Technological Characteristics of Garnets for Ultra High Pressure Water Jets

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ABSTRACT

The abrasive used in ultra high-pressure water jet cutting systems is one of the important elements in the kerf opening. To cut rocks, metals, ceramic, and other hard materials, the abrasive more used is the garnet mineral. Their technological characteristics are important for this cutting technology and can influence in the definition of a powdered material as an abrasive; mainly they are size, hardness, and the geometric form of the grain. The treatment tailings of the monazite's sand ore of Espírito Santo State, processed at the plant in Buena are constituted mainly of ilmenit and garnet. Preliminary rehearsals accomplished on sample revealed that the tenor in garnet is superior to 20% in weight. A concentrate, prepared in laboratory was rehearsed for determination of their main technological characteristics. The mineralogical constitution reveals almandine/almandite existence, and some grossular. The size rehearsals accomplished in laser diffracting beams (Malvern) show that the same has appropriate diameter grains to be used as powdered abrasive. His form revealed by pictures in binocular magnifying glass shows that the same is adapted for job as powdered abrasive, so much for sandpaper, or abrasives bricks as well as for use in advanced water jet cutting systems.

INTRODUCTION

The present paper treats of the technological characterization of the garnet mineral obtained from tailings of monazitic sand treated by Nuclemon, in an improvement plant located at Campos’s municipal district in the state of Rio de Janeiro. The characterization seeks the use of the garnet as abrasive in the hardness materials cutting process using abrasive water jet. Until today, the abrasive water jet workshops existing in Brazil are forced to import this material.

The abrasive water jet technology of ultra high-pressure (42.000 psi = 289,5798 MPa and more) is largely used in development countries. That’s could be verified in the great quantity of edited
bibliographical material. In the modern automated cutting systems, the control operation by computer using software of CAD/CAM is possible to do pieces and parts of precision for our modern industry. The System of abrasive water jet installed in the Mechanics of Rocks Laboratory of EPUSP and the main Brazilian objectives for next years were described in paper presented last year at SWEMP2000 in Calgary, Canada (Lauand et al., 2000).

In Brazil, the number of abrasives water jet installed machines is still little but, for the future, there are some possible alterations in this landscape. Some manufacturing companies of this type of equipment began to install in our country and every time is growing the interest by these machines of abrasive water jet. In fact it is plenty justify because the advantages of this process. In any kind of material provides cuts, quick, precise, with small material loss, good finishing and without a material heating. For dimension stone cutting the results are not less satisfactory. It is possible to cut granite and marbles foils with high precision, allowing to raise geometric forms never before obtained by the traditional process.

Abrasives are, by definition, hard and sharp materials, used to work the surface of soft and less resistant materials. Included, inside of the term of abrasives are natural materials, synthetic and manufactured substances that space from the relatively soft ones that are used in home-made cleaners and the jeweler's polishing to the known hardest material, the diamond. Abrasives are indispensable for the production of almost all of the products done in the modern industry with components of high precision as automobiles, airplanes and space vehicles, mechanics and electric parts, and appliances.

History of abrasive use is very old. The primitive man cleared a hard stone against other with abrasive effect to sharpen his weapon or tool. During the mechanization phase of the first industrial revolution the natural abrasives were used.

An interesting history happened in 1873 in the United States when Swen Pulson, working in the Norton and Hancock Ceramic Co., Worcester, Massachusetts, won a beer pitcher betting that he could make a wheel milling in form combined emery with ceramic powder and dismissing them in an oven. A little before the turning of the century the man discovers the process to make aluminum oxide and silicon carbide in an electric oven. In 1955 the General Company Electric had success in the obtaining of synthetic diamond.

More recently the mechanization of the industry develops, plus every day, for the automation. However, to make the form cut controlled by computer of most of the modern materials, in the hardest the use of abrasives is essential.

To operate the system of water jet with efficiency the manufacturer prescribes to use 80 mesh size garnet as abrasive. Unfortunately, the quality garnet as natural abrasive for water jet is not produced in Brazil, and it is necessary to import the product. The cost of the imported product, including price and Brazilian taxes, is approximately 2 R$/kg (more or less 1US$/kg).

On the other hand, there are many suppliers of synthetic abrasives in Brazil, of aluminum oxide or silicon carbide. The prices of these manufactured abrasives (size of 80 meshes) it is of 1,13 R$/kg for aluminum oxide and 1,86 R$/kg for silicon carbide that is cheaper than the imported garnet.

The present work seeks to make a complete characterization of the available abrasives in the moment, however they will only be presented the partial results obtained at the Ore Technological Characterization Laboratory of the Mining Engineering Department, Polytechnic School at the University of São Paulo.
TECNOLOGICAL CHARACTERISTICS OF ABRASIVE MATERIALS.

The main technological characteristics that should present an abrasive so his grains can be used in abrasive water jets high pressure cutting systems (Agnus et al., 1995 & 1996) are the ones that express his Abrasive Power and can be calculated by the following mathematical expression:

\[ P_{\text{Abr}} = H_p^{a1} \cdot S^{a2} \cdot \rho^{a3} \cdot d^{a4} \cdot m^{a5} \]  

In equation [1]:

- \( H_p \): Knoop hardness of abrasive material
- \( S \): Particle shape factor
- \( \rho \): density of the abrasive material
- \( d \): diameter of the abrasive grain
- \( m \): flow rate of the abrasive mass

To better understand the feature, the Brazilian Garnet was evaluated according to their abrasive power as determined in equation [1].

The mineralogical composition of the sample was studied and determined in a semi-quantitative determination by Spectrometry with an X-ray apparatus. Shape of the particles was measured by a method suggested by Ayres da Silva & Hennies, 1983, to determine the mean roundness of the abrasive grains. Chemical analyses of the garnet were also performed. Abrasive grain hardness was determined from microhardness indentation test on polished grain section samples. Density of the abrasive material was calculated directly by a pignometer method. Finally, grain size distribution was determined using a laser beam apparatus (Malvern) to evaluate the garnet grains diameter.

ASSAYING RESULT

Mineralogical characterization
The Brazilian garnet sample is mainly composed by Almandine / Almandite, including some Grossular, Quartz, Allophane and Pseudo-brookite.

Particle shape characteristics
According to the method suggested by Ayres da Silva & Hennies, (1983) presented at the 6th International Rock Mechanics Congress of Melbourne, Australia the shape factor of the Brazilian garnet is 0,73. It’s mean that is a high roundness factor as an abrasive material.

Hardness of the Brazilian garnet
Polished slice was prepared for Vickers microhardness determination, after that submitted to an indentation test by a tetragonal diamond prism. The resulting values, by correlation was taken to Knoop values, using the Momber, Kovacevik (1999) proposal.

<table>
<thead>
<tr>
<th>Table 1 Microhardness of the Brazilian garnet</th>
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<td>Vickers hardness</td>
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<td>175</td>
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Specific gravity of the Brazilian garnet
This determination was performed using the pignometer method as described in the literature. The result is 4.04 g/cm³.
Chemical analysis results of the Brazilian garnet in %

Table 2

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<tbody>
<tr>
<td>SiO₂</td>
<td>28,3</td>
<td>Fe₂O₃</td>
<td>35,3</td>
<td>K₂O</td>
<td>0,06</td>
</tr>
<tr>
<td>TiO₂</td>
<td>3,44</td>
<td>CaO</td>
<td>1,79</td>
<td>SO₃</td>
<td>0,06</td>
</tr>
<tr>
<td>MnO₂</td>
<td>1,17</td>
<td>MgO</td>
<td>3,41</td>
<td>P₂O₅</td>
<td>1,88</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>13,9</td>
<td>Na₂O</td>
<td>-----</td>
<td>V₂O₅</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ZnO</td>
<td>0,08</td>
<td>ZrO₂</td>
<td>4,02</td>
</tr>
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Grain size distribution

![Brazilian Garnet Grain Size Distribution](image)

Fig. 1
Fig. 2 Brazilian garnet in 320 magnification showing the rounded grain as a result of the erosion natural process

REFERENCES


