The Effect of Microwave Pre-Treatment of Ores on the Comminution Process

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Introduction

• Mineral processing is the process of separating valuable minerals from gangue
• The process is estimated to account for 6 percent of global energy consumption and is as little as 3 percent efficient [1]
• With the increased focus on environmentally friendly practices, the optimization of the comminution process is of vital importance

Objective

• Analyze the effect of microwave pre-treatment on the grindability of the Voisey’s Bay ore
• Optimize the pre-treatment process to produce the greatest reduction to the energy input during grinding

Microwave Heating

• Microwave radiation encompasses the range of the electro magnetic spectrum between 300 MHz and 300 GHz
• Microwave heating functions only for dielectric substances, where heat is generated primarily through the rotation of dipoles
• A dielectric substance is an electric insulator which is polarized in the presence of an electric field [2]

Microwave Pre-Treatment of Ores

• Minerals show varying responses to microwave radiation
• Microwave heating of ores functions on the basis that valuable minerals are receptive to microwave radiation, while gangue minerals are transparent to their effect
• Microwave radiation causes differential heating within an ore body which leads to cracks forming along and across grain boundaries [3]

Grinding

• Grinding, along with crushing, is the primary source of size reduction in mineral processing
• As the mill rotates the mechanical forces acting on the ore body overcome the bonding forces and cause a general reduction in grain size
• The size reduction is directly proportional to energy input by the mill. i.e. the ball charge, grind time

Bond Mill Test

• The Bond mill test was developed as a method to classify an ore based on the energy required to achieve a given size reduction
• The work index represents the energy required to reduce ore from infinite grain size to a predetermined passing size [5]
• The ore tested is Vale’s Voisey’s Bay Eastern Deep Massive Ore; it is a nickel and copper ore composed primarily of chalcopyrite (CuFeS₂) and pentlandite [Fe₃Ni]S₈ and contains traces of some other minerals

<table>
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<th>Material</th>
<th>Fe</th>
<th>Ni</th>
<th>Cu</th>
<th>S</th>
<th>MgO</th>
</tr>
</thead>
<tbody>
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<td>Massive Ore</td>
<td>±54.7</td>
<td>±35.3</td>
<td>±3.4</td>
<td>±0.7</td>
<td>±0.1</td>
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</tbody>
</table>

Results

• The Bond Work Index was established for the untreated ore; it was found to be 13.5 kWh/mt
• Samples were treated in a 3000 W 2.45 GHz microwave for 30, 60, and 90 seconds
• The samples were ground for 5 minutes and a full size analysis was performed to determine the most efficient exposure time
• A second Bond test was performed on the ore after being treated at 3000 W for 60 seconds
• The Bond Work Index of the treated ore was found to be 10.5 kWh/mt: a reduction of 22%

Conclusions

• Microwave pre-treatment reduces the energy input required in grinding to obtain a designated level of reduction
• Microwave pre-treatment shows diminishing returns after an optimal exposure time has been achieved
• Optimization of the microwave pre-treatment process is required before Vale would be able to utilize it in the size reduction of the Voisey’s Bay Eastern Deep Massive Ore

Future Work

• Optimize the microwave pre-treatment process
• Analyze the effect of microwave pre-treatment on the whole comminution process
• Test the effect of different microwave powers as well as the effect of utilizing a mono-modal microwave

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References


Figure 1: A standard laboratory Bond ball mill

Figure 2: Scanning electron micrograph showing an untreated (a) sample as compared to microwave pre-treated sample (b) [4]

Figure 3: An unground ore sample (a) as compared to a sample ground for 30 minutes (b)

Figure 4: Percent cumulative passing vs. mesh size for ores at varying microwave exposure times

Figure 5: Bond work index vs. microwave exposure time

Figure 6: Modal microwave treatment process to produce the treated sample