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Measurement of wear pattern of studs on High-Pressure Grinding Rolls (HPGR)

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ABSTRACT

The application of high-pressure grinding rolls (HPGR) in iron ore processing is expanding. However, to maximize their utilization, it is crucial to understand the impact of various parameters on their operation, given their advanced technology. Wear is an essential factor that needs to be considered when operating these mills. Failure to manage wear can lead to substantial costs and a decline in machine efficiency, as well as the efficiency of the comminution circuit. Therefore, it is imperative to control the wear rate of rolls by adjusting the machine accordingly. This research aims to measure the wear pattern of HPGR rolls in the primary grinding circuit of the Sanabad Iron Beneficiation Plant in Iran. The results indicated that the wear rate of the studs along the rolls was not uniform but rather concave, and the maximum wear rate was observed in the central part of the rolls. The wear rate of the studs on the fixed roll was higher than that of the floating roll. For the current mill, the predicted useful life of the rolls was estimated to be between 12000-13000 hours, considering the operating time of 8000 hours of the current HPGR.

KEYWORDS

HPGR (High Pressure Grinding Roll), Floating Roll, Fixed Roll, Stud, Wear Pattern

I. INTRODUCTION

The available time of industrial mills is one of the effective factors in the economic efficiency of the mineral processing plants. High Pressure Grinding Rolls (HPGR) consist of two counter-rotating rolls, one fixed and one floating, to apply pressure to the material being ground (Fig. 1). As the mill feed material passes between them, one roll remains stationary while the other rolls over it. To generate the necessary grinding pressure, a pneumatic hydraulic system creates pressure which is then transferred to the movable roll through plunger cylinders. An automatic system regulates the working pressure. The fixed roll is attached to the machine frame while the movable roll moves along guide rails within the roll frame with minimal friction and responds to the force exerted by the feed material. Each roll rotates independently through planetary gear units at variable speeds, powered by frequency-controlled motors. For optimal performance, it is essential to use chocked feeding (Klymowsky et al. 2002; Kawatra, 2006; Aydogan et al., 2006).

The industrial experiments were performed on the HPGR primary grinding circuit of the Sanabad iron beneficiation plant in Iran. In this plant, approximately 1250 t/h of iron ore containing 45-48% Fe with a top size of 50 mm is processed to produce a concentrate assaying 67% Fe. The primary grinding circuit involves a high-pressure grinding roll (HPGR) operating in a closed circuit with a vibrating screen with an 8 mm aperture size. Any particles larger than 8 mm are sent back as part of the circulating load to the input of the high-pressure grinding roll, while particles smaller than 8 mm continue on to the secondary grinding circuit.

The total feed to HPGR consists of 700 t/h of fresh ore plus 550 t/h of recycled material. The operational and design specifications of the HPGR are listed in Table 1.

Each roll in the HPGR consists of a shaft, a replaceable tire, and bearings. The tire surface is made of forged steel, which is coated with tungsten carbide studs. Studs are undoubtedly one of the most effective factors in the particle comminution efficiency and energy consumption of HPGRs. Studs not only protect the rolls against wear but also increase the mill's capacity by increasing the friction coefficient between the mineral material and the rolls. Using studded rolls has several advantages, including significantly improved throughputs and reduced extrusion effects, which can lead to reduced wear of the rolls. However, these benefits come at the cost of higher energy consumption and grinding forces required to achieve product size distributions comparable to those obtained using smooth rolls (Lim and Weller, 1999; Ozcan et al., 2014; Barrios and Tavares, 2016).

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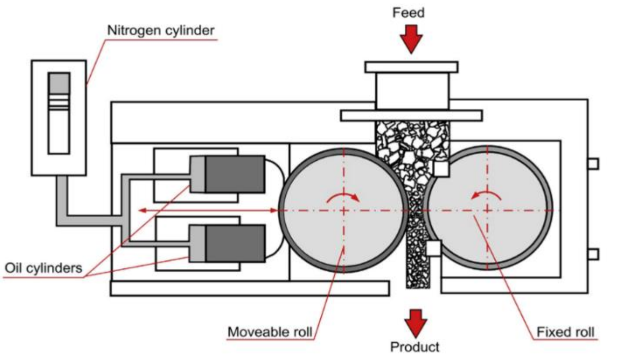

Fig. 1. Schematic diagram of high-pressure grinding rolls (Wills and Finch, 2016)

Table 1. Operational and design specifications of the HPGR

Roll diameter (mm)	1760
Roll length (mm)	1230
Roll speed (m/s)	1.97
Operating pressure (bar)	165
Working gap (mm)	40
Power draw (kW)	2083
Fresh feed (t/h)	700
Total feed (t/h)	1250
Top size of feed, d_{100} (mm)	50
Feed moisture (%)	< 5

The presence of studs creates a protective layer of mineral material on the surface of the rolls, which protects the roll surface against wear and tear and facilitates the process of transferring materials between the rolls. Therefore, the formation of this layer increases the nip angle and consequently the throughput of the mill (Fuerstenau and Abouzeid, 2007).

The most important factor in stopping the process in the HPGR circuit is the time required to replace worn or broken studs. The amount of wear of the studs depends on the quality of materials used, the characteristics of the feed (particle size, hardness, and moisture content) as well as the operational parameters of the process (capacity of the liners, pressure force of the rolls, and feed moisture. (Kazerani and Sam, 2016).

Research has shown sufficient moisture (2-4%) in the feed is necessary to form a protective layer between the rolls. If there is not enough moisture, water spray can provide moisture to the feed. However, excessive moisture in the input feed of the HPGR can wash away the autogenous layer between the rolls and result in an increase in the wear rate of the rolls (Fuerstenau and Abouzeid, 2007; Kazerani and Sam, 2016).

The presence of fine particles in the feed of the HPGR has a significant impact on the grinding efficiency and the wear rate of the rolls. When the fines in the feed are reduced, the bulk density of the feed decreases, which leads to an increase in the wear rate of the rolls (Meer van der and Gruendken, 2010). The hardness and abrasiveness of the feed also have a significant impact on the wear rate of the studs. An increase in the silica content of the feed leads to an increase in the wear rate of the rolls (Morley, 2010).

This study aims to determine the wear pattern of studs on the floating and fixed rolls and, as a result, predict the time of replacement based on the working time of the HPGR.

II. Experimental

The industrial tests were performed on the HPGR in the primary grinding circuit at the Sanabad iron beneficiation plant. The measurement of studs was carried out after 2460, 3736, 5695, and 7400 hours of the HPGR operation. Each roll is covered with 5000 studs, 45 mm long and 22 mm in diameter. When the rolls are new, the length of the outer stud is 4 mm, and 41 mm is located on the steel tire bed. The center-to-center distance of each stud is about 30 mm. To measure the amount of stud wear at different points on the surface of the rolls, a metal strip with holes at specified intervals and a digital caliper were used (Fig. 2).

At first, the metal strip was placed on the roll surface (parallel to the shaft axis) so that the holes were on the studs and the tire. Then, the strip was fixed on both sides of the roll using special clamps. Finally, the vertical distance from the edge of the strip to the surface of the studs and the tire was measured using a digital caliper. In total, each of the 39 studs along the rolls was measured using the above method. Measurements were taken in different positions on the surface of the rolls.

III. Results and discussion

The required time for replacing worn or broken rolls is one of the critical factors in stopping the process and determining the available time of HPGR in the industry. Therefore, determining the wear pattern of rolls in different sections of floating and fixed rolls is very important. The results of measuring the wear rate of HPGR rolls are presented. Figs. 3 and 4 show the wear rate of studs on the fixed and floating rolls of HPGR over time, respectively. Fig. 5 shows an image of a worn roll and the autogenous layer between the studs.

As the operating time of HPGR increases, the wear rate of the studs in different positions on both rolls increases. The average wear rate of the studs on the floating roll has increased from 5.67 mm (after 2460 hours of operation) to 12.33 mm (after 7400 hours). The average wear rate of the studs on the fixed roll has risen from 6.48 mm (after 2460 hours of operation) to 13.77 mm (after 7400 hours of operation).

The wear rate of the studs along the rolls is not uniform but rather concave, and the maximum wear rate is observed in the central part of the rolls (Fig. 6). This is due to the pressure gradient along the rolls. The pressure gradient along the rolls is such that the highest pressure and thus, the highest wear rate of the studs occur in the middle section of the rolls, and the minimum pressure occurs on the two sides of the rolls (Fig. 7). This creates a difference in the operating gap between the rolls along their length. The lower wear of the rolls on the two sides requires in some cases cutting and shortening the edge rolls in order to prevent contact between the two rolls at the edges and to maintain the optimal operating gap (Knorr et al., 2016).

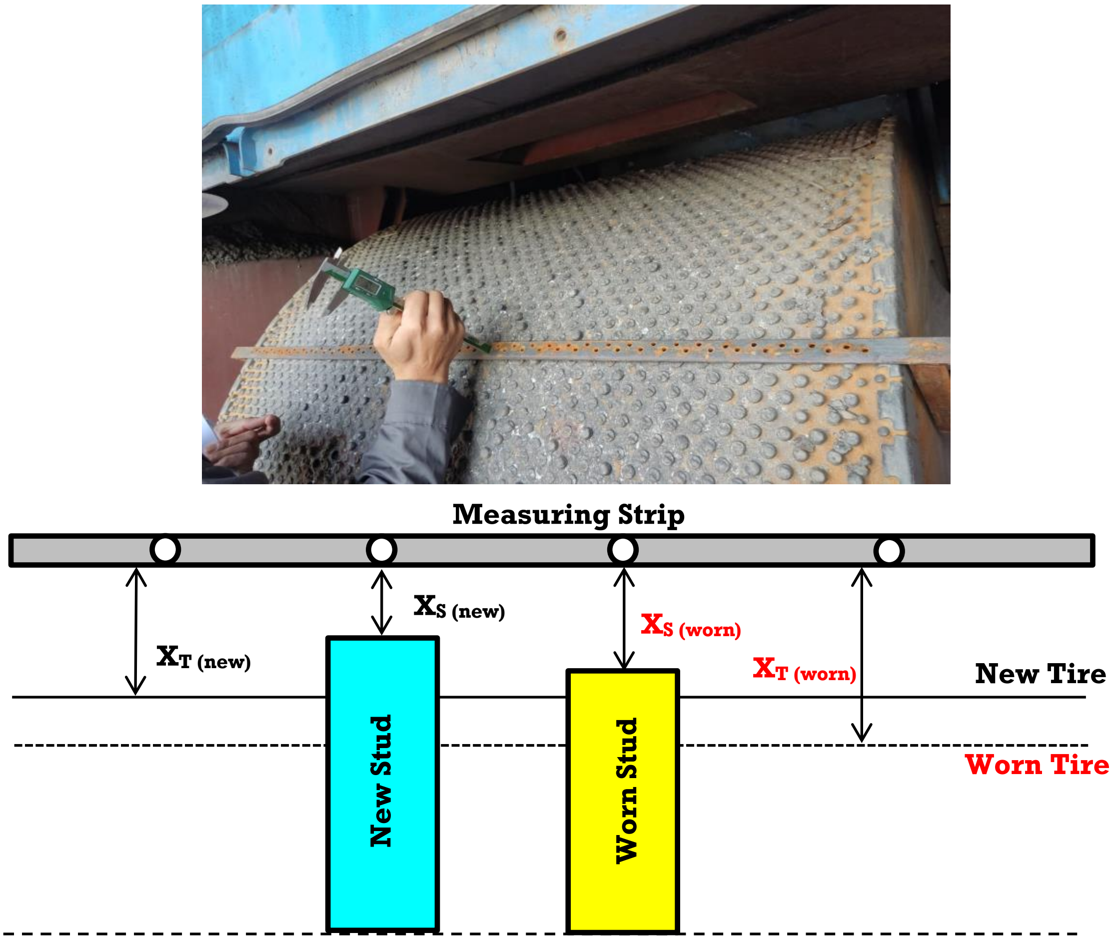

Fig. 2. Measuring the stud wear rate using a metal strip and a digital caliper
The distance from the metal strip to the surface of the new ($X_{S(new)}$) and worn ($X_{S(worn)}$) studs
The distance from the metal strip to the surface of the new ($X_{T(new)}$) and worn ($X_{T(worn)}$) tires

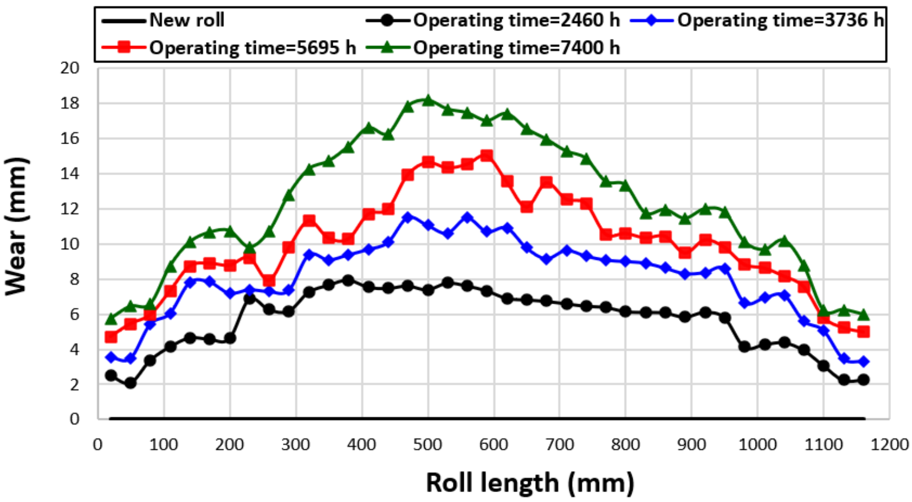

Fig. 3. The wear profiles of studs on the floating roll of HPGR over time

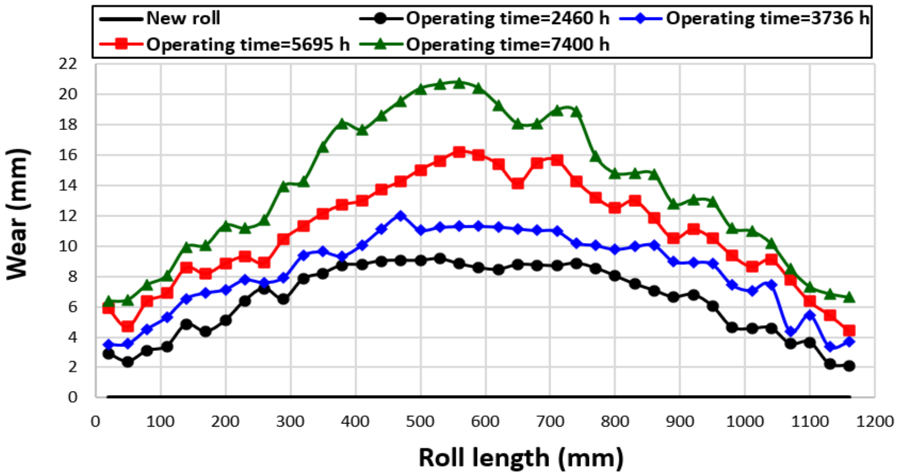

Fig. 4. The wear profiles of studs on the fixed roll of HPGR over time

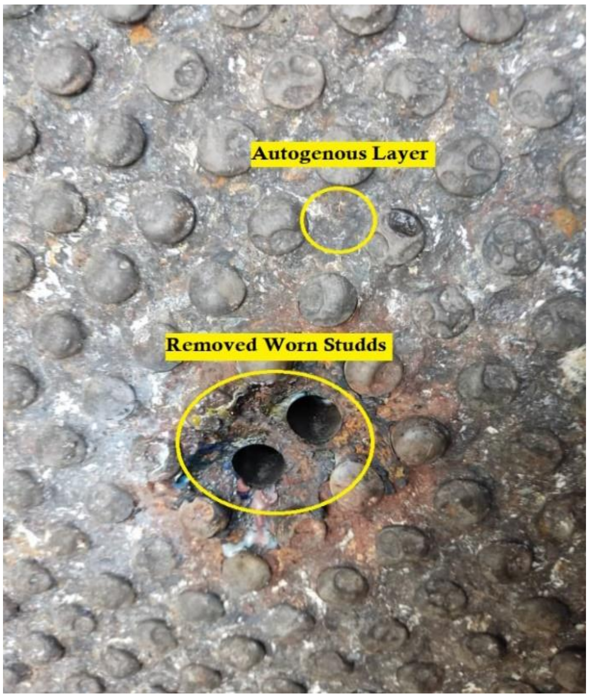

Fig. 5. An image of the removed worn studs and the autogenous wear protection layer

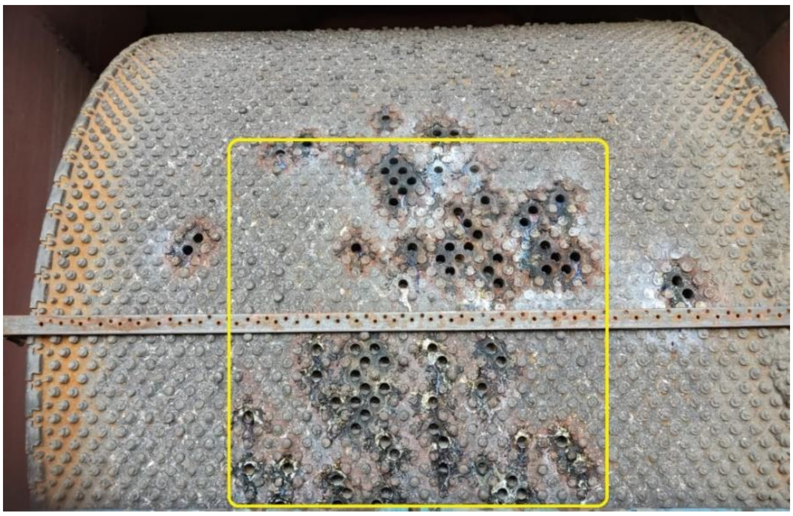

Fig. 6. Non-uniform wear of the studs on the roll surface

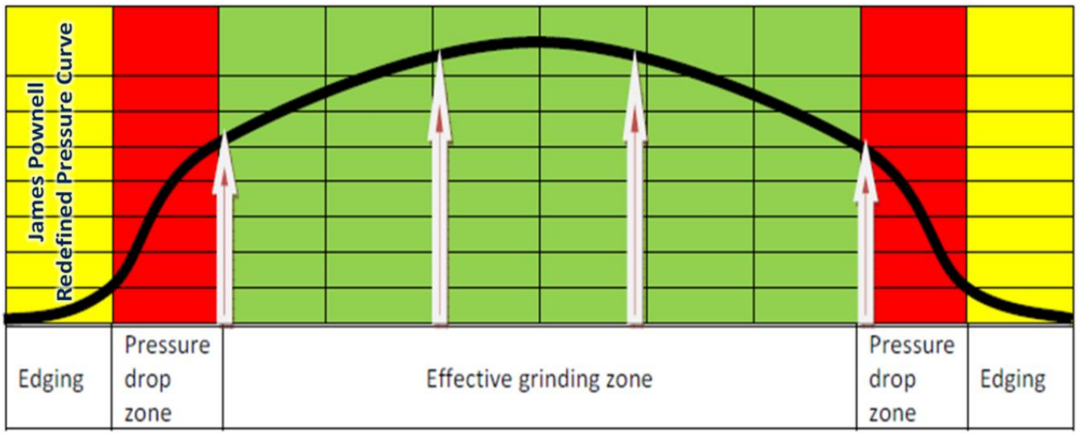

Fig. 7. Pressure gradient on the surface of HPGR roll

The wear rate of the studs on the fixed roll is higher than that of the floating roll. This is due to the pressure force applied by the hydraulic system on the floating roll which is ultimately transferred to the fixed roll. Furthermore, the position of the feed guide plate, which is slightly closer to the fixed roll, causes the feed particles to initially come into contact with the fixed roll before entering the crushing zone (Fig. 8).

Considering the higher wear rate of studs in the central section, it is recommended to use harder studs in these sections in order to achieve a relatively uniform wear distribution on the rolls. The implementation of this plan in the Los Colorados iron beneficiation plant led to a reduction in the wear rate and an increase in the lifespan of the rolls (Meer van der and Gruendken, 2010). Another solution is to use flanges or cheek plates on both sides of the rolls (Fig. 9). This leads to a more uniform pressure distribution along the rolls and consequently a more uniform wear distribution while maintaining the pressure at the roll edges.

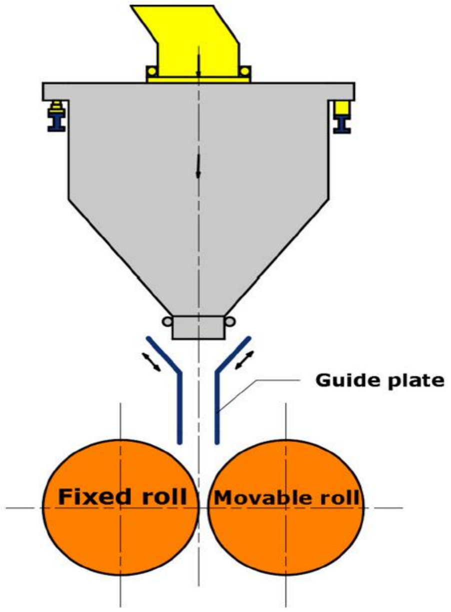

Fig. 8. Position of the feed guide plate above the rolls

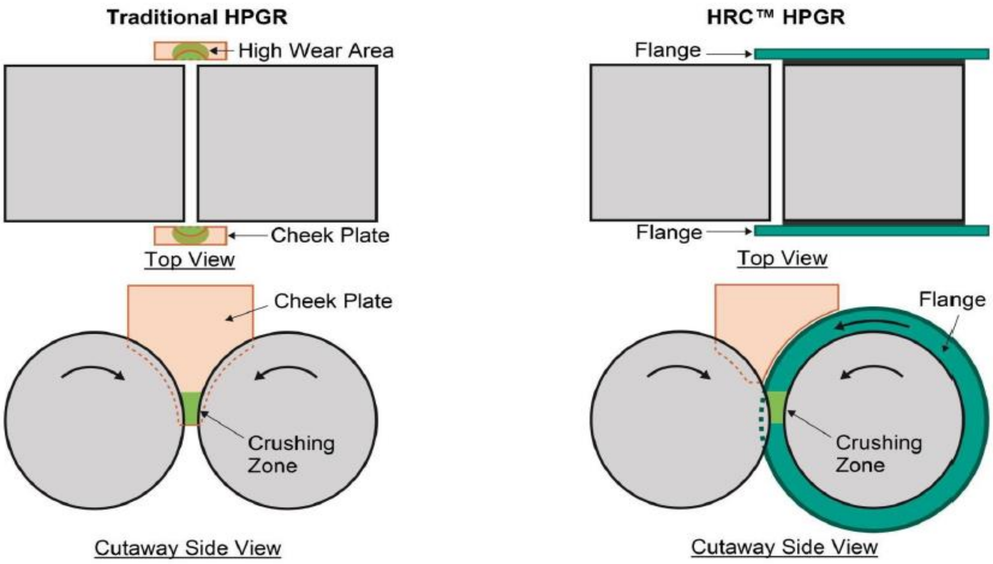

Fig. 9. Position of flanges and cheek plates on both sides of the rolls (Knorr et al., 2016)

Studies have shown that to protect the rolls and maintain the desired grinding efficiency, at least 15 mm of the stem of the studs must remain on the tire bed (Polysius, 2010a,b). Therefore, the acceptable wear limit for the studs is 30 mm, and they must be replaced as soon as they reach this limit. According to the results, the maximum wear limit for the studs in the central section of the floating roll is around 18 mm, and for the fixed roll, it is around 20 mm. Therefore, considering the roll height of 45 mm and the wear limit of 30 mm (because at least 15 mm of the roll stem must remain on the tire bed), about 65% of the studs in the central section of the rolls have been worn. Given that the current operating time of the HPGR is about 8000 hours, the expected useful life of the rolls is predicted to be in the range of 12000-13000 operating hours for the current mill.

IV. CONCLUSIONS

Based on the experiments conducted in this study, the following conclusions can be drawn:

(1) The measurement of the wear of studs along the floating and fixed rolls shows that the wear is not uniform and the highest rate is observed in the central section of the rolls. This phenomenon is due to the pressure gradient along the rolls.

(2) The studs on the fixed roll experience a higher wear rate than those on the floating roll. This can be attributed to the hydraulic system exerting pressure on the floating roll, which is eventually transmitted to the fixed roll.

(3) Considering the higher wear rate of studs in the central section, it is recommended to use harder studs in these sections to achieve a relatively uniform wear distribution on the surface of the rolls.

(4) According to the wear rate measurements, it has been found that approximately 65% of the studs in the central section are currently worn out. Based on the operating time of the current HPGR (around 8000 hours), the replacement time of the rolls is estimated to be after 12000 to 13000 hours of operation of the mill.

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