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DEVELOPMENTS IN THE FIELD OF TECHNOLOGY FOR CUTTING FIGURES OF DECORATIVE ROCK MATERIALS EMPLOYING WATER JET CUTTING EQUIPMENT

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ABSTRACT. The article provides information on modules assembling the water jet cutting equipment. Various fabrications of the separate modules are described. Information is given on the function and purpose of the modules and their basic technical features.

РАЗРАБОТКИ В ОБЛАСТТА НА ТЕХНОЛОГИЯТА НА ИЗРЯЗВАНЕТО НА ФИГУРИ ОТ ДЕКОРАТИВНИ СКАЛНИ МАТЕРИАЛИ НА ХИДРОРЕЖЕЩО ОБОРУДВАНЕ

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РЕЗЮМЕ. Статията съдържа сведения за модулите, изграждащи оборудването за хидроабразивно рязане. Описани са различни видове изпълнения на отделни модули. Дадени са сведения за функционалното предназначение на модулите и основните им технически характеристики.

The processing of decorative rock materials has always been connected with a series of problems, which complicated their figure cutting. The method treated in the paper considerably increases the potentialities for their artistic processing. Stone mosaics, which illustrate the method potentialities for cutting up by water jet, are presented in fig. 1.

Fig. 1 Mosaics made by water jet cutting up.

Water with abrasive allowance under high pressure is used at the water jet cutting, so the equipment contains modules, providing the needed jet parameters. Fig. 2 shows a simplified diagram of such stationary equipment, which can conditionally be divided in the following three parts:

- Hydraulic – provides a water jet with the parameters needed;
- Mechanical – provides the relative movement of the half-finished material and the cutting head;
- Electric – controls the cutting process.

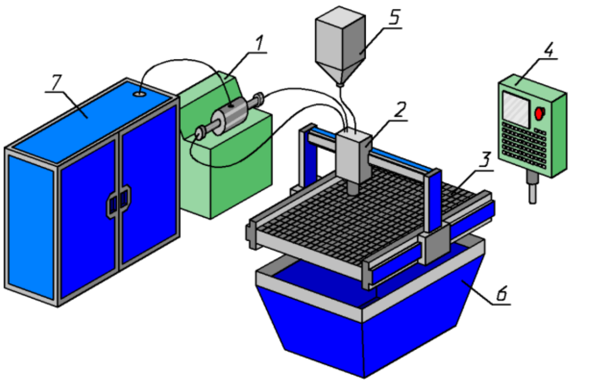


Fig. 2. Modules of a stationary water jet. 1 – multiplier; 2 – cutting head; 3 – co-ordinate table; 4 – control system; 5 – abrasive feeding system; 6 –sewer- catch basin; 7 – water feed system.

The operation principle of all the types of water jet equipment is the same. It is based on the use of a water jet under high pressure, so a unit that increases the pressure to the grade needed is necessary. Under such a pressure the water represents a very corrosive medium, so a special filter system is used in order the lifetime of the pipelines parts to be prolonged. Fine abrasive is added to the water in need of cutting materials, which are difficult to be cut. This is realized by a special block, which by vacuum or pressurized air feeds the abrasive in the mixing chamber disposed in the cutting head. After that, the hydro-abrasive mixture is fed through an opening with diameter $d \approx 1mm$ in order particles supersonic speed to be to be obtained. A sewer- catch basin is used for separation the particles from the abrasive and the processed material particles from the outlet water before the utilization. The functional relation of the described units is shown in fig. 3. The equipment modules are connected by high pressure hoses.

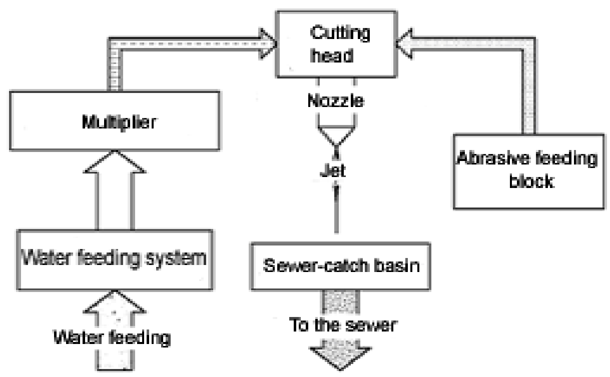


Fig. 3. Functional relation of the water jet modules.

The water feed aggregate includes systems for water purification and softening, tank, a system for maintenance of the pressure at the station inlet, and a closed water cycle for the high pressure station cooling. Usually, the water feeding aggregate is combined with the high pressure station (multiplier) – see fig. 4, which considerably increases the lifetime of the latter.

A universal principle hydraulic diagram, where a special single or double acting multiplier is used for the pressure increase, has been developed (fig. 5). The disposition choice depends on the concrete processing conditions (like allowable pressure drop and the needed fluid consumption), which allows the determiner results connected with the output and quality to be obtained. Standard adjusting, controlling and secondary hydraulic devices have been used. The signal from the control system enters in the electromagnetic couplings of the controlling slide valve 1, which moves the power slide valve 2 of the high pressure pipeline. The fluid gets into one of the operating chambers of the double acting hydraulic cylinder 3 moving the piston with the stock. Furthermore, the prepared fluid, which after that is pressurized to the extent needed, is fed by the water aggregate.

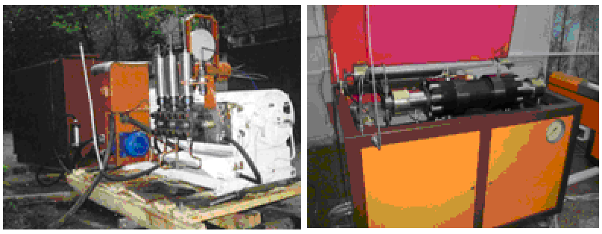
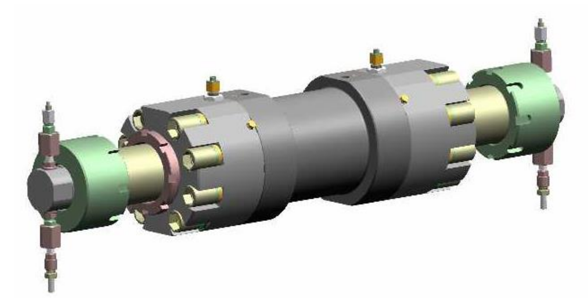
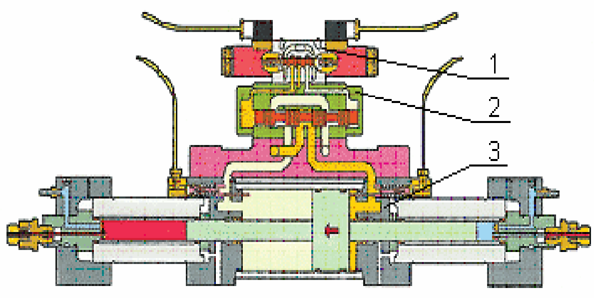


Fig. 4. Design of the water feed system.



A) General View



B) Diagram of operation
Fig. 5.Double action multiplier.

Two types of systems for abrasive feeding are used – vacuum (in the sprayer principle) and operating under high pressure. The system represents a separate block (Fig. 6). The abrasive is dumped in a bin, disposed under the operational table, and is fed in the cutting head by a curving hose. Usually, powders from hard alloys, carbides and oxides are used as abrasives and the choice depends on the processed material hardness: for hard alloyed steels – extremely hard garnet particles; for glass – the respective fractions of simple sand; for plastics reinforced with glass or carbon fibers – siliceous slag particles.

The design features of the jet head (the parts relative disposal, the type of connections and their sealing) influence the hydro-dynamic characteristics and compactness of the jet shaped and determine the quality and reliability of it operation.

On one hand, the existence of great number of jet head designs (Fig. 7) testifies to the diversity of the demands toward them and on the other hand to the fact that an optimum design has not been created up to date.

Fig. 6. Bin of the abrasive feeding block.

The following classification of jet heads is based on the analysis of the existing designs:

1. Jet heads for hydraulic materials cutting – for processing with a pure jet under high pressure without use of additional allowances in order the cutting output to be increased.
2. Jet heads with improved dynamic characteristics for fluid materials processing – unifies the jet heads equipped with elements for improvement of the cutting jet dynamic characteristics.
3. Fluid-abrasive jet heads – with feed of abrasive in the cutting jet with the purpose of intensifying the process. The designs with free feeding of abrasive in the jet and minimum disturbances of it hydro-dynamic characteristics are thought to be the best.
4. Jet heads with coolant feed for the fluid running out the nozzle – drives to improvement of the jet cutting potential caused by the ice particles formatting in it as well as to increase in the nozzle wear resistance due to it frozen surface.
5. Combined heads – allow an increase in the cutting efficiency due to the combined use of coolant and abrasive.

Fig. 7. Designs of cutting heads.

The principle diagrams of cutting heads are presented in fig. 8. Usually the nozzles are made from synthetic stones (sapphire, diamond and corundum) and bear up about 250-500 hours operation.

After the cutting, the outlet water runs into the sewer-catch basin, which is disposed under the co-ordinate table. There the particles from abrasive and waste material fall on the bottom while the purified water is utilized. The particles are separated and used repeatedly.

A relative movement of the tool and the half-finished material is necessary during the material cutting. Technically this is realized by three drives according the respective coordinates. The co-ordinate table allows the cutting head to be moved along the three co-ordinate axes in high accuracy. Above the table, along the axis X moves a gantry with a trolley moving along the axis Y. An operation head, which moves along the axis Z is mounted to the trolley. This affords the opportunity of cutting along the three axes, which provides a high accuracy in the processing of 3 D as well as of flat materials. The interaction of the control system and the drives is shown in fig 9.

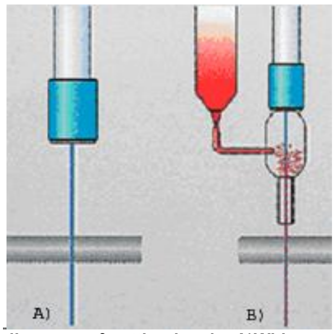


Fig. 8. Principle diagrams of cutting heads. A)Without abrasive feed; B) With abrasive feed.

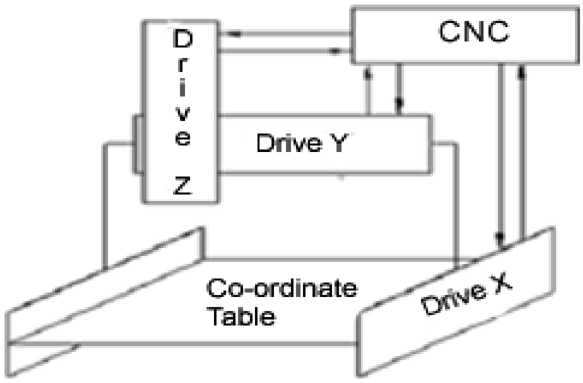


Fig. 9

The gantry diagram of disposition allows the drives and guides to be taken out of the processing zone (in height and by the sides). By that means the corrosion of the parts caused by the splashing water jet is reduced.

The co-ordinate table is designed for the foundation of the half-finished material at the processing and a set of changeable clamps and supports, which are mounted on changeable grates, are used for the fixation. On one hand the grates decrease the demolishing influence of the jet on the table surface and on the other hand they cut up the jet.

There are protective fences along the perimeter of the co-ordinate table, which prevent the jet flying off out of the operation zone at processing of inclined half-finished materials.

The movement in longitudinal, transverse and vertical direction is realized by screw-balls gear, driven by three-phase induction motors and rarely by linear motors.

Designs with manual drives providing the movement along the axis Z are used. The rotary motion of the flywheel with the crank arm is transferred in reciprocal by a rack. The drive designs with back-couplings related to the cutting head position toward the half-finished material simplify the equipment exploitation by excluding the necessity of manual adjustment.

The drives are protected from pollutions, abrasive and water by metal fences.

The gantry with the drives for longitudinal and transverse shifting as well as the cutting head move along guides mounted to the opposite fronts of the co-ordinate table. The drive providing the vertical shifting moves along guides mounted to the gantry beam. Usually, rolling guides, which provide easier movement I comparison with the slide ones are used.

The cutting head moves along slide guides in vertical direction because it is necessary only at the initial adjustment of the system.

When the cutting is according to three co-ordinates, the cutting head is suspended on a special rotating unit with manual or automated rotation.

The cutting process is realized by a CNC system which delivers a signal to the electric motors of the drives and to the electromagnetic relays controlling the water equipment. The transducers, mounted to the drives allow the CNC system to control their position, speed and acceleration. The transducers choice depends on the type of the dive: when the drive represents a threaded screw, built-in tachogenerators, potentiometers and circular photoelectric transducers are used while in case of linear drives – linear potentiometers and linear photoelectric transducers. Each drive is equipped with a limit switch. From the pressure transducers and the limit switches the signals are sent to the water equipment units.

Transducers for control of the distance between the nozzle and the half-finished material are employed at the automated drive in vertical direction.

Control systems GE FANUK, SIEMENS, NUM etc. are applied in water jet equipment. Some foreign and Russian companies have developed their own program packages, which combines to Auto CAD and other similar programs. The control cabinet is equipped with data input units (from CNC and manually), monitors for indication of the cutting time, nozzle abrasion control, adjustable radius compensation during the operation and for universe function in the program (Fig. 10).

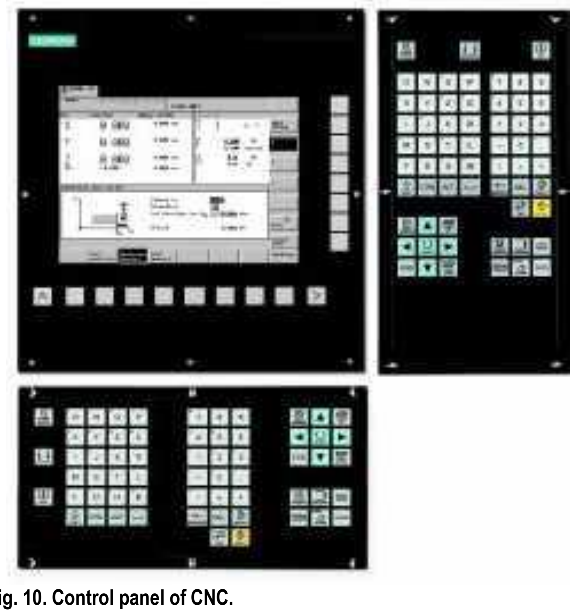


Fig. 10. Control panel of CNC.

The control system is based on the standard ISO codes. The executive program could be input from the operator desk or by input device (CD-ROM or a device for connection with a computer).

In view of the fact that most of the water jets are equipped with several cutting heads, the proposed processing programs have up to 4 zero co-ordinate points. Furthermore, there is protection, on a program level, against collision of the heads during the operation.

From the point of view of technology, the water jet operation is very simple and resembles to the processing by milling machine. The only difference is the tool radius, which is about 1 mm, so the executive program is similar to that for the milling machine. The mosaic element is divided into separate primitive parts, which could be obtained by circular or linear interpolation. After that, the optimal places for the tool entering and going out of the processed part have to be determined. This is necessary, because of the inhomogeneity of the rock materials, which could drive to refuse in case of inaccurate choice. When the equidistant is obtained, the executive program could be created. The example of the program for creation of the element of fig. 11 is presented in fig. 12.

The water jet cutting is often used for complex contours from tiles. Due to the extremely narrow cut-off the method is suitable for creation of incrustations from decorative rock materials. The most important is that an opportunity for industrial production of articles, which have been manually made only, is afforded. In order the method output to be illustrated the speeds of the actuator feed at the processing of decorative rock materials with different thickness are presented in Table 1. In broad outlines, the feed is restricted by the jet ability to penetrate the cut material and the cleanliness of the cut-off surface.

Fig. 11. Example of mosaics element, obtained bu water jet cutting.

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%M07
:
N1G90
:
N20G0X230.425Y5
N21M77
N22G2X208.152Y-20.045 I205.229J4.981
N23X62.265Y-20.045 I135.208J604.43
N24X117.065Y-116.979 I-28.158J-135.122
N25X20.132Y-62.178 I135.208J28.244
N26X20.132Y-208.065 I-604.343J-135.122
N27X117.065Y-153.265 I135.208J-298.488
N28X62.265Y-250.199 I-28.158J-135.122
N29X208.152Y-250.199 I135.208J-874.674
N30X153.351Y-153.265 I298.575J-135.122
N31X250.285Y-208.065 I135.208J-298.488
N32X250.285Y-62.178 I874.76J-135.122
N33X153.351Y-116.979 I135.208J28.244
N34X211.784Y-17.281 I298.575J-135.122
N35M78
N36M02
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Fig. 12. Part of the executive program.

Recommended for publication by the Editorial staff

Table 1

Material thickness, mm	5	10	20	50	100
Marble	4,5-6,0	2,0-2,7	0,9-1,2	0,3-0,45	0,1-0,15
Granite	3,2-4,0	1,5-1,8	0,7-0,8	0,2-0,3	0,06-0,1
Glass	5,8-6,5	2,5-3,0	1,1-1,4	0,35-0,5	0,1-0,16

The consumption of abrasive is thought to be the main expense at the water jet processing, so. It is reduced by equipment, which provides restoration of a part of the used abrasive and its repetitive application. The general costs for the process are presented in fig. 14.

Fig. 14

Specialists in the field of construction and architecture, designers and restorers all over the world are interested in the water jet cutting of hard materials and in the fist place of natural rock materials and ceramics. In actual fact, the technology could be applied in realization of cut-off along all sorts of lines, which makes it especially suitable to be applied in the artistic processing of rock materials, ceramics or glass, at the manufacture of complex mosaics floors, murals, vitrails, etc.

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