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Slag grinding by roller press—major issues

S.M. Mehra

The Tata Iron and Steel Co. (TISCO) Ltd., Jamshedpur 831 001, India

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Abstract

The paper sums up the results of observations made during the commissioning of the roller press (RP) for slag grinding for TISCO cement project. At the time of selection of the RP technology for this project, there was not adequate experience available in regard to the process and design parameters leading to series of problems during start up and commissioning. This necessitated examination of various parameters. It has been established that the feed arrangement to the RP, moisture in feed slag and the roll-speed are critical factors in achieving a stabilised and efficient RP operation. The process is inherently prone to build-up of iron concentration in the grinding circuit from a very small percentage in the feed slag which needs to be taken care of during the process. © 1998 Elsevier Science B.V.

Keywords: slag grinding; roller press

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1. Introduction

Conventionally the Portland Slag Cement (PSC), commonly known as Slag Cement, which forms nearly 15% of the total cement production in India, is manufactured in the existing plants primarily designed for the production of Ordinary Portland Cement (OPC). In these units, the blast furnace slag with a varying percentage (15–40) is co-ground with the clinker in open/close circuit ball-mills (BM). This method is not optimally suitable for production of slag cement and has a number of disadvantages. The slag cement thus produced has coarser slag particles and a higher fraction of below 5-μm fines of clinker because of the difference in their grindability. This has a direct bearing on the quality of cement. The coarser slag particles have poor reactivity and adversely affect the initial strength, whereas the −5-μm fines of clinker do not contribute much to the strength of the cement. The method also does not allow optimum energy utilization because of the difference in the grinding properties of the slag and clinker. Since the BM is designed for a particular slag-to-clinker ratio, any variation

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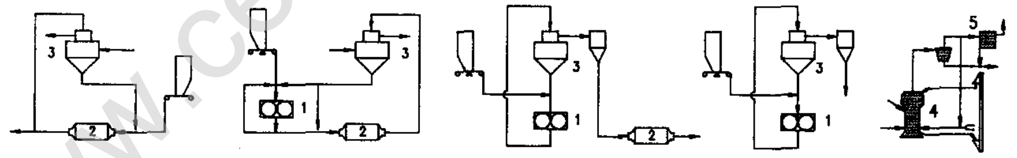
from this which may be necessary due to variations in the properties of slag and clinker, will have an effect both on the performance of BM and the quality of product.

With the establishment of the quality of slag cement at par with OPC and increase in availability of blast furnace slag, which otherwise poses disposal problems, there is a growing trend for the production of slag cement. In addition, the slag cement has many advantages over the OPC such as high ultimate strength, low heat of hydration, high resistance to acid action, high water-tightness, etc. It has become essential to examine the various options available to produce slag cement taking into consideration the higher power requirement and abrasive nature of slag.

2. Status of grinding technology

The comparison of various grinding methods, viz., close-circuit ball-mill, roller press (in semi-finish mode in combination with BM and in finish mode) and vertical roller mill (VRM) is shown in Fig. 1. The most recent developments have been the use of VRM and RP (in finish-mode) for slag and clinker grinding. The Japanese have gone for VRM for slag grinding after a fair degree of success with the clinker. However, some of the problems connected with the wear of grinding components are yet to be sorted out. The RP technology developed in Germany by KHD and Polysius, on the principle of inter-particulate comminution (Schoenert, 1979, 1988) has been well established for clinker grinding. For slag grinding (particularly in the finish-mode without the BM) the RP technology is still in the initial stages of development. At the time of selection of equipment for the TISCO project, there was only one RP unit for finish grinding of the

GRINDING SYSTEMS



	CLOSE-CIRCUIT GRINDING IN BM	HYBRID GRINDING IN RP	SEMI-FINISH GRINDING IN RP	FINISH GRINDING IN RP	GRINDING IN VRM
POWER CONSUMPTION	100%	70–80%	55–75%	40–60%	50–70%
MAINTENANCE	100%	110%	130%	120%	115%
PRODUCT QUALITY	O.K.	O.K.	O.K.	*	*
INVESTMENT COST	100%	90–110%	130%	100%	100–115%

(1) ROLLER PRESS (2) BALL MILL (3) SEPARATOR (4) VERTICAL ROLLER MILL (5) ESP

* TO BE ESTABLISHED

Fig. 1. Comparison of various grinding systems.

slag under order. However, the RP had been in use for some time in combination with the BM for slag grinding. The RP has a distinct advantage over VRM in terms of reduced wear of the grinding components due to lower speed and inter-particulate comminution.

2.1. Roller press

In view of the scope of the present paper, it will be relevant to discuss the principle of operation of RP, based on inter-particulate comminution.

In the RP operation, the feed material is pressed between two rotating rolls and is subjected to a very high pressure of the order of 500 bar leading to generation of fissures and cracks in the grains of the material which substantially reduce the requirement of energy for further comminution. The output material commonly known as slabs, on deagglomeration, releases a certain percentage of fines of the requisite size which can be collected in a separator. The percentage of these fines depends on the characteristics of the material and the operating parameters of the RP. The process is ideally suited for hard and brittle material like slag which allows the generation of high pressure and subsequently leads to formation of higher granular fissures and fines.

The basic requisites for a successful RP operation is the formation of stable bed of material between the rolls so as to impart the high pressure required to produce fissures in the material. Our experience with the operation of RP shows that the following factors are critical for the formation of a stable bed. These are discussed in detail later in the text.

(a) *Feed arrangement*. The feed arrangement (feed-chute) should ensure that there is always a column of material above the rolls, and should allow release of entrapped air during pressing. The feed hopper should be of mass-flow design.

(b) *Inter-particle cohesion*. This can be improved by addition of a certain percentage of moisture in the feed material.

(c) *Granulometry of feed material*. A coarse material with wider particle size distribution is conducive to formation of stable bed.

(d) *Quality of roll surface*. The roll surface should provide adequate friction to ensure the nipping action.

(e) *Roll speed*. While the roll speed is designed to achieve a specific throughput from the RP, there is essentially a limit to this speed for a stable bed formation.

3. Design of TISCO slag cement and grinding systems

In order to optimize the power requirement and to ensure a very high quality of slag cement, Holderbank (Consultants to the TISCO Project) carried out a series of laboratory tests and recommended a fineness of 4200 and 3400 cm^2/g for clinker and slag respectively, with the proportion of slag varying between 45% and 50%. With this fineness it was possible to achieve a 28-day strength of 55 MPa using 50% slag. Holderbank also recommended grinding of clinker and slag by RP in combination with BM and without it, respectively.

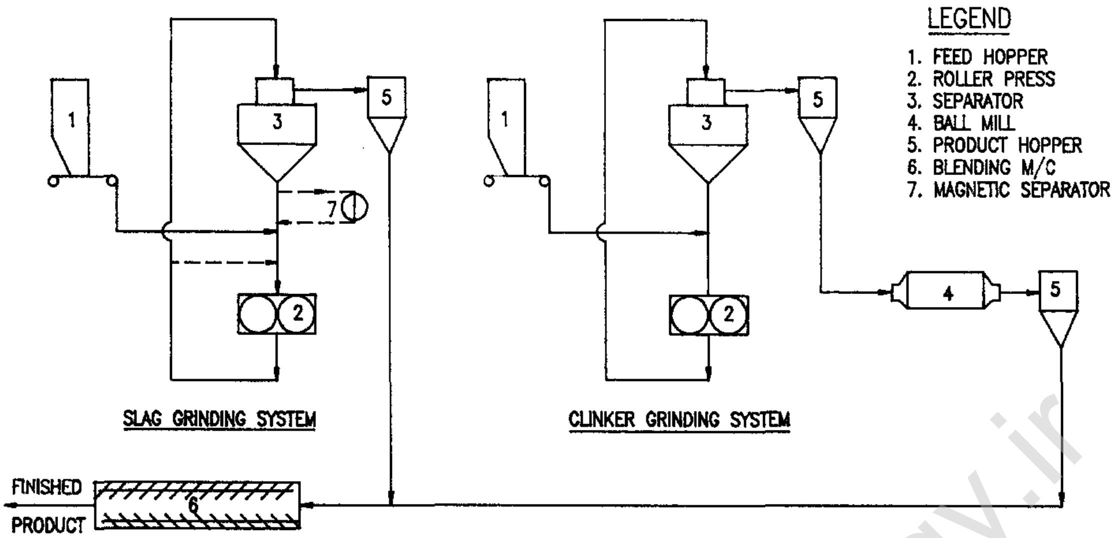


Fig. 2. Slag clinker grinding system for the TISCO plant.

The tests on slag at KHD's Porz Laboratory indicated that the particle size distribution (PSD) of the roller-pressed material with the laboratory separator was extremely narrow. However, a wide particle size distribution desirable for a satisfactory quality of the slag cement was expected in the actual production unit. This can be achieved by a higher re-circulation rate.

The process configurations for both slag and clinker grinding ckts. are described in Fig. 2. The basic parameters of the RP and the BM are indicated in Table 1. The higher fineness in case of clinker is achieved by finish grinding in the BM. The process ensures the requisite quality of the slag cement, particularly the early strength and water requirement. The lower fineness and finish grinding in the RP for slag is selected to reduce the overall power requirement.

From the data given in Table 1, it may be noted that although the rated capacity and other parameters of the RP for slag and clinker grinding are the same; the slab thickness, the roll-speed and the re-circulating factors are different. These parameters depend on the nature of the material, power requirement, fineness of the finish product, etc. and are established after detailed testing in the laboratory. It may be noted that the speed of RP for slag grinding had to be decreased after encountering problems during the start-up and commissioning.

4. Operating experience with slag grinding

The clinker grinding circuit employing the RP in the semi-finish mode did not offer any problem during the start-up and commissioning and the rated capacity was achieved without any difficulty. However, the slag grinding operation was plagued with numerous problems which did not allow to achieve more than 30% of the rated capacity initially. The prime reason for this was the absence of formation of a stable bed. The RP operation was more like a conventional roll-crusher and was accompanied with high

Table 1
Comparison of design parameters for clinker and slag grinding

	Clinker grinding	Slag grinding
Roller press		
Roll diam. (mm)	1400	1400
Roll width (mm)	1200	1200
Cake thickness (mm)	32	24
Throughput rate (TPH)	440	290
Roller speed (RPM)	18.18 (1.32 m/s)[b]	21.57 (1.58 m/s)[a]
Power requirement (KW)	820	1440
Drive motor (kW)	2×900	2×900
Moisture content (approx.)	nil	3%
Product (Blaine)	2700–2900	3400
Output (TPH)	70	70
Feed size (approx.)	see Table 2 (for typical size distribution)	
Recirculation factor	6	4
Separator	SKS175	SKS145
Air requirement (m^3/h)	2,40,000	1,60,000
Fan motor (kW)	450	300
Tube mill		
Inner diam. (m)	4.2	not required
Grinding path (m)	12.5	
Speed (RPM)	15.45	
Drive (kW)	3500	
Output (TPH)	140	
Feed (Blaine)	2700–2900	
Product (Blaine)	4200	
No. of chamber	1 (one)	
Drive	central with planetary gear box	

[a] Subsequently reduced to 1.32 m/s by interchanging the gear box with the clinker grinding unit.
[b] Final operating speed is 1.58 m/s as a result of change of gear box.

vibrations and heavy dust generation. After a series of trials with various process parameters without much success, it became evident that all the critical parameters mentioned earlier in the text need to be examined systematically in detail.

4.1. Feed arrangement

The original feed arrangement (feed chute) and the modifications carried out during trials are shown in Fig. 3. The main problem was due to release of the entrapped air during pressing which did not allow a stable bed formation. As the various modifications gave only a limited success, it was felt that the feed chute design needs a basic change incorporating mass-flow design and a motorised adjusting arrangement of both the feed plates. The final feed chute with various configurations of feed plates is shown in Fig. 4.

4.2. Granulometry

The typical size distribution of clinker and slag is indicated in Table 2. The problem of a stable bed formation in case of slag grinding was partly attributed to the fineness of

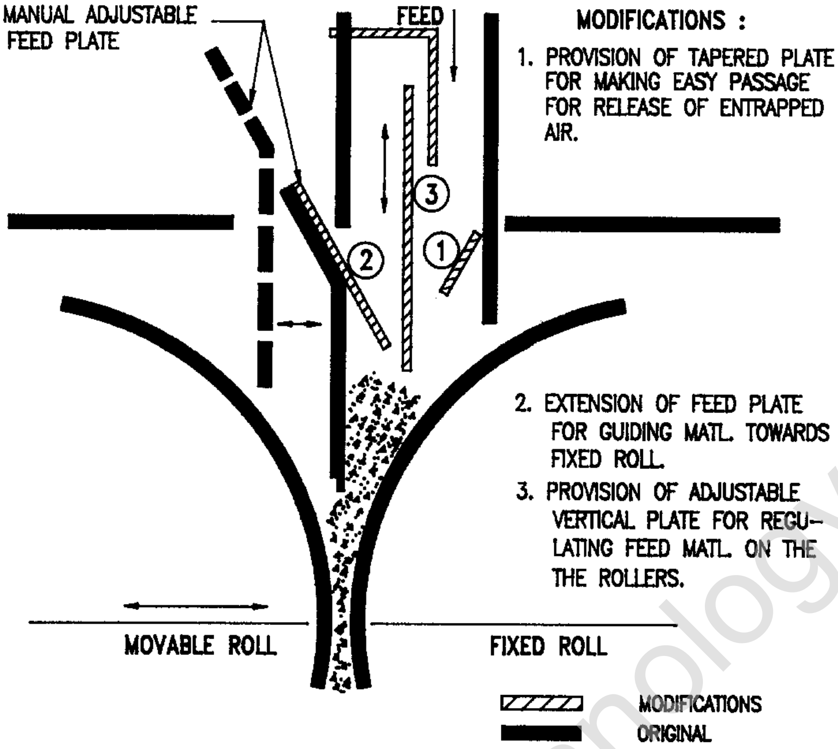


Fig. 3. Feed chute indicating various modifications.

the slag. It was also observed that a coarser slag (40% ≥ 0.5 mm) gave comparatively better results. This could be achieved either by moisture addition to the feed slag or partial re-circulation of the pressed slabs.

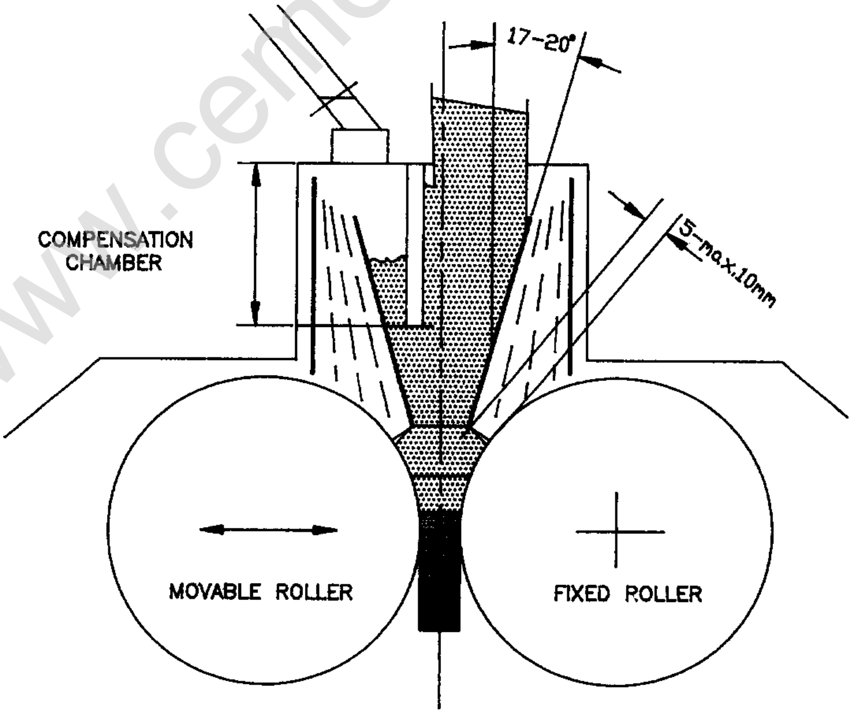


Fig. 4. Final feed chute with adjustable plates.

Table 2
Typical size distribution of clinker and slag

Size fraction (mm)	Cumulative residue (wt.%)
Granulometry of clinker	
+33.1	1.82
+16	22.73
+11.2	40.91
+6.3	63.09
+2.8	76.73
+1	85.82
+0.5	89.09
−0.5	100.00
Granulometry of slag	
+4.75	0.5
+2.80	2.1
+2.00	3.55
+1.00	28.55
+0.50	69.15
+0.30	90.95

4.3. Partial re-circulation of slabs

The partial re-circulation of slabs was first suggested by Holderbank. The experience at Civil and Marine Plant, UK, also confirmed the same. However, the slabs re-circulation required a major modification in the layout of the grinding circuit as it was not originally envisaged. Nevertheless, some trials were carried out by an improvised arrangement with only limited success; better results could have been possible by a more elaborate arrangement. It was therefore felt that this can be resorted to only as a last measure.

4.4. Moisture addition

According to the initial process concept of KHD, the slag grinding did not require any moisture addition in the feed slag and, therefore, no provision was made for this. Subsequently, the tests carried at KHD's Porz lab confirmed that a certain percentage of moisture in feed slag improved the nipping action and resulted in smoother RP operation. The fines recovery (-32 μm fraction) also increased from 25.3% to 27.2% with a moist slag. The moisture addition, however, required effective deagglomeration of slabs and subsequent drying. Accordingly, it was decided to use a deagglomerator and a hot air generator.

The continuing problems faced with the grinding of dry slag made it amply clear that moisture addition is a must. The experience of slag grinding at Civil and Marine, UK also confirmed this. Accordingly, a moisture addition system with a close loop control was installed to add approximately 0.7% moisture in the feed to the RP. With this, a significant improvement in the RP operation was achieved.

The moisture addition, however, was accomplished with a series of operating problems such as choking of bagfilters and suction ducts and jamming of the deagglomerator. To overcome this, bagfilters and suction were heat-traced and insulated.

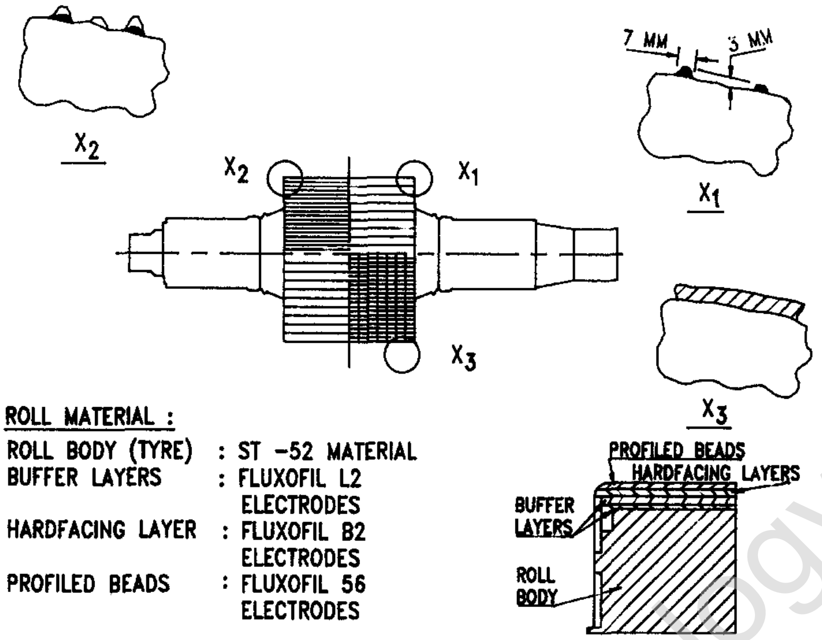


Fig. 5. Roll surface profiles.

4.5. Roll surface

The initial roll surface profile as well as the modifications carried out by additional weld-deposit to improve the nipping action are shown in Fig. 5. The modifications gave only marginal improvement in achieving a stable operation and formation of cake. Subsequently, the original surface profile was resorted to.

A suggestion was also made to use the KHD's latest design of rolls with studs, which provides an autogenous surface and will be specially suitable for the slag which is highly abrasive. This could not be tried because of the need for a complete change of rolls.

4.6. Roll speed

It was not until the experiment was carried out at our Jojobera slag grinding plant that the full importance of the roll-speed was realised. After the lab-scale testing, KHD established the basic design parameters and a roll speed of 1.58 m/s. Holderbank had however suggested a lower speed.

A trial grinding of slag in the clinker roller press which had a nearly 17% lower speed, gave encouraging results. With a fair degree of success achieved using a modified chute and moisture addition, it became clear that for achieving further improvement and the rated capacity, the RP speed should be reduced. After examination of various options, it was decided to interchange the gear boxes of clinker and slag RPs. This resulted in a distinct improvement in the operation of slag grinding RP and fortunately did not have any adverse effect on the clinker grinding operation because of increased speed.

4.7. Build up of metallic iron

During the slag grinding operation, it was observed that a very small percentage of metallic iron (less than 0.5%) in the feed slag leads to a very high concentration (over 30%) in the slag circuit within a short duration of operation. This build-up of iron in the circuit was the result of poor grindability of the metallic iron. The grinding process was seriously impeded once the concentration of metallic iron increased to more than approximately 8%. Although the granulated slag is expected to have a certain amount of metallic iron, this problem, which is typical of the finish slag grinding operation in the RP, was not foreseen. The problem was overcome, as an interim measure, by flushing the slag from the circuit periodically so as to limit the concentration of the metallic iron. For a permanent solution, it was decided to provide a drum-type magnetic separator in the circuit as shown in Fig. 2.

4.8. Hydro-pneumatic system

The movable roll of the RP is supported by hydraulic cylinders at each end to provide the necessary pressing force. The system is connected with a hydraulic accumulator with pneumatic bladders to provide the necessary hydro-pneumatic resilience. The higher stiffness of the system would lead to high hydraulic pressure and motor current in case of excessive feed or entry of foreign material. On the other hand, the lower stiffness would result in a significant decrease in the pressing force, thus affecting the grinding operation. Fig. 6 indicates the variations of pressure and motor power (kW) at different settings of the accumulator pressure. The large fluctuations in the motor current and hydraulic pressure can be observed in the first case when the system has a high stiffness. A much smoother operation can be achieved by an optimum setting of the accumulator pressure as shown in Fig. 6(3).

4.9. Shifting of tyre

The roll design of the KHD RP comprises a tyre shrunk-fit on a roll shaft. The tyre surface is subsequently built-up by weld-deposit in a definite profile to get the required wear resistance and the nipping action. The most serious failure experienced during the operation of the RP was the shifting of the tyre on the roll-shaft. The failure was attributed to the higher surface temperature of the roll because of the use of hot slag for which the interference fit was not designed. It may be recollected that the moisture addition had necessitated a subsequent drying in the separator using hot air, resulting in a temperature increase of the feed slag. Subsequently, KHD changed the roll design incorporating a higher interference fit. The roll with the new design is working satisfactorily.

4.10. Wear and failure of roll surfaces

The roll surface of RP has to meet a very stringent requirement of high operating pressure with cyclic variation and abrasive action of the material being ground. The

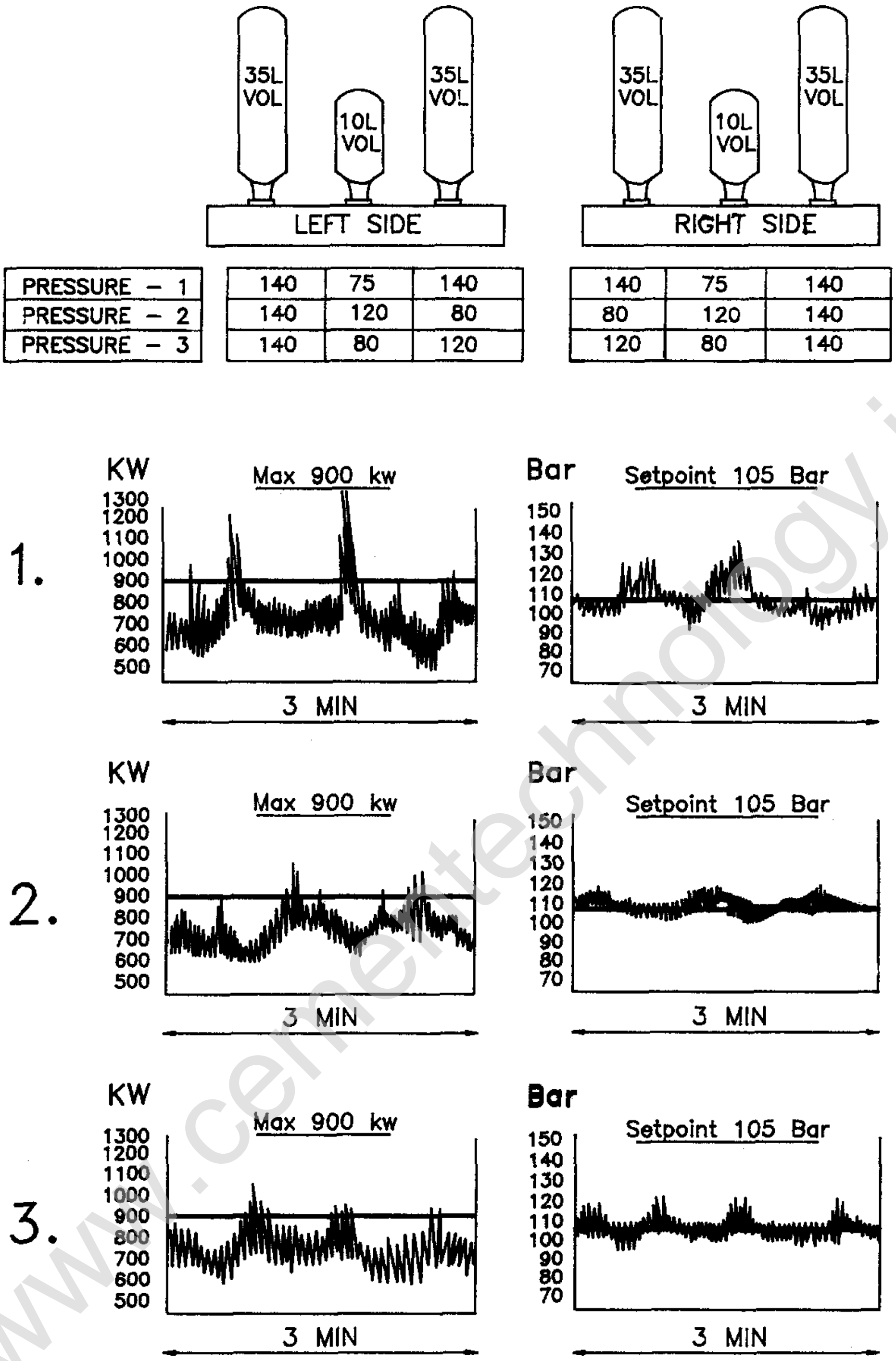


Fig. 6. The effect of stiffness of the hydro-pneumatic system on motor power and hydraulic pressure.

abrasion is even more severe in case of slag grinding. The surface should also be designed so as to allow subsequent regeneration by weld-deposit. The KHD design of the roll indicating different weld layers is shown in Fig. 5.

The roll surface is expected to have a life of 5000 h before regeneration. However, in practice this has not been achieved. Further efforts in this area are necessary. KHD has developed a roll design with studs to provide an autogenous surface for wear resistance. The results of this development are being studied.

4.11. Auxiliary equipment

The major problem faced with the auxiliary equipment was the wear of the components because of the highly abrasive nature of the slag. The conventional round link-chain bucket elevator was found to be grossly inadequate for slag application. The pin-bush chain design proved to be more suitable. The pipes and chutes conveying slag were suitably lined. The components of the separator, particularly the blades of inlet guides and impeller cage, have to be provided with suitable wear resistant surfaces. All these factors have to be well taken care of in order to achieve the plant requirements.

5. Conclusion

The important parameters found to be critical for a stable and efficient operation for slag grinding by RP, include: feed arrangement, moisture in the feed slag, and roll-speed. It has been observed that a small percentage of metallic iron in the slag, because of its poor grindability, builds up to a large concentration in the grinding circuit and seriously impedes the grinding operation. The problem can be overcome by periodic flushing and/or removal of metallic iron by a magnetic separator. Special attention has to be paid to the design of various components subjected to the highly abrasive action of slag to achieve the plant requirements.

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