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Analysis of grinding effects of HPGR-crushed copper ore

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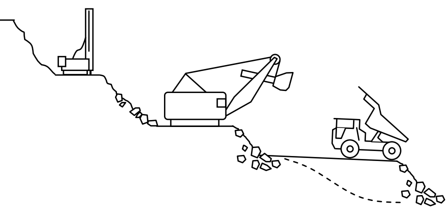
ABSTRACT

The article presents issues of HPGR product grinding operations. An influence of the HPGR operating press force and ball mill grinding time on the fine size fractions weight recovery were analyzed in the paper. The results of investigations show that for given ore type the operating pressure is a key-parameter determining the HPGR product grinding effectiveness. The model of -0.125mm size fraction generation as a two-variable function was also proposed.



1. INTRODUCTION

The comminution technology based on HPGR applications is currently one of the most efficient methods of hard ore comminution (Schoenert 1988) from the scope of the energy consumption. HPGR units have a lower unit energy-consumption index comparing to semi-autogenous (SAG) mills, ball and rod mills, and also tower mills. A high-pressure comminution process causes mechanical activation of initial cracks in material, as well as the micro-cracks formations, which results in decreasing the Bond’s work index value for the material. As a result of the above, the more effective feed size reduction and the useful component liberation take parts in downstream grinding operations in ball mill (Morley, 2003, Maxton et.al, 2003; Daniel and Morell, 2004; Saramak 2011).

Roller presses are also very efficient in terms of the particle size distribution of crushed product. The most favourable mass recovery of product particle fraction between 0.1mm and 1.0 mm can be obtained, comparing to the other crushing devices. It is a very desirable feature of product in the ore processing industry (limitation the material over-grinding) and in a limestone powder production (Kalinowski 2006, Kurdowski 1998).

The article investigates an influence of high-pressure comminution process on the grinding operations effectiveness. Therefore the main goal of the investigations was to verify how the HPGR process conditions affect the fine size fraction generation in ball mill grinding stage.

2. METHODOLOGY

Industrial operations of the size reduction constitute a crucial part in ore beneficiation technological circuits. They initially determine effectiveness of downstream operations of flotation or chemical treatment, because together with the feed size reduction liberation of useful components also takes part. The main goal of the comminution circuit is to maximize the useful component at limitation of the material over-grinding. The material particle size is a key feature influencing the effects of flotation, and it can be different for various types of ore. In general, particles below and above a given value causes a significant decrease in flotation effectiveness. For the purposes of investigation the generation of the size fraction below 0.125 mm was under analysis. Various investigations show (Potulska 2008, Brożek and Młynarczykowska 2010) that this size fraction can be a suitable feed material for the rough flotation operation for certain type of ores.

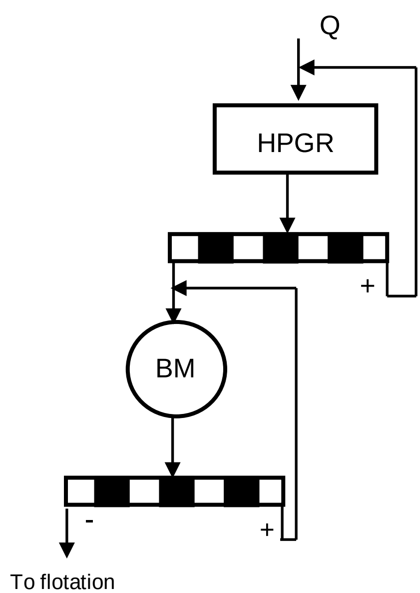


Figure 1. Typical combination of HPGR and ball mill in ore comminution circuit

The ore comminution technological circuit consists of several stages including coarse and fine crushing, grinding and re-grinding operations together with screening and separation processes. A typical combination of the HPGR and ball mill in comminution circuit is presented in Fig. 1.

HPGR unit usually operates at second crushing stage followed by the crusher. HPGR screening oversize product is recycled to the device, while the screening undersize is subjected to further grinding operation. The mill screening undersize product is a feed for flotation, while the oversize is re-grinded.

3. EXPERIMENTALS

A series of laboratory crushing and grinding tests were performed in order to verify the research problem. Four comminution tests for copper ore in a laboratory HPGR unit were run at following values of operating pressure F_{sp}: 2 N/mm^2, 3 N/mm^2, 4 N/mm^2 and 5 N/mm^2. Each product was then screened and subjected to further grinding operation in a ball mill. The size analysis was performed and size fractions under 0.125 mm was collected after 5, 10 and 15 minutes of grinding. In the first stage the contents of the four finest size fractions (0-0.125 mm, 0.125-0.200 mm and 0.200-) were determined. Results are shown on figures 2 – 5.

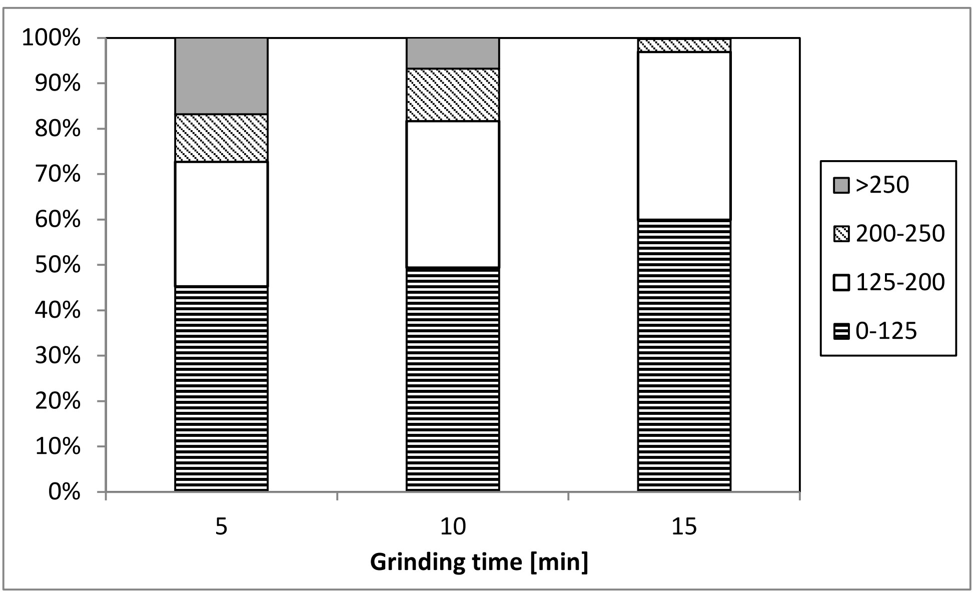


Figure 2. Contents of fine size fractions in HPGR product for *Fsp* = 2N/mm^2.

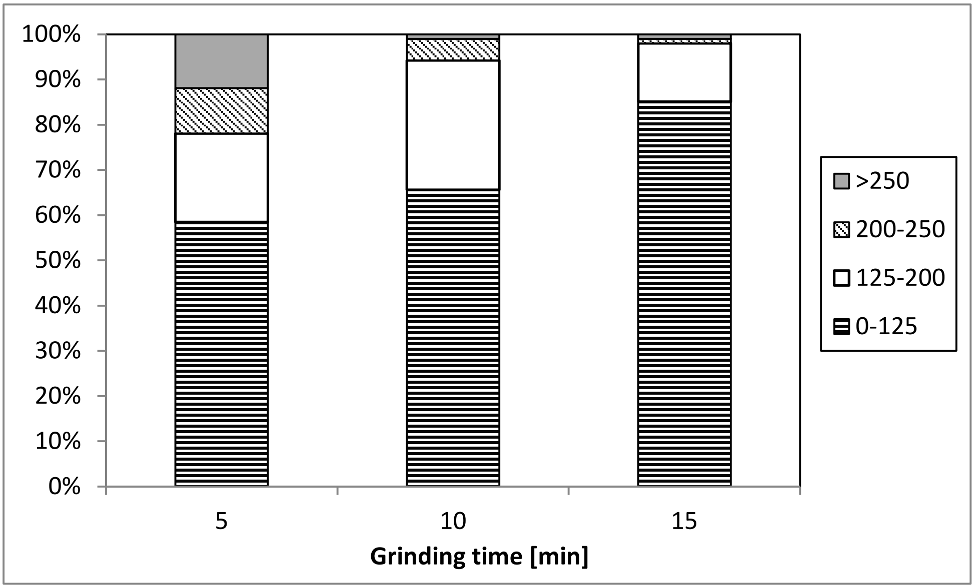


Figure 3. Contents of fine size fractions in HPGR product for *Fsp* = 3N/mm^2.

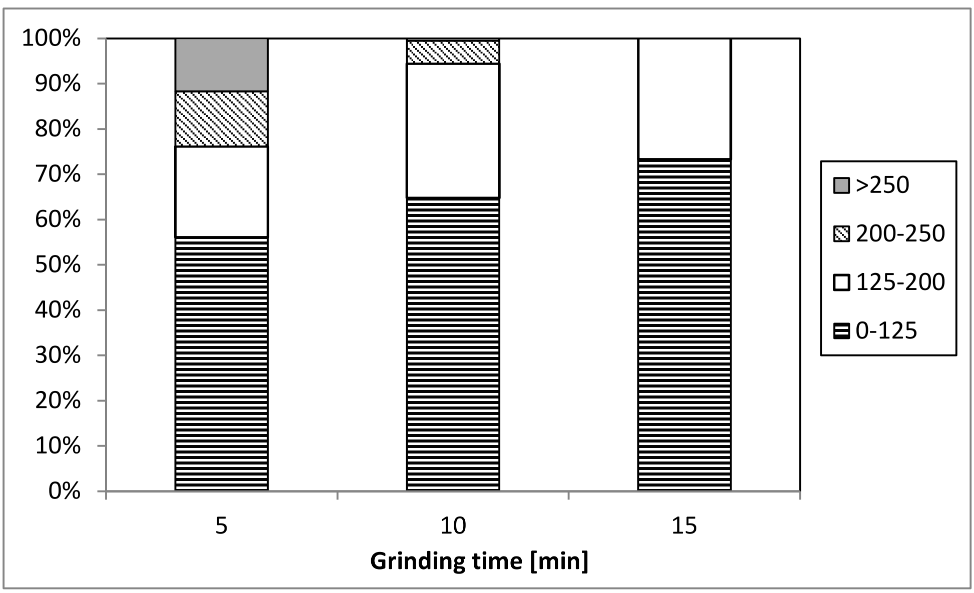


Figure 4. Contents of fine size fractions in HPGR product for *Fsp* = 4N/mm^2.

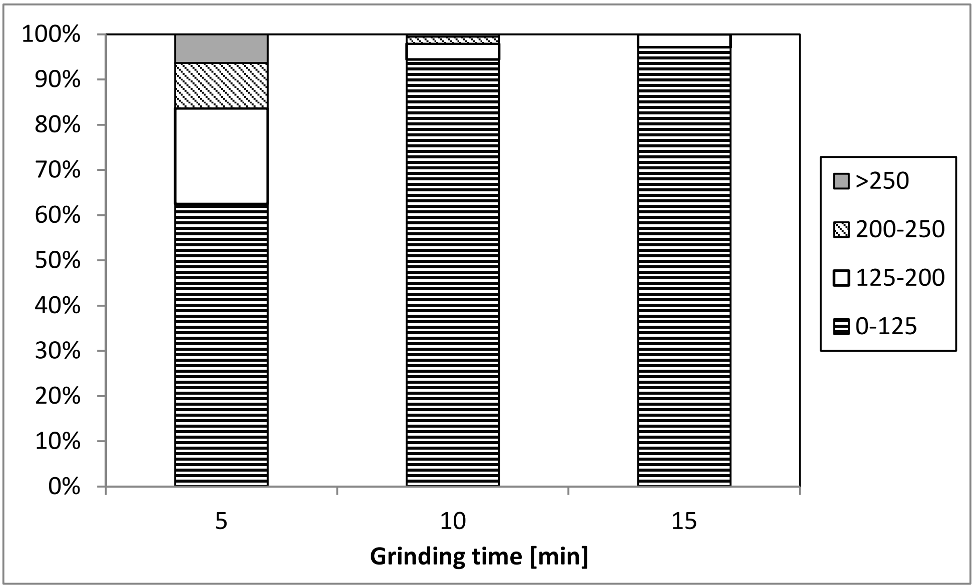


Figure 5. Contents of fine size fractions in HPGR product for *Fsp* = 5N/mm^2.

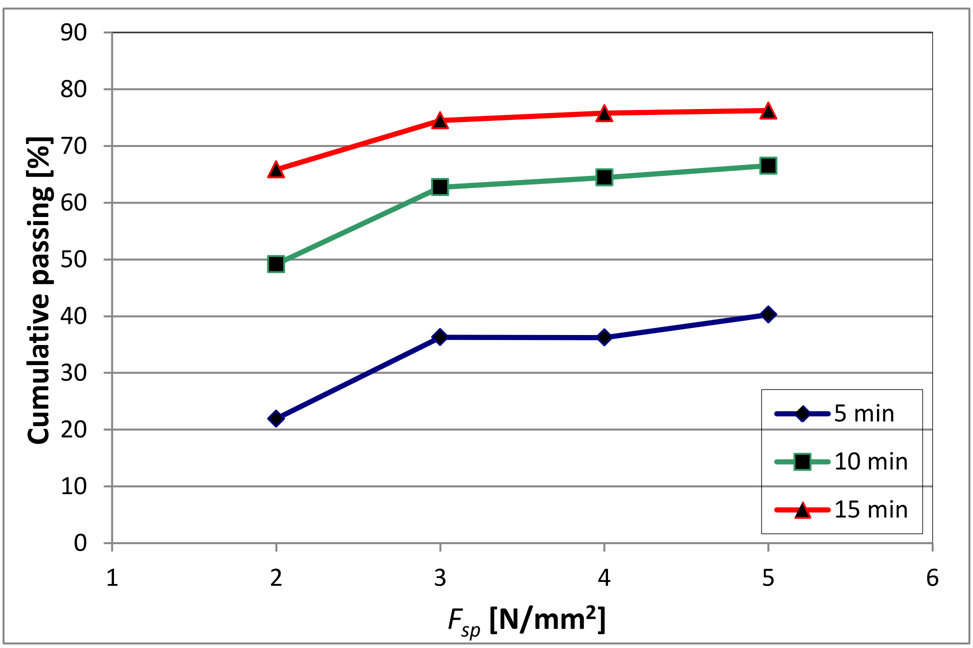


Figure 6. Relationship between the F_{sp} and the -0.125 mm size fraction recovery at different grinding time.

Analyzing figs 2 to 5 one can say that at highest value of operating press force, generation of the size fraction -0.125 is the highest too. What is more, the growth intensity together with increasing the grinding time is also the most favourable for the F_{sp} = 5 N/mm^2.

In further investigations the analysis of grinding time influence on the 0.125 mm size fraction weight recovery was made. Results are presented in Fig.6.

It can be seen from the Fig. 6 that for the grinding time 10 minutes the -0.125 mm size fraction weight recovery is more than as much as two times higher than for the one obtained for 5 minutes grinding. Comparing 10 and 15 minutes times, in turn, we can see that the increase is not as high as in previous case, but is still significant (about 20% on average).

4. RESULTS AND DISCUSSION

Results of investigations show that conditions of HPGR crushing process operation significantly influences on the downstream grinding stage effects. Together with increasing the grinding time we can observe respectively higher generation of fine size fractions, but the additional gain is progressively reduced. The same relationship can be observed considering the F_{sp} effect on the fines generation.

It is possible to determine functional relationship between the F_{sp} and the -0.125 size fraction production. It turns out that for all F_{sp} values, the relationship can be precisely described with using of logarithmic function (Eq. 1):

$$\gamma_{-0.125} = a \cdot \ln(F_{sp}) + b \qquad (1)$$

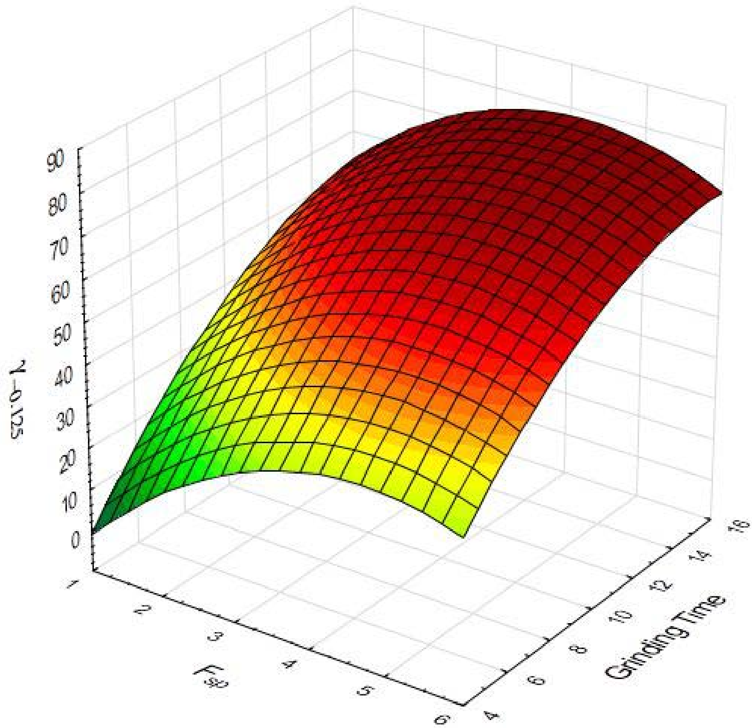
where a and b are constants and $\gamma_{-0.125}$ is the weight recovery of -0.125mm size fraction.

Apart from the F_{sp} also the grinding time influence on -0.125mm size fraction weight recovery was analyzed. It is possible to select such a combination of these two variables which determine the production of -0.125 size fraction. A suitable function is graphically presented in Fig. 7.

The mathematical formula of the function is given in Eq. 2:

$$\gamma_{-0.125} = 59.8 + 10.6 \cdot T + 24.4 \cdot F_{sp} - 0.3 \cdot T^2 - 0.2 \cdot T \cdot F_{sp} - 2.5 \cdot F_{sp}^2 \qquad (2)$$

where F_{sp} is the operating press force (N/mm^2) and T is the grinding time (min).



Figur 7. Recovery of -0.125 mm size fraction as a function of grinding time and F_{sp}.

The more significant influence on the -0.125mm size fraction recovery has the F_{sp} value. The coefficient at T value is more than two times lower than coefficient at F_{sp} what points at much lower impact of the grinding time on comminution effects measured through the fine size fractions generation, comparing to F_{sp}. The highest value in the model, however, has a constant (59.8) what means that it plays a key role here. The constant can be linked directly with the feed properties (i.e. grindability, hardness, lithologic fractions content) which, to a large extent, determine the comminution results.

In general, the results of investigations presented in the paper can be summed up as follows:

1) the recovery of fine fractions in HPGR products grinding operations is mainly dependent on HPGR process run (the value of operating pressure). This relationship is well described by means of logarithmic function (1).

2) a fine size fraction recovery can be also suitably determined on the basis of the grinding time, however the influence of this variable is of a lower importance than F_{sp},

3) it is possible to build a model of -0.125mm size fraction generation as a function of two variables: operating pressure F_{sp}, and grinding time T. In practical implementation of this model it is possible to select any combination of T and F_{sp} values and verify (calculate) the level of specific size fraction weight recovery.

The approach presented in the article is a starting point or for simulation of HPGR product grinding processes in ore processing industry. The models presented in the paper are useful in technological optimization of HPGR-BM grinding circuits, measured through the fine size fraction weight recovery, which, in turn, are a suitable feed for downstream flotation operations.

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