2005 WJTA American Waterjet Conference
August 21-23, 2005 • Houston, Texas

Paper 7B-3

BRAZILIAN FOCUS TUBES AND ABRASIVES RESEARCHES FOR ROCK CUTTING IN AWJ SYSTEMS

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ABSTRACT

Researches at the São Paulo University, between mechanical and mining engineering departments, try to produce national materials in substitution on the more expensive imported products. The construction of hard metal focus tubes as spar parts for AWJ system was successfully done in Brazil for tubes of 75 and 100 mm long and with an internal hole diameter of 1 mm. Use of those tubes, in conventional AWJ systems, are now under test, to compare its behavior with the imported tubes. The main objective of the investigation is to furnish national consume materials that are not so expensive as the imported ones, on the intention to decrease operational cost on the systems. On the other hand, experiments with national natural and synthetic abrasives in the cutting of rocks for use on marble and granite dimension stone enterprises are also under study.

1 INTRODUCTION

In 2000, about 5 years ago, the researches at University of São Paulo with AWJ, begun with the import of a 2652A type OMAX System and its main objectives were presented in a paper in Canada (Lauand et al., 2000a) about the Brazilian Waterjet Researches. In the same year, first results of the rock cutting were presented in Greece (Lauand et al., 2000b). Also, an additional paper about Abrasives used in AWJ for cut or milling procedures was presented at the same event in Greece (Martin C. et al., 2000).

In 2001, the first Master of Engineering Program at the University in the rock cutting with AWJ was successfully presented. An international cooperation paper with Italy makes possible to present the main results that were presented at the 11th American Conference in Minneapolis (Lauand et al., 2001).

Resuming in this first 5 years of activity, the abrasive waterjet research group of USP has produced more 43 papers presented in international and national meetings dealing with employment of the AWJ system. Other activities were graduated work, with 2 Master of Engineering and three PhD thesis. The target material cut and milled were not only rocks, but also several other engineering materials as plastics and soils and others.

This paper, try to present some more recent researches that are under investigation between a cooperation program of the mining and mechanical engineering departments of USP, about production of focus tubes and abrasives used in the AWJ systems.

Figure 1 presents a schematic view of the three main parts of the nozzle injection abrasive waterjet (AWJ) that are the jewel, the mixture chamber and the focus tube. The geometry of these parts mostly determines the performance of the total system, and these three mentioned parts are cylindrical or conical tubes which diameter (d_i) or length (l_i) are defined in this Figure. The jewel diameter or orifice diameter is designed as (d_0), the focus tube diameter as (d_F) and the waterjet diameter as (d_{jet}). The length of the focus tube is designed as (l_f) the length of the mixture chamber as (l_1), and the length over the focus tube that receives the abrasive feed as (l_2).

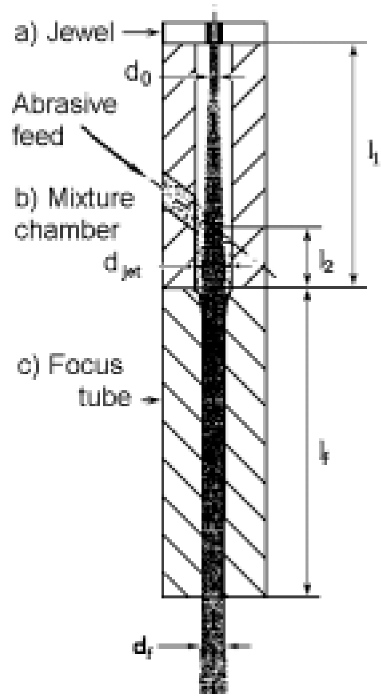

Figure 1 Schematic view of the AWJ nozzle.

2 FOCUS TUBES

Mixture or focus tubes geometry is an important element on the optimization procedure to cut or mill materials mainly if the target material is rock. The mixture tubes are part of the AWJ nozzle and in the OMAX system this is composed of a cylindrical ceramic WC tube as can be see in figure 1. Its length (l_f) is of about 100 mm, and its diameter (d_F) of 0,75 mm (0.030').

Momber discusses the influence of focus tube geometry in the radial speed of the abrasive in papers of Himelreich, Chen & Geshin, Neusen et al. (apud Momber, 1998). In these papers the abrasive particle speed is very sensitive to a change in the focus tube diameter (d_F). From this profile, a severe disintegration of the waterjet outside of the focus tube is concluded.

Also the influence of the focus tube diameter over the mean abrasive particle speed is reduced when the pump pressure higher.

Other aspects discussed are the abrasive mass ratio and the focus tube diameter and its influence over the turbulence grade in the injection abrasive water jets. Coarser particles contribute to the increase in the turbulent motion of the water flow and promote the break of the water slurry at shorter standoff distances.

Technology in the beginning of the 90 deals with focus tubes diameters between 2 to 1.1 mm. (Himmelreich, 1992 apud Momber & Kovacevic, 1998). The parameter to characterize the structure of an abrasive waterjet is the turbulence defined as:

$$T_U = \frac{\sigma_{V_P}}{V_P} \qquad [1]$$

in which T_v is the turbulence grade in the abrasive waterjet σ_{Vp} the shearing force and V_p the abrasive particle speed.

The conclusion is that for shorter focus tube diameters the shearing tension is more predominant, while for greater focus tube diameters, the mixture procedure between waterjet and abrasive particles is responsible by the generation of turbulence.

On the other hand the use of short length focus tubes (l_F = 30 mm) conduct to high turbulence compared (about 30%) which denotes inefficient mixture, and that is better in longer focus tubes (l_F = 40 mm) when this turbulence decrease to 10%.

Momber (1995) suggests Normal Gaussian Distribution (DGN) to characterize the distribution of the speed of abrasive particles, with the following equation:

$$f(V_P) = \frac{1}{\sqrt{2.\pi.V_P}} \cdot \frac{\left(V_P - \overline{V}_P\right)^2}{2.\rho_{V_P}^2} \qquad [2]$$

Typical values of average particle speed of V_p = 250 m/s, and σ_{Vp} = 41,4 m/s for the standard deviation are suggested, respectively.

Chen and Geskin (1991) (apud Momber, 1998) shows that the average standard of particle speed distribution is similar for different abrasive diameter sizes, what can be attributed to the comminuting of the abrasive grains during the process of mixture and acceleration.

It can be observed a development tendency, in the focus tube geometry that is the changing of its diameter (d_F) and length (l_F). It seems that shorter is the diameter better is the performance of the tube and also if longer is its length better its performance. These two geometric elements must be related to the jewel orifice diameter and to the grain size of the abrasive particles that is discussed in the next item.

The manufacture of hard metal focus tubes in Brazil is perfectly possible and its cost is well inferior to the 250 US $ that is that of the imported ones. In a first stage tubes with identical external diameter to the original of 12 mm (1/2') and having a length of 75 and 100 mm (l_f) had been manufactured, and with internal diameter (d_F) of 1 mm.

Figure 2 shows photography of the 100 mm length focus tube, and Figure 3 the 75 mm length focus tube, used mostly in the Flow type waterjet systems.

Figure 2 Focus tube of 100 mm length.

Figure 3 Focus tube of 75 mm length.

The next step of test was a comparison performance of this focus tubes with the original in which was the determination of its loss in weight to estimate its life time.

3 ABRASIVES

In 2000, a first paper of abrasives that can be used in the OMAX System was presented. This deals with technological characteristics of the disposable synthetic and natural abrasives (Martin C. et al., 2000).

At the beginning of the research Program, it was a problem; than the standard recommended abrasive the natural garnet does not exist at Brazil, and must be imported. The first solution was to buy some synthetic abrasive powders as aluminum oxide and carborundo that exists. As recommendation of our consulting assessor (Professor Raimondo Ciccu of Italy, verbal communication) that says doesn't use synthetic material as abrasive, there was tried to use the aluminum oxide. Due to its acicular form, this material was retained in the focus tube and gives some reverse shock that breaks the jewel. After two tests that had destroyed two jewels the experiments were stopped.

A second tentative to use synthetic or artificial powder abrasives was with the use of brown rounded aluminum oxide with the cooperation of an abrasive producer in Brazil. Also in this second tentative, the result of the tests was excellent, when looking to the surface finishing of the generated kerf in the granite cut by the AWJ. Otherwise, the lifetime of the focus tube, the original one, was very short. There only has a duration of some hours, in opposition when the use of garnet which lifetime can be extended to about 100 hours.

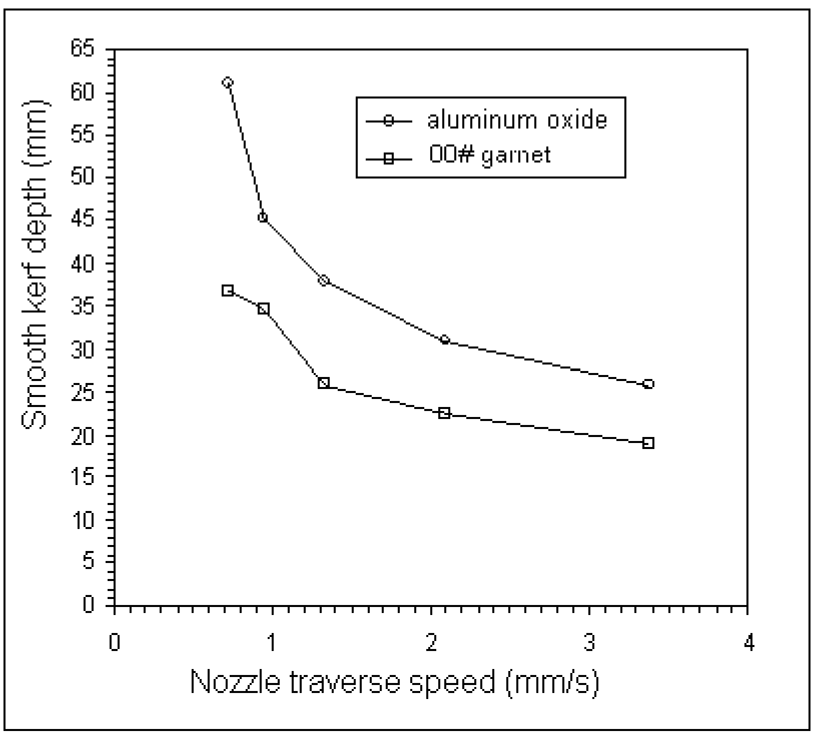

Figure 5 Comparison between Smooth kerf depths (mm) obtained with round brown alumina and garnet in granite cut.

Figure 5 shows the comparison between smooth kerf depths in mm obtained in the cut of the Red Capão Bonito Granite with garnet and with the synthetic round brown aluminum oxide.

Figure 6 shows the entrance of the abrasive waterjet and Figure 7 the exit of kerf cut in the granite. Figure 8 shows the mixture or focus tube nozzle destroyed by synthetic abrasive.

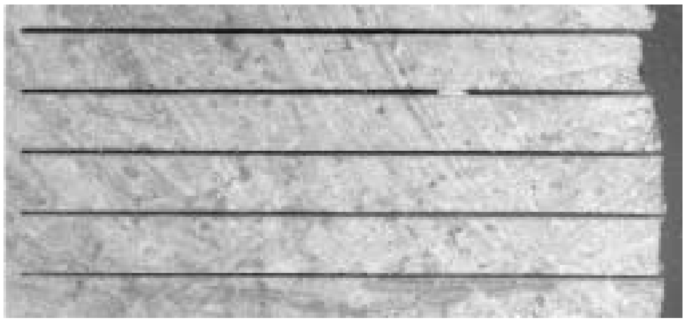

Figure 6 Entrance of waterjet in the granite

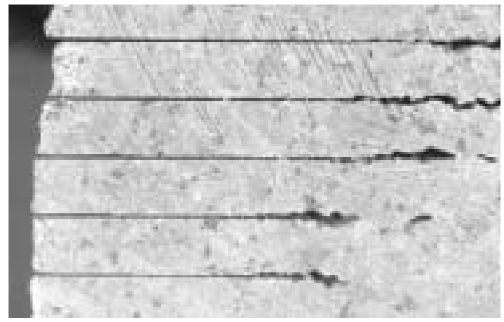

Figure 7 Exit of the water jet in the granite

Figure 8 Mixture tube nozzle destroyed by synthetic abrasive.

If there is made an observation about development of use of powder abrasives in the AWJ systems, it is possible to observe some development tendencies. So, at the end of the 80 and beginning of the 90 if was common to use coarser grains, about 50# in size of the garnets particles. When the research begins in Brazil at the year 2000, it was common to use 80# sizes of the garnets. Today it is a tendency to use finer sizes of 120#.

Dimension of synthetic abrasive grains were evaluated under the magnifying glasses. Figure 9 and 10 shows these pictures of a 50 and 60# synthetic abrasive on a 50 times magnification. A scale of 200 μm gives an idea of the grains dimensions and geometric forms.

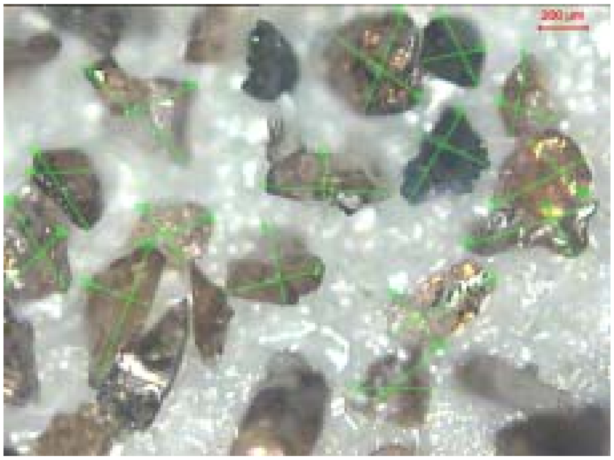

Figure 9 Synthetic abrasive grains 50#.

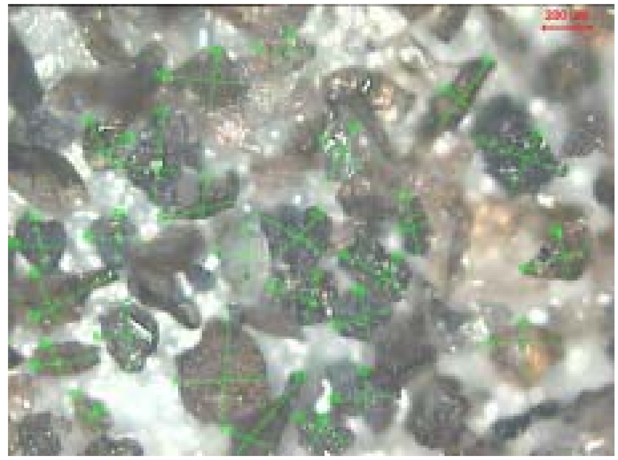

Figure 10 Synthetic abrasive grains 60#.

Researches of rock milling in the system was done preferentially with the use of the finer garnet with mean size of 120# (Stellin et al., 2004).

4 CONCLUSION

As main conclusion of this paper it can be established:

- ✓ Focus or mixture tubes can be produced in Brazil, very cheaper than the imported, and its quality now under tests, will be comparable of the originals.
- ✓ Artificial or synthetic abrasives may not utilised in AWJ systems, some experiments with round brown alumina, gives good results in performance of the cut in rocks, but destroys the focus tube.
- ✓ Natural abrasives as garnets, that are the more conventional material, exist in Brazil as tailing material of monazite beneficiation processes, and it can be recycled.

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