Impact of HPGR pressing force on the level of product recovery

D Saramak
AGH University of Science and Technology, Faculty of Mining and Geoengineering, Cracow, Poland,
dsaramak@agh.edu.pl

Abstract. Results of investigations show that HPGR operating pressure is proportional to the metal recovery, however too extensive pressure values have relatively lower impact on the increase of metal recovery. Particle size distribution of HPGR feed has a lower impact on the recovery level than HPGR pressure which was also investigated in the paper. Flotation tests of each HPGR product were also performed in order to investigate potential impact of various conditions of HPGR process runs on the metal recovery.

1. Introduction
The high-pressure grinding technology, invented and developed by Professor Schoenert in 70’s [1], is currently regarded as one of the most efficient methods of hard ore comminution. Since then the technology was introduced into raw materials treatment circuits in many mining and mining-related industrial sectors, including iron and non-ferrous metal ores processing (copper, platinum, gold), as well as cement and limestone flour production [2]. Considerable number of works concerning modeling and optimization of High-Pressure Grinding Rolls devices (HPGR) operation were also presented [3,4,5,6,7]. Nowadays high-pressure grinding rolls devices are considered as well know technology with over 500 sold machines, according to various sources.

Results of various investigations show that the major benefit from industrial application of high-pressure comminution devices is the lower energy consumption. There are also observed some positive effects in terms of greater comminution degree values, as well as higher throughput, when the feed material is treated by HPGR instead of conventional crushing devices [8,9].

Results of various investigations show that higher recoveries of useful mineral in flotation operations can be expected, for products crushed upstream in HPGR devices. Positive effects of HPGR can be observed in leaching [10,11], flotation [12,13] and gravitational separation [14].

The aim of this study is to investigate the impact of operational pressing force on comminution effects in HPGR. Effect of operational pressure was investigated through comminution degrees, as well as through flotation recoveries obtained for HPGR comminution products.

2. Operational principles of HPGR
The HPGR operation is similar to the roller crusher work. The device consists of two counter-rotating rolls; the one (fixed roll) is settled in the frame in the fixed position, while the second one (floating roll) is allowed to move horizontally. The rolls are driven by two separate motors connected to the roll shafts.
with the use of gear reducers. The comminution process in HPGR is evoked by the pressing the floating roll towards the fixed one. During the movement of rolls, the feed material is choke-fed and dragged into the nip zone of working chamber (figure 1). Together with decreasing of the distance between rolls, the pressing force significantly increases, causing the breakage of the individual particles structure and formation of micro-cracks. This results in a large reduction of the product particle size, which comes out during the next processes, usually the tertiary grinding in mills.

![Diagram of comminution in HPGR](image)

**Figure 1.** Scheme of comminution in HPGR.

The main parameter determining the process results is the operating pressure of HPGR. For high values of pressing force, the greater comminution intensity is observed, but too high pressure causes a formation of harder flakes which do not get de-agglomerated on the screen after HPGR. In operational practice the Fsp index (specific pressing force) is calculated on the basis of pressure value. It depends on the pressure and dimensions of HPGR device, and can be calculated from following formula:

\[
F_{sp} = \frac{F}{D^2 l^2 1000} = \frac{d^2 n^2 P_h}{4 D^2 l^2 1000}[N/mm^2]
\]

where:
- \( F \) – pressing force [kN]
- \( D \) – roll’s diameter [m]
- \( d \) – pistons’ diameter [m]
- \( n \) – number of pistons (usually four)
- \( P_h \) – hydraulic pressure [kPa]

The speed of rolls is the second main operating parameter influencing the process. It can be measured both in [m/s] and in the number of revolutions per minute. This parameter has a crucial influence on the process capacity, determining the throughput of HPGR [9].

\[
Q = l * s * v * \rho * 3600[Mg/hour]
\]

where:
- \( Q \) – throughput [Mg/hour]
l – working length of the roller [m]
s – gap [m]
v – roller speed [m/s]
\( \rho \) - product density [Mg/m³]

There are also a number of secondary operational parameters of HPGR device, but in this paper only the pressing force is taken into account. Results of various investigations and operational practice of HPGR show that their influence on crushing process is of lower significance.

3. Material and methods

The purpose of the paper was to investigate the effectiveness of HPGR operation under various values of Fsp. The HPGR effectiveness can be evaluated through the obtained comminution ratio of crushing products. In HPGR products that achieve a greater fineness the more intense liberation of useful mineral from the gangue can be observed. The more intense liberation, in turn, affects the efficiency of separation process. Therefore the fineness of HPGR product is to some extent positively correlated with the process efficiency. It is possible to determine the relationship between operational pressing force and comminution degree (Sx) of HPGR product, however, individual results greatly depend on physical and mechanical properties of feed material.

Increasing of pressing force affects the press productivity, because higher force acting on the floating roll move it towards the fixed one and, as a result, the gap is decreasing, too. It can be balanced, however, with higher speed of rolls.

Sulfide copper ore was used in entire investigative programme, and two samples were comminuted in HPGR device (figure 2). Experimental programme aimed at testing the operational pressure (Fsp) of HPGR, and four values of Fsp were applied: 2, 3, 4 and 5 N/mm². Flotation process indicators for each HPGR crushing products were also determined.

4. Results of experiments

In the first stage of analysis the fineness of HPGR products comminuted in the press under various values of operating pressure, was evaluated. Results are presented in figures 3 – 4.
Figure 3. Particle size distribution of HPGR products for sample 1.

Figure 4. Particle size distribution of HPGR products for sample 2.

It can be noticed that in case of sample 1 increasing in operating pressure value results in obtaining finer particle size composition of products, but differences were not as high as in the case of sample 2. Increased yield of finest size fractions in feed helped to obtain the finer HPGR product. The more detailed information, however, can be received after determination of comminution degrees for each crushing product. Such values were determined for each HPGR product, and results are presented in figures 5 and 6.
Results of investigations show that obtained values of comminution degrees are generally higher for the sample 1. Differences are especially noticeable for the average comminution degree S50. For sample 1 theses values exceed 4 and 5, for operating pressure values 4 and 5 N/mm$^2$, respectively, while for sample 2 analogous values were within the range 2 and 3. Only for operating pressure 5 N/mm$^2$, average comminution degree exceeds 4.

Two issues are worth noticing when the comminution effect of a given comminuting device is analyzed: 10 percent and maximum comminution degree values. The first one shows the potentials of breakage of the feed material into finest particles, while the second one (Smax) informs about intensity of disintegration of the coarsest particle size fractions. If the S10 value is high, that indicates a high content of fines in HPGR product. These particle size fractions may be divided from the product and directed either directly for separation operations, provided they have achieved a suitable fineness, or for re-grinding circuit. By-passing the downstream stages of crushing/grinding causes lower load of the
circuit and results in decreasing the energy consumption. For sample 2, that contains higher amount of fines, S10 value obtained for 5 N/mm² is more favorable than for sample 1. That may indicate that for this type of ore a slight increase in fines in HPGR feed may be beneficial in terms of production of fines.

The recovery of useful mineral in flotation process was also assessed. Laboratory flotation tests were performed for selected two HPGR products from each sample: comminuted at 3 and 4 N/mm². The results are presented in table 1.

Table 1. Results of flotation tests

| Flotation indices | Sample 1 | Sample 2 |
|-------------------|----------|----------|
| **ε [%]** | 80.4 | 86.6 |
| **δ [%]** | 0.23 | 0.15 |
| **β [%]** | 21.2 | 15.4 |
| **HPGR product. Fsp = 3 N/mm²** | | |
| **ε [%]** | 82.9 | 86.4 |
| **δ [%]** | 0.23 | 0.16 |
| **β [%]** | 19.4 | 15.3 |
| **HPGR product. 4 N/mm²** | | |
| **ε [%]** | 84.6 | 87.6 |
| **δ [%]** | 0.24 | 0.16 |
| **β [%]** | 15.4 | 15.2 |

Flotation tests for both samples comminuted in conventional crushers were also performed as reference tests. Analysis of date presented in Table 1 shows that more favourable values of recovery were obtained for sample 1. An increase of recovery from 80.4% to 82.9% (2.5% higher) for Fsp=3 N/mm² and to 84.6% (4.2% higher comparing to conventionally crushed product) for Fsp = 4 N/mm², were observed. Analogous values for sample 2 equaled -0.2% and 1%, respectively. Higher recoveries obtained for HPGR products are mainly due to more intense liberation of useful component. However this effect is more significant for the sample 1.

5. Summary and conclusions

The aim of the paper was to assess the impact of operational pressure in HPGR and particle size composition of feed on effectiveness of downstream separation process. The obtained results show that value of HPGR pressing force Fsp influences positively the comminution degree of HPGR products. Fineness of comminution products was higher with the increase of operational pressure, yet further increasing of Fsp resulted with relatively lower increases of comminution ratio. That may indicate, that it is possible to determine a kind of optimal value of pressure that maximizes effects of the press in technological (fineness) and economical (energy consumption) aspects. This issue will be the subject of further investigations.

Results of investigations also confirmed that exists a relationship between pressure value and recovery of useful mineral. For the type of material under investigation an application of HPGR into processing circuit may be beneficial, because the achieved recoveries of useful mineral for all HPGR products were higher. It can be also seen that the sample with average content of finest particle size fractions responds better in terms of recovery together with increasing of Fsp. However, the above issues need to be investigated more thoroughly in order to determine more general relationships and will be continued in future.
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