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*Received May 14, 2011; reviewed; accepted August 5, 2011*

## **DE-AGGLOMERATION IN HIGH PRESSURE GRINDING ROLL BASED CRUSHING CIRCUITS**

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**Abstract.** The problems of possible application of de-agglomeration operations into industrial HPGR-based crushing circuits, were presented in the paper. The HPGR technology has the potential to provide a significant circuit efficiency increases from technological (better comminution efficiency) and economic (lower energy- consumption of crushing process) scopes. However, the HPGR product is usually compressed into a flake product, what may constitute a technical challenge in effective classification of crushing product and the overall efficiency of the circuit.

Three methods of flakes disintegration were investigated in the paper: an impact de-agglomeration, drum de-agglomeration and the wet one. Results showed that the wet and drum de-agglomeration operations are the most favourable methods of flakes disintegration. Additionally the wet process is especially beneficial for material with lower moisture content.

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*keywords: comminution, agglomeration, disintegration, flakes, efficiency*

### **1. Introduction**

High-pressure comminution is regarded as an important technology in mineral processing circuits primarily because it offers considerable energy savings. There are also many evidences in literature (Morley, 2003) that High Pressure Grinding Roll (HPGR) technology is more energy-efficient than typical tumbling comminution machines including autogenous, semi-autogenous and ball mills, as well as vertimills (Kalinowski, 2006). The HPGR technology has been widely used in the cement industry and, to a lesser extent, in the diamond industry, but still relatively rarely in the hard ores processing industry (Celik and Oner, 2006; Morrell, 2008; Persio et al. 2011).

Application of the HPGR technology has the potential to provide a significant circuit capacity increases in existing plants because the HPGR product has a significantly lower Bond Work Index. As a result of that the grinding time in downstream milling process can be reduced, because required size of product on that comminution stage is obtained more quickly than after conventional crushers on

second stage (Ergun et al., 2004; Norgate and Weller, 1994). Other benefits of the high-pressure comminution concern the following issues:

- the energy efficiency of the circuit increases with the proportion of comminution degree obtained in HPGR
- the micro-crack generation is observable, what significantly lowers the energy-consumption in downstream grinding processes
- the specific capital costs per unit capacity for the HPGR-ball mill circuit are more than 20% lower than for the SABC circuits (Pahl, 1993)
- the energy-consumption of circuit is also more beneficial for the HPGR-ball mill option, SABC circuit utilizes 20 to 30% more of energy (Saramak, 2011)
- the term of delivery in new machines implementation is also shorter for HPGR units than for SAG mills
- considerable smaller footprint of HPGR comparing to the SAG unit
- comparable costs of linings, but no costs of grinding media costs for HPGR machines.

The HPGR machines usually work in a closed circuit combined with the screen (Fig. 1), from where the oversize product is recycled to the press (van der Meer and Gruendken, 2010; Naziemiec and Saramak, 2009; Saramak, 2011).

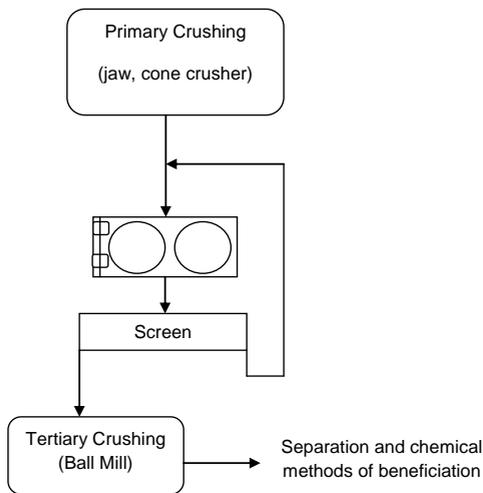


Fig. 1. Comminution circuit with HPGR device on second crushing stage (Saramak et al., 2010)

### 1.1. Problem definition

The technical challenge in achieving effective classification of crushing product occurs because the HPGR product is usually compressed into a flake product. The strength of flakes is a proportional functional relationship of the operating pressure. Even though the comminution degree increases together with the higher volumes of operating pressure, also the greater weight recovery of more competent flakes is observable in the HPGR product. Investigations in that matter carried out by the

author show that an extensive generation of flakes takes place especially for higher volumes of operating pressure in middle and coarser size fractions of the product (Fig. 2).

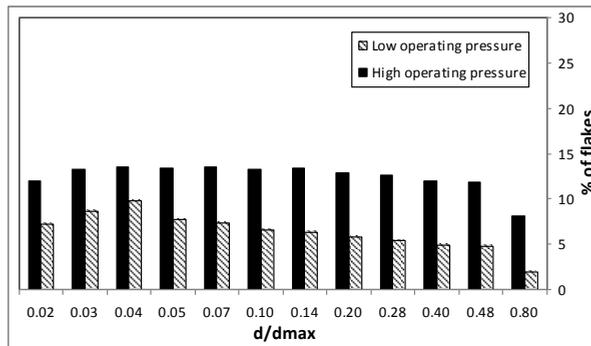


Fig. 2. Flakes mass recoveries in HPGR products crushed under high and low operating pressure

On-site experiments in iron and gold ore processing plants enable author to state that together with increasing the operating pressure in the HPGR press, the mass flow of the oversize screening product, which is recycled to the press, is higher too. The greater volume of operating pressure, the more considerable share of flakes in recycle mass flow what significantly decreases the overall efficiency of comminution circuit. Apart from the operating pressure, the flakes competency is a function of the ore type and the moisture content. Generally, competent flakes are being generated to a larger extent in softer ores or those with increased clay content (like kimberlites), while harder ores tend to produce rather fragile flakes.

## 1.2. De-agglomeration process

A method of overcoming of competent flakes generation is the implementation to the circuit the operation of the HPGR product de-agglomeration. This operation can be also utilized depending on the technological process requirements or the flakes competency. This is a significant issue in the flow-sheet development; it enhances the circuit efficiency, reducing the recirculation of already crushed material, which could be otherwise recycled to the press within the flakes.

Various de-agglomeration methods can be applied into the flow-sheet. Flakes product may be de-agglomerated by using rotary drum scrubbers, drums with lifter bars, by handling in chutes and bins, utilizing the impact forces (hammer mill or vertical impactor followed by the screening operation) or even on vibrating screens (especially in wet screening operations). Wet screening of the HPGR product is regarded as a mild de-agglomeration. When intense de-agglomeration is required, the HPGR product is delivered directly to the mill, the mill discharge is screened and the screen oversize is returned to the HPGR. Some methods of de-agglomeration are possible to implement without the need of adding any extra machines to the

technological circuit. An impact de-agglomeration can be done even on the vibrating screen, where either the dry or wet process can be carried out.

The technological flow-sheet configuration for a given material is driven by the requirements of the process and consideration of the crushing devices characteristics (mainly HPGR). In particular, the mass of possible fines recirculation and existence of a separate de-agglomeration operation will have a significant effect on the formulation of the flow-sheet technological and economic efficiency. The need and type of possible de-agglomeration operation can be assessed by suitable tests. The main aim of such tests is to identify suitable de-agglomeration and classification variant for the HPGR product disintegration.

## 2. Experimental programme

The main aim of the paper was to examine different methods of de-agglomeration. Two tests were carried out in following manner: test one was proceeded for material under natural moisture condition (about 2%), while in test 2 the feed moisture was increased to about 4%. This enabled to investigate an influence of both the method of de-agglomeration and the selected feed condition (the moisture) on the de-agglomeration process efficiency. In laboratory tests the iron ore with the bulk density approximately 2.0 g/cm<sup>3</sup> and the hematite content about 60% was used, which was entirely crushed in laboratory HPGR unit. Table 1 summarizes technological parameters of the HPGR crushing process.

Table 1. HPGR tests summary

	Test 1	Test 2
Operating pressing force [kN]	8 000	8 000
Speed of rolls [m/s]	0.4	0.4
Roller diameter [m]	0.2	0.2
Roller width [m]	0.15	0.15
Type of linings	plain	plain
Type of material	Iron ore	Iron ore
Feed $d_{\max}$ [mm]	10	10
Feed moisture content [%]	2	4

The HPGR centre product from each test was then split into three representative samples designed for further de-agglomeration tests. Sample 1 was de-agglomerated in hands to obtain ideal disintegration of flakes and this sample was treated as a reference one. The flakes content in every single sample was analyzed within the size fraction of 1.168–4 mm, additionally the mass recoveries of -3.15 mm material were determined.

## 3. Experimental results

Screen analyses of both reference samples together with particle size distribution curve of feed are presented in Fig. 3.

The results has shown that both de-agglomerated samples have a content of almost 80% of particles smaller than 3.15 mm and the influence of different moisture of samples is of a rather low importance if about the HPGR product particle size.

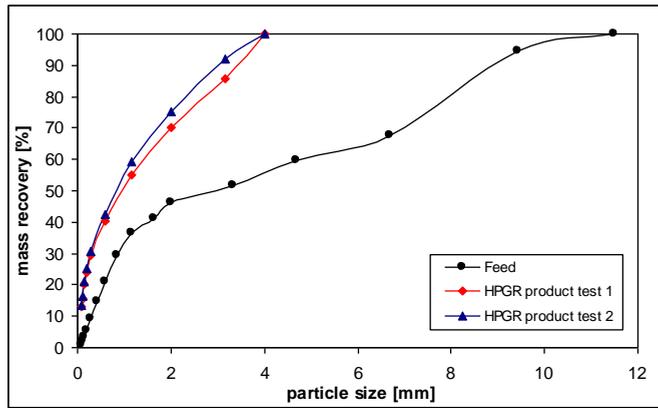


Fig. 3. Particle size distribution curves of feed and crushing products

### 3.1. Impact de-agglomeration

The first de-agglomeration method under investigation was the drop test. In that test the influence of impact forces on the de-agglomeration process were examined. The material flakes were dropped from the height of 1 meter, and then screened.

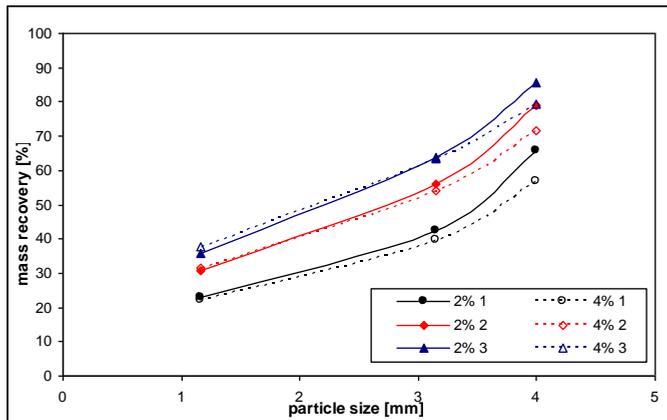


Fig. 4. Impact de-agglomeration

The procedure has been repeated three times for each sample. Results are presented in Fig. 4. The results show that with every drop the mass recovery of particles smaller than 3,15 mm steadily increasing, but even after third drop it cannot even approach the value of 80% obtained for HPGR products. The impact de-agglomeration is also more

efficient for the material with lower moisture content for several percent. After each consecutive drop the weight recovery of  $-3.15\text{mm}$  product increases, but the growth is smaller than after previous drop.

The impact de-agglomeration is relatively simple to implement, even without adding no machine to the circuit. It can be obtained for example during the screening process by implementing a suitable screen evoking a higher vertical trajectory of the particle movement.

### 3.2. Drum de-agglomeration

On the contrary to the impact de-agglomeration, the drum de-agglomeration process must take place in a separate machine, usually the rotary drum with lifters or rotors. A laboratory test was carried out in a 0.5 m diameter drum with two lifter bars. The samples were treated in the drum for 10, 20 and 30 seconds, while the drum rotated with speed slightly lower than 1 rev/s. After each test, the sieve analysis was performed and results are presented in Fig. 5.

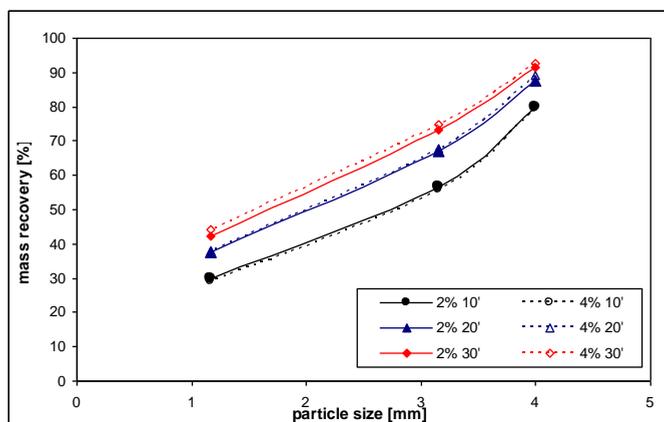


Fig. 5. Drum de-agglomeration results

The test has shown that obtained results are better comparing to the drop tests. Just after 10 seconds of material tumbling, the de-agglomeration results were more favorable than after two drops in impact tests. After 30 seconds of tumbling time the products contained only 10 – 15% of flakes exceeding 3.15 mm ( $+3.15\text{mm}$  particles content was 75% for drum de-agglomeration and 85-90% for the de-agglomerated HPGR product – see Fig. 3). Furthermore, the moisture influence on the obtained results is of a minor importance.

### 3.4. Wet de-agglomeration

Apart from the above investigations, an additional test was carried out. The sample was laid for several minutes in a water bath. After the water treatment the material was

screened on a sieve with 3.15 mm mesh. This method of de-agglomeration can be obtained by the wet screening of the HPGR product. Under operating conditions, the screening process should be modified respectively, because the material should be intensively sprinkled with water, and the screening time needs to be optimized as well.

The sample with 4% of moisture was investigated by that method and the weight recovery of -3.15 mm particles was as high as 83%. The result for 2%-sample was practically identical. This result shows that the soaking of material is the most efficient method of de-agglomeration, because the flakes content in screen oversize product (-3.15 mm) is 3 to 8%. Table 2 also presents comminution degrees obtained in impact and drum de-agglomeration processes.

Table 3 summarizes the test results presented in the paper.

Table 2. Technological effects for both de-agglomeration methods

	HPGR product		Impact de-agglomeration		Drum de-agglomeration	
	2%	4%	2%	4%	2%	4%
S50	3.2	3.44	1.34	1.39	1.76	1.89
S80	2.92	3.42	2.10	1.86	2.29	2.33

Table 3. Percentage weight recoveries of -3.15 mm particle fraction in all samples

Type of test	2% moisture content	4% moisture content
De-agglomerated product	85.9	92.2
Impact de-agglomeration	63.8	63.5
Drum de-agglomeration	73.2	74.8
Wet de-agglomeration	83	

#### 4. Summary and conclusions

Results show that the wet de-agglomeration and next the drum process are two the most favorable methods of flakes disintegration. The wet process is especially beneficial for material with lower moisture content, because only about 3% of material stays as flakes. The satisfactory flakes disintegration can be also obtained when the drum de-agglomeration method is implemented. For material moisture content of 2% the flakes content is about 10% or less. The impact de-agglomeration for this type of material appeared as a less efficient method.

The material with higher moisture content produced a more favorable value of overall comminution degree, no matter of the method of de-agglomeration. However, the higher comminution level was weakened by the lower ratio of disintegrated flakes (Table 3) for products with higher moisture content. As a result of that, a part of undersize fines stays in the oversize screening product as flakes and they are recycled to the press again, decreasing the process efficiency.

The proper selection of de-agglomeration method should be made in general on the basis of three aspects: the first issue ought to take into account the type of material crushed, the second one should consider the desired degree of flakes disintegration,

while the third one the technological parameters of the HPGR operation. Application of the de-agglomeration operation into the technological circuit can be carry out in several ways. Connecting points between two conveyors can be a suitable place for installation the impact plates (mild de-agglomeration), if the height is as high as 2 meters or more. Another solution of mild de-agglomeration is the flushing of material onto the screen with excessive addition of water. When the process involves more intense process of particle disintegration, the drums should be applied together with mechanical treatment of moist flakes during the screening process.

### Acknowledgments

The article is an effect of Polish Ministry of Science research grant N N524 466139.

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