, a sharp increase in the temperature of the gas flow.

The first row of ejection holes, when drilled, inside the nozzle forms a roughness, which contributes to the creation in the jet of a powerful compaction jump (shock wave) in which the excess fuel entering the jet from the combustion chamber is afterburning, the combustion of this fuel increases the flame power, that is a more complete use of its energy characteristics without using cumbersome compressor equipment.

The second row of ejection holes, made in the end of the second stage, the area of the hole exceeds the area of the nozzle opening by 30-32% and serves to cool the outlet nozzle of the nozzle, and the length of the outlet nozzle of the nozzle is equal to its diameter.

The technical result of the invention is to increase the burner flame power due to more complete combustion of fuel components and to perform the burner design with rational parameters.

Figure 1 shows the proposed device of thermal tool (a fragment of section without fuel components supply system is given), Figure 2 shows the burner's external element A - the annular channel for atmospheric air suction and nozzle cooling by it.



1 - burner, 2 - combustion chamber, 3 - Laval nozzle, 4 - critical section of Laval nozzle, 5 - nozzle, 6, 7 - ejection windows, 8 - outlet nozzle, 9 - annular channel, 10 – casing

Рисунок 1 - Устройство для термического разрушения горных пород
Figure 1 - Device for thermal destruction of rocks

The device consists of a burner 1 having a combustion chamber 2 with a Laval nozzle 3 having critical section 4. Behind the Laval nozzle 3 a cylindrical elongated nozzle 5 with inner diameter 11 somewhat larger than the critical section of the Laval nozzle 3 is arranged coaxially with the Laval nozzle 3, in which the ejection ports 6 and 7 are made at an angle of 45-50° to the nozzle axis. The end of the nozzle 5 is made with a larger diameter 12, and also has ejection windows 7 for sucking in the ejected outside air going to cool the outlet nozzle 8.

Also, to cool the surface of the nozzle 5 in the first stage - in the area of development of the hearth of combustion of fuel components inside the nozzle, the latter is provided with a protective outer casing 9, which has an annular channel 10, between the body of the nozzle 5 and the casing 9, through which the ejected air is sucked in, which goes to maintain combustion in the jump seal. Устройство работает следующим образом.

In the combustion chamber 2 of burner 1 combustion of fuel components (combustible and oxidizer) supplied by supply lines (not shown in the drawing) takes place. Combustion in combustion chamber 2 of burner 1 of combustible fuel components is accompanied by ejection of a red-hot gas jet from combustion chamber 2 through critical section 4 of Laval nozzle 3 to nozzle 5 and further to outlet nozzle 8 of nozzle 5 to the object of destruction.

In order to increase the efficiency of the burner, in particular on destruction of rocks, in the proposed device there is a buildup of its power. The high-speed high-temperature jet of burner 1, enriched with combustible, is directed to the nozzle 5 through the Laval nozzle 3, from the combustion chamber 2. At the exit from the Laval nozzle 3 the stream of burner 1 sharply expands in the nozzle 5, the cross-section area of which is 2,5-3 times larger than the area of the critical section of the Laval nozzle 4 of burner 1, and turbulence occurs in the gas stream and as a result the temperature of the gas stream sharply increases. At further movement of the high temperature gas stream, due to friction against the roughness of the inner wall of the nozzle 5, formed by drilling of inclined ejection holes 6 and 7, as well as meeting with cold, ejected through the ejection windows 6, atmospheric air, a powerful stationary compaction jump is excited. This achieves rapid (detonation) combustion and complete afterburning of the fuel and, as a consequence, increasing the power of the jet and its further acceleration in the cylindrical nozzle 5. The jet of increased power and larger diameter from nozzle 5 is ejected through the outlet nozzle 8 to the outside and goes to the destruction of the rock. The casing 9 and the annular channel 10 formed by it provide the volume of sucked air through the ejection holes 7 and cooling of the surface of the nozzle 5, which is heated by the combustion front inside the sealing jump in the nozzle 5. At the same time the ejection holes 7, made in the end of the second stage of the nozzle, are used for sucking in atmospheric air, going to cool the outlet nozzle 8 of the nozzle 5 because, due to their small diameters, the ejected air flow does not mix completely with the main jet formed in the nozzle 5, but is underlaying, protecting the outlet nozzle 8 from overheating, and the area of the outlet nozzle internal opening, relative to the area of the internal opening of the nozzle is 30-32% larger.

Example. Gas-air burner with a nozzle, the outlet diameter of the nozzle is 0.024 m. Maximum power which can be developed by the burner without the nozzle is 120 kW at the air consumption of compressor of 5 m3/min at a pressure of 0.6÷0.7 MPa. The fuel (gasoline) consumption is 12-17 kg/hour. The flame of the burner at its outlet from the nozzle increases to the length of 250÷300 mm, and its diameter also increases noticeably, indicating the conclusion of the combustion mode of the burner with the nozzle. The flame power increases up to 170÷200 has the length of 0.45 m with the diameter of 0.06 m, the critical diameter of Laval nozzle is 0.012 m, internal diameter of the nozzle is 0.02 m, kW. For comparison: 200 kW power would be developed by gas-air burner without nozzle with critical section of Laval nozzle 0,022÷0,025 m, air flow 20-25 m3/min, at pressure 0,6÷0,7 MPa. The use of the proposed invention will make it possible to reduce labor intensity of manufacturing the flame-jet burners, their metal intensity, and, most importantly, to obtain the required flame output without using additional cumbersome compressor equipment and thus improve the technical and economic performance of the thermal tool.

The authors also received a patent for a device for thermal destruction of rocks, in which the main design parameters of a burner (a thermoninstrument), which implements the combustion of fuel components in a high-speed burner jet, in shock waves, in which the burning rate of fuel components is hundreds of times faster than in normal combustion conditions, were substantiated [12].

The studies conducted by the author to obtain the detonation phenomenon in a free burner jet, when fuel components in various stoichiometric ratios are burned in it, did not lead to the creation of powerful shock waves and, as a consequence, detonation phenomena [6]. However, the introduction of a missing fuel component, an oxidizer, into the fuel-enriched gas jet of the burner and combustion of these components in the bottomhole space, i.e., in the compaction jump disconnected from the bottom hole, gave positive results. The gain of productivity is insignificant, because these combustion processes can be carried out more qualitatively in the burners themselves at the corresponding stoichiometric conditions and, therefore, there is no need to complicate the construction of the burner. Especially in case of a technological treatment scheme in the form of a "strip heat source", when the contact spot of the jet with the rock is located along the whole length of the gas jet of the burner [13].

Conclusions:

1. A device for thermal destruction of rocks, including a flame-jet burner with a combustion chamber and a Laval nozzle, to form a flowing jet, has been developed.

2. Also, installed coaxial to the nozzle, with increasing inside diameter, a cylindrical nozzle, with two cascades of ejection holes - the first cascade is made at a distance from the Laval nozzle, equal to the distance to complete expansion of the jet of the torch, then, the accelerating section of the nozzle and the new, formed by burning the unburned fuel, jet of the burner.

3. It is found that the cross sectional area of the inner hole of the cylindrical nozzle, is made with an excess of the area of the critical cross section of the nozzle Laval burner 2.5-3 times, in which, because of the rapid expansion of the gas flow in the nozzle, there is turbulization, with the formation of a powerful zone of heating of the gas flow and the appearance of a standing detonation wave in it.

4. The drilling angle of the ejection holes of the first stage is 45-50º to the axis of the nozzle, which serves for ejection of atmospheric air, the oxygen of which reacts with the surplus of combustible in the main jet of the burner and the formation of a more powerful jet;

5. The ejection holes, made in the end of the inner diameter of the second stage of the nozzle, are used to eject atmospheric air and to cool the outlet nozzle, the area of which exceeds the area of the inner hole of the nozzle by 30-32%.

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СОВЕРШЕНСТВОВАНИЕ КОНСТРУКЦИИ ТЕРМОИНСТРУМЕНТОВ ДЛЯ РАЗРУШЕНИЯ ГОРНЫХ ПОРОД

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Аннотация. В статье рассматриваются основные параметры термодинамического рабочего устройства для разрушения горных пород за счет реализации нового способа сжигания топливной смеси в ударных волнах, инициируемых высокоскоростной факельной горелкой в газодинамических интенсификаторах горения. Разработано устройство для термического разрушения горных пород, которое относится к горной промышленности и может быть использовано для направленного воздействия на горные породы при их разрушении горячими газовыми струями в горнодобывающей, камнеобрабатывающей и строительной отраслях. Также установлена соосно соплу, с возрастанием внутреннего диаметра, цилиндрическая насадка, с двумя каскадами эжекционных отверстий - первый каскад которого выполнен на расстоянии от сопла Лаваля, равным расстоянию до полного расширения струи факела горелки, далее, разгонного участка насадка и новой, образованной горением несгоревшего горючего, струи горелки. Установлено, что площадь поперечного сечения внутреннего отверстия цилиндрической насадки выполнена с превышением площади критического сечения сопла Лаваля горелки в 2,5-3 раза, в котором из-за резкого расширения газового потока в насадке, происходит турбулизация, с образованием мощной зоны нагрева газового потока и возникновения в нем стоячей детонационной волны. Угол сверления эжекционных отверстий первого каскада выполнен под 45-50º к оси насадки, который служит для

эжекции атмосферного воздуха, кислород которого вступает в реакцию горения с избыточным горючим в основной струе горелки и образовании более мощной струи.

Ключевые слова: термоинструменты, горная порода, детонационное горение, топливные компоненты (бензин, керосин, воздух).

ТАУ ЖЫНЫСТАРЫН БҰЗУҒА АРНАЛҒАН ЖЫЛУ ҰРАЛДАРЫНЫҢ КОНСТРУКЦИЯСЫН ЖЕТІЛДІРУ

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Аңдатпа. Мақалада жану газдинамикалық үдеткіштерінде жоғары жылдамдықты алау оттығымен басталған соққы толқындарында отын қоспасын жағудың жаңа әдісін енгізу арқылы тау жыныстарын бұзуға арналған термодинамикалық жұмыс құрылғысының негізгі параметрлері қарастырылады. Тау-кен өнеркәсібіне жататын және тау-кен, тас өңдеу және құрылыс салаларында ыстық газ ағындарымен бұзылған кезде тау жыныстарына бағытталған әсер ету үшін қолдануға болатын тау жыныстарын термиялық бұзуға арналған құрылғы жасалды.

Түйінді сөздер: жылу құралдары, тау жынысы, детонациялық жану, отын компоненттері (бензин, керосин, ауа).

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APPLICATION OF ADDITIVE TECHNOLOGIES IN MODERN FOUNDRY PRODUCTION

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Abstract: The paper studies and analyzes the use of additive technologies in modern foundry production, determining their innovative development to create new products with high