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HARD AND DECORATIVE STONES PROCESSING WITH HIGH PRESSURE WATER JETS

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Abstract. *The study of dimensional stone cutting using water jets is one of the major fields of activity of the Hydromechanization team of the Department of Mining Equipment of the University of Petrosani. The paper presents the researches carried out in laboratory cutting of marble and other rocks in order to derive the laws, which are governing this process.*

Keywords: *hydromechanization, cutting, rocks, water jets*

INTRODUCTION

For obtaining some better cutting surfaces, for elimination the cutting lines created through classical dislocation, in present it has developed more and more a unconventional technology namely the cutting with high pressure water jets. In comparison with the classical methods through perforation – shooting or with diamond cables, the decorative rocks cut through water jets method have a recoverable percent of 70%.

THE DECORATIVE ROCKS, ESPECIALLY MARBLE SITUATION IN ROMANIA

In Romania there is a tradition in marble and other decorative rocks exploitation. Today, the biggest Industrial Group that produce and process decorative rocks has in its structure 14 quarries (5 of marble, 3 of travertine, 2 of andesite and 4 of limestone) and two modern processing factories. At the present, this produces 95% from the marble and limestone blocks production and 75% from the finished produces production. The pink marble from Ruschita is the most known among the finished produces, exported in many countries like Japan, Hong Kong, Great Britain, etc. One of the development solution of the finished produces from marble or other decorative rocks is their processing with high pressure water jets.

THE TEORETICHAL ANALYZE OF THE ROCKS HYDRAULIC CUTTING PHENOMENA

In order to establish the influence of each water jet and rock parameter on the cutting process wad developed a new model [3] which tries to explain the interaction between the jet and the rock be cut.
This model proposes a means of analyzing the efficiency of the water jet in the process of rock cutting. It

starts from the premise that the jet power is used to cut a Δv volume of rock. The rock is characterized by unique parameter A, that is the resistance of the rock against the jet attach [3].
According to this model, the final simplified relation for the depth of the slit h determination is:

$$h = k_1 \frac{\left[d_1 \left(\rho_p + \rho_0 \right) p_0^{\frac{3}{2}} \right]}{A u^{0,33}} - \frac{\pi}{2} d_1 \qquad \textbf{(1)}$$

where: d_1 - – the nozzle diameter of the water jet or of the abrasive one; p_0 - the initial pressure of the jet; u – the speed of the jet displacement against the rock; ρ_p - the density of the abrasive; ρ_0 - water density.
In relation (1) it can be noticed that the cutting process starts from a pressure ps [3] called threshold pressure, this being the starting point in cutting process, also the slit formation. The resistance of the rock against the jet action A can be identified from the equation (2):

$$A = \frac{k_1 d_1 (\rho_p + \rho_0) p^{\frac{3}{2}}}{(h - \frac{\pi}{2} d_1) u^{0,33}} \qquad \textbf{(2)}$$

This characteristic of the rock takes into account the nature of the rock and its porosity, the size of the sample, its fissures and permeability, etc.

EXPERIMENTS WITH PURE WATER JETS

The research scope was, on one hand to evidence the most efficiency nozzle forms and cutting heads, and the other hand to determine the legal cutting with water jets according to jet and rock parameters.

a. The angle of the jet attack influence.

The first set of tests intend to study the attack angle of water jet effect on the sample. We directed the jet on samples, both perpendicular (Φ = 0) and at $+45^o$ and -45^o against the perpendicular direction.
It observed that the perpendicular jet action on the rock surface offers the best results. Exception made the rocks which have already fissures or a cleavage directed after an certain angle. With approximation this dependence is defined by the equation $\mathbf{h=h_0\cos\Phi}$, where $\mathbf{h_0}$ is the depth of the slit for **Φ=0**.

b. The jet pressure influence.

For study the pressure influence in the cutting process we made a lot of experiments on marl, grit stone, marble, granite samples, etc. The slits created with high pressure water jets on coal, marble, grit stone and granite are presented in figure no. 1. The experiments numbers were enough big for observe that, indifferent of the cutting rock nature, the slit depth increase at the same time with jet

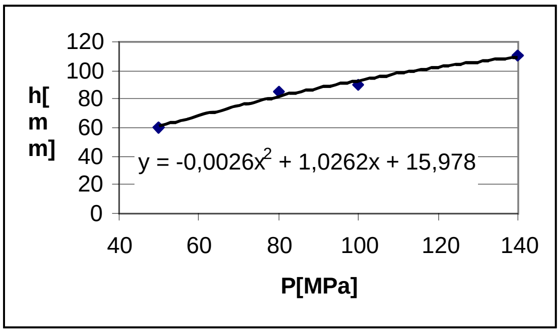

Fig.1

pressure increase. This increase is not linear but parabolic, deeper slits had obtained in abrasive and homogene rocks (grit stone).

c. The nozzle diameter influence.

The created slit sizes (depth and width) are proportional with the jet diameter. Although it can believe that the slit depth will increase as well as the nozzle diameter increase, the experiments show that for different jet pressure there is an optimum nozzle diameter. In figure no. 2 we presented the dependence resulted for a marble sample tested at high pressure, for which the cylindrical nozzle from sapphire have an optimum at 0,8 or 1,0 mm.

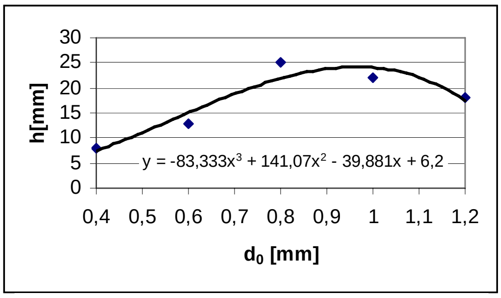

Fig.2

d. The jet displacement speed influence.

For all kind of rocks which were tested and especially for homogene rocks the dependence law is $\mathbf{u}^{-\alpha}$. The $\boldsymbol{\alpha}$ coefficient is almost constant for different types of rocks.

The constant phenomena at all kind of rocks is that as well as the jet displacement speed increase, the slit depth decrease. Although, in the case in which is executed deep slits, we suggest more high speed instead of a number of lower displacement speed.

e. The nozzle – rock distance influence.

As well as the nozzle – rock distance increase the slit depth decrease. The constant phenomena is explained that as well as the jet distance increase is dispersed due to the friction with air. The cutting depth decrease at first at once, and then as well as the distance increase lower.

EXPERIMENTS WITH ABRASIVE WATER JETS

The experiments made on world plan in specialized laboratory were demonstrated without doubts that the perforation and cutting the rocks and hard materials with water jets can be improved through using the abrasive water jets.

In these experiments we use as abrasive particles the quartz sand, electrocorindon, silicon carbide and garnet produced in Romania, mostly at CARBOCHIM S.A. Cluj –Napoca.

We created and realized a feeder with abrasive particles for study the abrasive water cutting, adaptable to the existing laboratory stand.

In essence, the cutting with abrasive water jets is similar with the cutting with pure water jets. Although, there is some differences for which we considered opportune their presentation.

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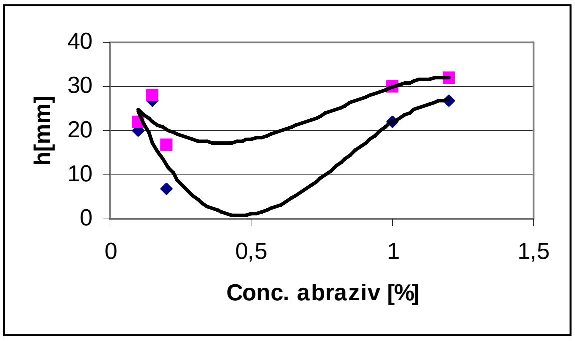
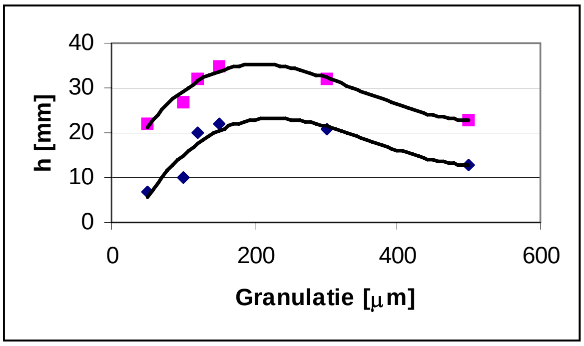
b. The water jet and abrasive water jet nozzle diameter influence.

From the made experiments it has resulted that the optimum diameter of nozzle $\mathbf{d_0}$ is contained between 0,8 and 1 mm, exception made the garnet for which the optimum diameter is 1,2 mm. In stead for all kind of tested rocks, the optimum diameter of abrasive jet exit is d_1 = 4 mm.



e. The abrasive particles concentration influence in cutting process .

For all kind of abrasive particles we tested constant that there is some optimum concentrations for which the slit depth is maximum. For example, in granet cutting case with water jet in which the abrasive is the silicon carbide, the best results (figure no.3) we obtained for concentrations of 0,2 and 1,2 kg/min.



If the water and abrasive particles mixture is realized only in the mixture room of the hydromonitor and not in the feeder tub, the recomanded concentration is smaller (0,8 kg/min). In this final case the abrasive particle mustn't be hygroscopic, otherwise is obturated the direction ways of the abrasive particles at the mixture room of the hydromonitor.

f. The abrasive particle granulation influence.

During the experiments we used abrasive particles with granulation contain between 10 and 600 μm (figure no. 4). The abrasive granulation influence also the slit depth and the cutting surfaces quality. At bigger granulations of abrasive particle, the created slits are wider.

CONCLUSIONS.

In conclusion, although the abrasive jets performances are superior than the pure ones, for the economical efficiency of using abrasive particle we must analyze the work pressure scale, the utilized nozzle diameters, the nozzle – rock distance and the utilized abrasive concentration.

The high pressure jets, in general, and the abrasive one especially, due to transmit some high powers are a revolutionary instrument for the extraction and processing of the decorative rocks and building materials, and a lot of advantages of this new technology let to expect a certain future.

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