New blasting methods to a efficiency in economics and environmental

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Abstract

The blasting operation in open pit, causes environmental impacts and discomfort to the populations living in the surrounding areas. Currently are used the best techniques of explosives application and their monitoring of environmental impacts, and it’s possible to reduce them within the limits of the law, and managing to a minor inconvenience for people.

The degree of rock fragmentation after a blasting is one of the most important aspects in the optimization of production costs in mining. The qualities of fragmentation influence the cost of subsequently operations, like loading, transport and crushing. Because of that the blasting explosives requires a careful study in order to optimize the design diagram of fire to achieve the desired fragmentation.

It is in this context that the present work arises as a preliminary approach to a possible improvement both in minimizing environmental impacts, as well as in the technical/economic efficiency of subsequent operations. That ensures good fragmentation permitting saving features.

Then is considered the use of articulated air-deck system with plug's to improve stemming quality, studying the theoretical effect and comparing it, with fieldwork in the quarry of Cimpor-Souela.

Based on the degree of fragmentation obtained by applying the method in test, was estimated their influence in terms of cost in subsequent operations including loading, transport and crushing.

Keywords: Blasting, costs, unit operations, environmental impacts, air-deck, degree of fragmentation.

1. Introduction

Any mining or geotechnical work that uses explosive and is performed near a residential area, always produces various environmental impacts. This consequences rarely are well received by the communities, which makes mining or civil works, to be always under enormous public pressure so that these occurrences are minimized.

To comply with environmental protection measures, there is now an increasing need to monitor, control and minimize such impacts, reinforcing the need to know how to characterize the phenomena associated with the fragmentation of rocks using explosives. Such behavior will allow
not only the protection of the population and surrounding structures, but also greater economy and efficiency in blasting. For it is known that it is compatible with the minimization of the impacts, unlike what happens in most other industrial activities.

Given the existing interconnection between the various unit operations, it is important that when looking to minimize costs, always look at the global economy, not as an independent operation. For example, a minimization of excessive costs for a given operation will reflect negatively in subsequent operation.

Contrary to what occurs in most industries, where the most economical solutions are accompanied by major environmental impacts, minimizing costs in rock excavation is compatible with minimizing their environmental impacts. In fact it turns out that there is a connection between the magnitude of environmental impacts and the costs of rock blasting operation with explosives which are minimized through fragmentation while encouraging the application of appropriate technology to the solution of two problems (Bernardo, 2004).

![Figure 1 - Minimization of costs in the various unit operations depending on the size of the fragments and consequent environmental impacts (Dinis da Gama & Jimeno, 1993).](image)

2. Case Study

The Souselas Production Centre (CPS) is located 14 km from Coimbra and is one of three cement plants that Cimpor operates in Portugal.

2.1. Methodology

2.1.1. Theory of Air-deck and stemming plugs:

The theory was first proposed by Melnikov and Marchenko (1971), and Melnikov et al. (1979), who postulated that when shock waves reflect from the boundary between the stemming bed and an air gap, a secondary shock wave is generated that extends the network of fractures prior to gas pressurisation. The degree of fracture is increased by the second shock wave and the duration of the shock wave action on the rock surrounding the hole is also extended.

Consequently, the crack network within the rock mass is increased when using air-deck blasting techniques. Moxon et al. (1993) indicated that if the air deck is placed in the middle of the explosive column, the pressure front will collide at the centre of it. This interaction should develop a reinforced stress field and result in a radial crack pattern than if an air deck was kept on the top of the charge.
The reduced blasthole pressure caused by the air-deck is still capable of creating an extended fracture system and there is sufficient high-pressure gas to obtain the desired amount of ground movement. The lower peak blasthole pressure reduces the loss of explosive energy associated with excessive crushing of the rock adjacent to the hole. This process adds only microseconds to the event and an observer would not notice anything different about the blast (Cleeton, 1997).

Today there are several devices available in the market that allow an improvement in the overall performance of the blasting, in flyrock control and productivity. The appearance of such devices is associated with the need to optimize the stemming, to prevent the exhaust gas from the top of the hole, and ensure that this flows across the free face instead of stemming. The final result is an increase in the energy transmitted to the rock mass in a way that is expected an improvement in fragmentation so that the operation becomes a more efficient blasting due to the decrease of energy losses.

A plug like in Figure 3 (when properly supported by a suitable stemming) is destroyed in the heat release phase, thereby adding a few milliseconds to allow the gas released by the detonation to be spread into the rock mass.

2.2. Blasting experimentation

The experiments were conducted in two different benches located in the same quarry, in a total of 5 blastings. Blast performance, more specific the fragmentation size of the rock, was observed and analyzed, using Split Desktop image processing software. In order to isolate and evaluate the effect of air-deck, other blast design parameters were kept similar. On the bench N60 were performed 2 blastings, and on S40 other 3.
2.3. Assessment of fragmentation

Using the Split Desktop, its obtain the fragmentation values. Through Table 1, that shows an improvement in fragmentation when applying the method under test. This improvement is particularly significant in the mean size of the fragments which decreases by 14,12%, and $\phi_{70}$ which presents a reduction of 19,32%. With regard to larger fragments ($\phi_{90}$) in can be noticed a reduction of 10,82%, further study could confirm that this reduction in size would not have any effect on the amount of material that needs secondary fragmentation. If this aspect is confirmed could represent a significant reduction in the quarry costs, given the high cost of this operation.

Table 1 – Fragmentation analysis results.

<table>
<thead>
<tr>
<th>Date of the blasting</th>
<th>Mean size of the fragments (cm)</th>
<th>$\phi_{70}$ (cm)</th>
<th>$\phi_{90}$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS Method</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-11-14</td>
<td>19,34</td>
<td>31,53</td>
<td>43,92</td>
</tr>
<tr>
<td>19-11-14</td>
<td>23,70</td>
<td>38,51</td>
<td>53,31</td>
</tr>
<tr>
<td>24-11-14</td>
<td>22,15</td>
<td>34,54</td>
<td>55,98</td>
</tr>
<tr>
<td>Average</td>
<td>21,73</td>
<td>34,86</td>
<td>51,07</td>
</tr>
<tr>
<td>Method under test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-11-2014</td>
<td>20,28</td>
<td>29,5</td>
<td>49,7</td>
</tr>
<tr>
<td>25-11-2014</td>
<td>17,04</td>
<td>26,75</td>
<td>41,39</td>
</tr>
<tr>
<td>Average</td>
<td>18,66</td>
<td>28,13</td>
<td>45,54</td>
</tr>
<tr>
<td>Variation</td>
<td>-14,12%</td>
<td>-19,32%</td>
<td>-10,82%</td>
</tr>
</tbody>
</table>

2.4. Blasting operation

Based on specific consumption presented on Table 2, it can be seen that when applied the method under test, with lower specific consumptions, is possible to obtain an improvement in the quality of fragmentation (Figure 4). Contrary to the general trend, in which to obtain an improvement in the fragmentation is needed a greater amount of explosive.

Table 2 - Specific consumptions and costs by Tone.

<table>
<thead>
<tr>
<th>Bench</th>
<th>Method</th>
<th>Date</th>
<th>Average Size of Fragments (cm)</th>
<th>Variation of specific consumption when applied test method</th>
<th>Variation of cost by tonne when applied test method (€/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N60</td>
<td>CPS</td>
<td>19-11-2015</td>
<td>23,70</td>
<td>-14,3 %</td>
<td>- 5,6 %</td>
</tr>
<tr>
<td></td>
<td>Teste</td>
<td>21-11-2015</td>
<td>20,28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S40</td>
<td>CPS</td>
<td>17-11-2015</td>
<td>19,34</td>
<td>-16,7 %</td>
<td>- 3,5 %</td>
</tr>
<tr>
<td></td>
<td>Teste</td>
<td>24-11-2015</td>
<td>22,15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>25-11-2015</td>
<td>17,04</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 See Confidential Attachment
By observation the Figure 5\textsuperscript{2}, which relates the cost per ton with the mean size of the fragments obtained, there has been an improvement on fragmentation without an increase in the cost of blasting. Instead to a decrease in the degree of fragmentation is obtained by a increase in the cost per ton.

\textbf{2.5. Environmental impacts.}

Because of the difficulty in comparing the intensity of environmental impacts derived from vibrations and airblast when using explosives, there is a need to develop a weighting factor for vibrations.

This weighting factor is calculated using the ratio between the vibration velocity, or air blast intensity obtained in the monitoring point considered and the tolerable by the legislation.

\textsuperscript{2} See Confidential Attachment
Making an assessment of the weighting factor and the average fragmentation obtained (Figure 6) where it’s see that as the fragmentation increases the environmental allocation level also increases. It is important to mention that the blasting’s which were conducted by the test method, the values obtained both in terms of environmental impact and the average size of the fragments were always better when compared with the remaining blasts performed on the same bench.

3. Evaluation of the Influence of fragmentation on load, transportation and primary fragmentation operations

3.1. Loading

Taking into account that the loading operation is performed using a wheel loader, its performance will be greater to a greater degree of fragmentation obtained from the blasting, since it will decrease the time needed for loading transport equipment and increase the volume material charged per cycle so it can easily fill the bucket (Hustrulid, 1999).
When representing the value obtained for the cost per tonne of loading operation, based on the average size of fragments, there is a relationship between these two variables as the degree of fragmentation decreases the costs per tonne increase (Error! Reference source not found.). This is mainly due to improve load operation efficiency that allows a reduction in the cost per tonne when applied test method.

3.2. Hauling

A higher efficiency of the loading operation also influences the hauling operation, because are loaded a larger number of dumper’s per hour, due to the reduction of load cycle times that reflects in a reduction of cost per tonne. Thus it is possible to do the same analysis for the previous load operation, in this case for the transport operation (Figure 8). When comparing cost values per tonne in the transport, it is found that the method under test, always have a lower cost than for the remaining blasting performed on the same bench. In addition to that by analysis of Figure 8 it appears that as the average size of the fragments increases the cost per tonne increases.

3.3. Primary Fragmentation

Through Bond formula, it’s calculated the cost for the primary fragmentation depending on the size of the feed material. Order to evaluate the progress of fragmentation costs with increasing average size of the fragments obtained to Figure 9 where as expected as the average size of the feed material increases, fragmentation costs per tonne will increase slightly.

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3 See Confidential Attachment
3.4. Total cost

The total cost is the sum of the costs previously presented, including blasting, loading, transport and crushing. Through Error! Reference source not found., it can be seen that an increase in the average size of fragments implies an increase in the total cost per tonne. Proving if so, the relationship between the degree of fragmentation of the blasted material and the total cost of all operations. To more fragmented is the material, the lower the subsequent operations costs.

As shown in Figure 1 where, by Dinis da Gama (1993), to a greater size of the fragments, higher are the costs related to the loading, transport and crushing but will lead to a reduction in cost per ton blasting operation.
4. Results discussion

By analysis on Figure 11, that relates the values for the cost per ton of various operations based on the average size of fragments. When compared to the graph obtained with Figure 1, it appears similar behavior for the various operation, and Dinis da Gama (1993) considered to evaluate the fragmentation of the maximum size of the fragments and in this study we used the average size of the fragments, as a larger amount of fragmentation quality and easier to obtain.

![Figure 11 - Relationship between the cost per ton of various operations and the MSF.](image)

Regarding the behavior of the various operations in terms of costs based on the average size of the fragments (Figure 11), it appears that the load and transport operation has a similar behavior to that of Figure 1, and the cost per tonne in operating transport affected mostly by the decrease in the degree of fragmentation.

With regard to environmental impacts present in blastings analyzed by relating the environmental weighting factor and the average size of the fragments (Figure 12). When compared with the graphic developed by Dinis da Gama (Figure 1), wherein the environmental impacts decrease as the maximum size of the fragments increases, and this behavior is due to the fact of considering that an improved fragmentation is due to use of a larger amount of explosive that makes occur at a higher intensity environmental impacts.

In this situation using the test method, that allows an improvement in the average size of the fragments, without an increase of the environmental impact.

![Figure 12 -](image)
5. Conclusions

With the development of this study has confirmed the influence of the fragmentation in the efficiency of the subsequent mining operations, and the higher the degree of fragmentation lower cost per ton. Another important aspect of the economy in mining is that this should not be seen as a maximum cost minimization in each operation, but the global economy of all operations, ie the total cost per ton at the end of all operations. Since an excessive cost minimization in a given operation may lead to increase in costs consequent operation.

In terms of environmental impacts when applied the method in test, they showed lower values of intensity for both the airblast as for speed of vibrations.

References:


