EFFECTIVENESS OF AUTOGENOUS VSI CRUSHERS FOR PREGRINDING IN THE CEMENT INDUSTRY:

REDUCING SPECIFIC ENERGY CONSUMPTION AND INCREASING CAPACITY OF EXISTING UNITS.

Translated and Adapted from an original paper by

TAMAL B. BHATTACHARYA

Formerly DIRECTOR,
PYROMET TECHNOLOGY (P) LTD.
56, CHOWRINGREE ROAD, CALCUTTA 700 071

ABSTRACT

Grinding operations in the cement Industry account for 60-70% of the total electrical energy consumption. Electrical energy is probably the single largest input in terms of cost, and the consumption per tonne can be reduced effectively by employing pre-grinding crushers ahead of the grinding mills. In this paper, the effectiveness of autogenous VSI crushers as pregrinders ahead of ball mills for limestone and cement is discussed. The VSI crusher can be configured appropriately to achieve maximum benefit from existing mills or to reduce the capital cost of new grinding units, after testing of the material to collect adequate information on fracture characteristics under high energy impact crushing. It is proposed that the harder the material, the greater is the benefit realisable from installing a VSI crusher. The possibilities of using a VSI crusher to replace a roller press or as a supplement to a roller press are also discussed. Installing a VSI crusher as a pregrinder may result in increased capacity of existing grinding units by anything from 20% to 60%, depending on the existing situation and constraints. A VSI may reduce substantially the heat energy used for drying in limestone raw mills.

1. INTRODUCTION

1.1 Size reduction is a dominant and energy-intensive operation in the cement manufacturing process. With the high cost of energy, depending on the region, electrical power is probably the single largest cost input in the cement Industry. While considerable savings have been effected in fuel energy over the years by technology and process upgrades resulting from concerted research efforts, the improvement in the electrical energy consumption, though noticeable, is less spectacular, and is generally confined to reducing wasteful consumption and some de-bottlenecking, rather than any changes in process technology, especially in the energy-intensive size reduction operation. The processes of crushing, and grinding in ball mills, have not undergone much of a change in character over the last 100 years, and only comparatively recently have advances been apparent with the advent of vertical and horizontal roller mills.

1.2 In many areas crushing and grinding operations account for 70-80 per cent of the total electrical energy consumed. Since, in the crushing stages, the average ratio of reduction is much smaller than that in the grinding stage, the power consumption in the crushing stages are very much lower than in the grinding stages. Also, it is widely known from research literature that crushers are about 4-5 times more efficient than ball mills, though in an absolute scale of energy utilisation both may be considered as inefficient.

1.3 Generally the grinding operation alone is responsible for around 60-70% of the total energy consumption, with 50% or more of the grinding energy input to the mills accounted for by the cement grinding operation, the rest being consumed in raw materials and coal grinding. The ball mill is still the universal grinding mill for cement production while the vertical roller mills (VRMs) are gaining preference over ball mills in new installations for raw material grinding, where the product gradation may be coarser. The VRM is more energy efficient thann the ball mill, and attempts are being made to use the VRM for production of finished cement also. Recently a new concept has emerged in the form of horizontal roller mill or Horomill for raw material grinding, and a few units are reported to have been installed. However, the ball mill is still the most widely used grinding mill.

1.4 The ball mill is generally configured in multiple chambers, the most common being the two chamber mills of smaller L/D ratio than the earlier generation tube mills. The output and energy consumption depend on factors like mill parameters and configuration, grindability and hardness of material, the particle size distributions of feed and output, grinding media load and mix, etc. The auxiliary equipment also plays a critical role. The separator efficiency and ventilation are very important for maintaining optimal production level from a closed circuit milling circuit.

2. FACTORS AFFECTING MILL PRODUCTION :

2.1 Assuming that the physical and operating parameters of a milling circuit are properly designed and balanced, and the required output specification is laid down in terms of particle size distribution, then the grinding media charge mix and the final output, as well as power consumption, will be governed by the particle size distribution of feed material and the Bond Index of the material. Given the same material, the output will change according to alterations in feed gradation at the same absorbed power. The output will be higher with finer feed grading. Similarly for the same feed granulometry, the output will be higher with material with lower Bond Index, and lower when Bond Index is higher, at the same input power or absorbed power.

2.2 Since the amount of work done in the mill will be different for different feed gradation, it is not uncommon to find two mills made by the same manufacturer, to same design and dimensions, and provided with driver motors of same specifications, and power rating, actually yielding two different production levels when installed in two different locations. The material characteristics, local conditions and unbalanced operating parameters, as well as output specifications, result in different production levels from similar mills. Actual feed gradations of' input clinker particles from some cement mills are shown in Fig.1 represented by Curves A, B, & C. The final output curves X, Y, represent particle size distributions corresponding to different Blaines surface.

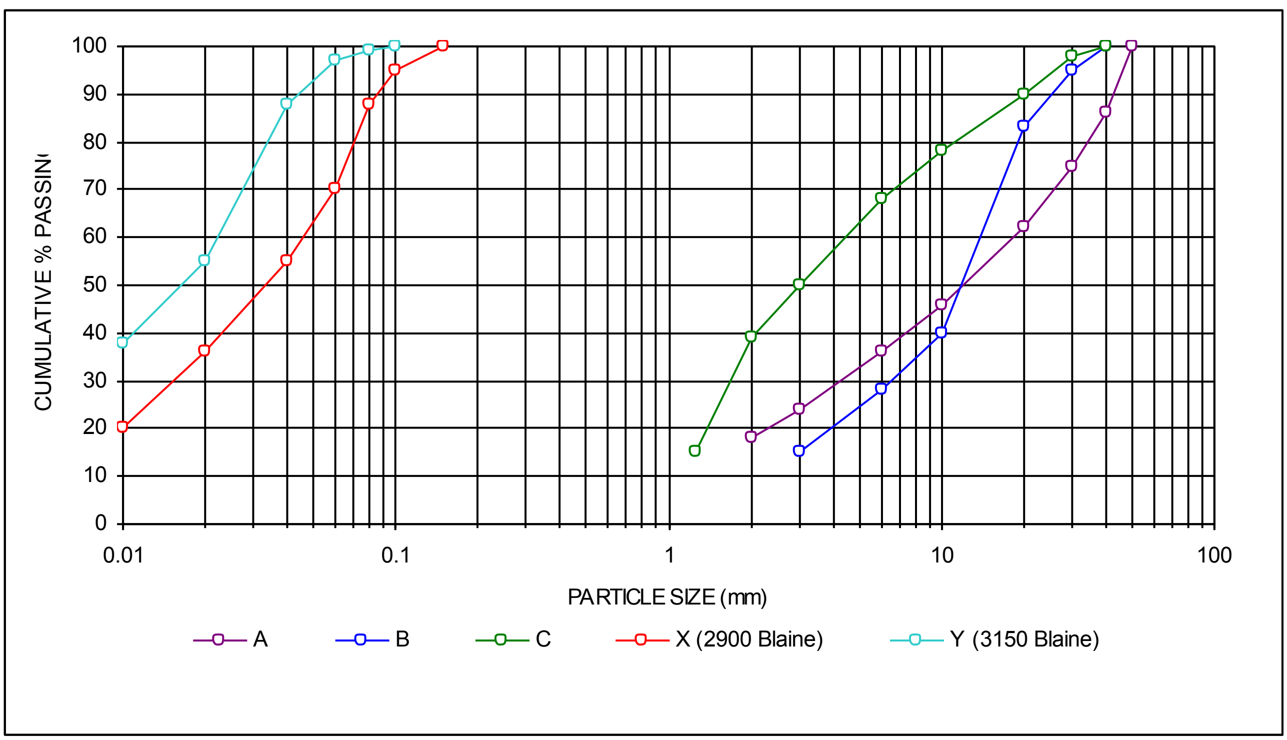

Fig.1

2.3 As an illustration, 43gr OPC might be produced with Blaines Surface of around 2800-2900cm^2 /g, PPC with 3100-3300 cm^2/gm and PSC with 3600 Cm^2/gm.

3. EFFECT OF PREGRINDING :

From the gradation curves shown in Fig.1, it is evident that Feed ‘C’, which is finer than other feeds, will need the least work to be done by the mill to produce a given output, such as ‘Y’. By installing a VSI as pregrinder ahead of the mill, the particle size distribution of the existing mill feed can be made finer outside the mill. If this finer VSI output is then given to the mill as feed, the work done by the mill will be much reduced, resulting in energy savings in the mill. However, in an existing mill, the power drawn is governed by mill configuration and the charge load, and all of this absorbed power is available for the comminution process. Since the installed power of the mill is not now fully absorbed, as less work is required with a finer feed, the mill parameters having been designed originally for a coarser feed, the output from the mill can be increased substantially by using the spare power fully in grinding extra material.

3.2 In Fig.2 the gradation Curve ‘F’ represents a distribution with top particle size of 3mm as obtained from the Screen underflow of a closed circuit Barmac autogenous crushing plant. Curve ‘F’ gives the mill feed gradation after installation of the Barmac crusher as pregrinder. Curve Wj3~9 represents the mill feed before installation of a pregrinder, as well as the feed to the Barmac crusher on installation of the Barmac as pregrinder ahead of the mill. Curve ‘8’ represents the Barmac discharge distribution with ‘A’ as feed.

3.3 The VSI as pregrinder takes the existing mill feed as its own feed, and gives an output of much finer distribution, with a top size in the range of perhaps 3 – 12mm, using a suitable screen in closed circuit with the crusher. The VSI sizing and drive power will depend upon the desired cut size of the screen. The screen underflow, if cut at 3 mm as shown by Curve ‘F’ in Fig.2, will have a particle size distribution very close to what enters the second chamber of many cement mills: The effect of installing the VSI is that it almost eliminates the need for having the first chamber in the mill. The mill is now required to perform only the functions of the second chamber and the mill could produce the full output without having the first chamber.

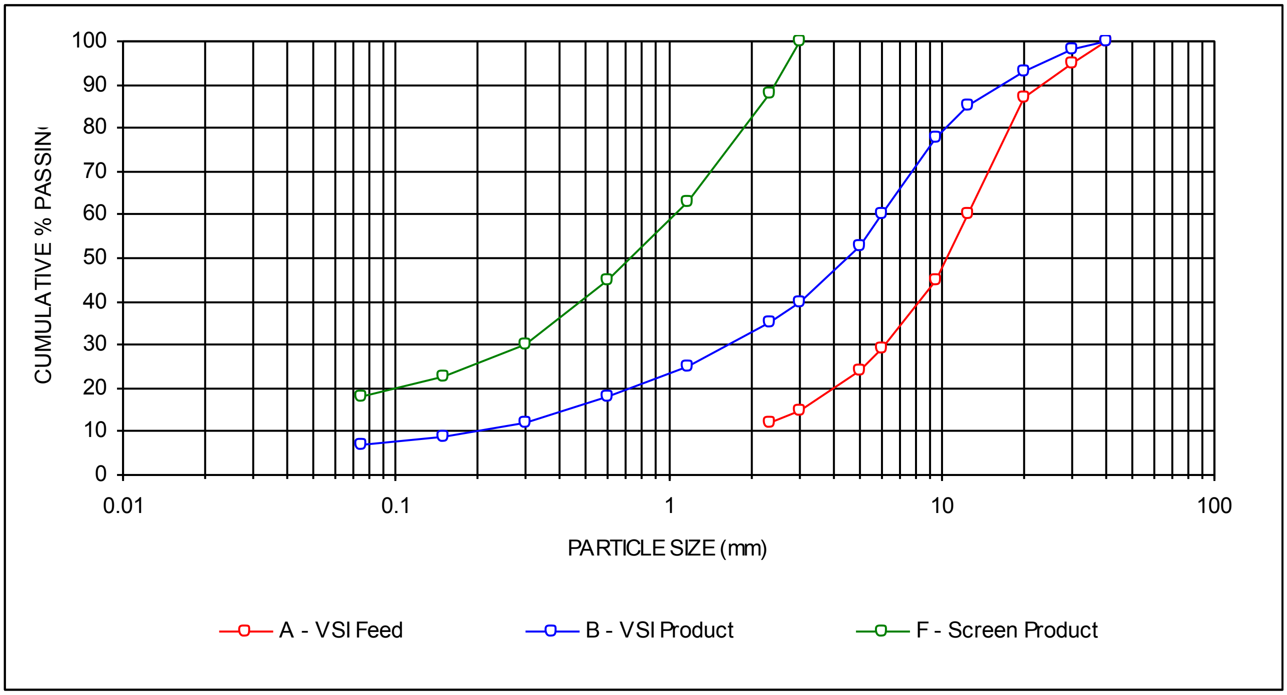

Fig.2

3.4 In a new milling unit, with VSI included, the mill would need to be smaller with lower installed power, resulting in substantial savings in capital cost.

3.5 In an existing mill, the first chamber remains physically, and the power input is also available. Therefore the compartment rendered redundant as a first chamber can be used as an extension of the second chamber, and the whole mill can be made to function as if with a larger single chamber. Because of the availability of mill space and power input, the mill can be given a feed at a higher rate, resulting in a substantially higher production without increase in absorbed power.

4 POWER SAVING AND INCREASE IN MILL PRODUCTION

4.1 Under average conditions, in a well configured and balanced mill, the first chamber may consume about a third of the total power needed to produce OPC at about 2800 Cm^2/gm Blames Surface. A VSI crusher will consume about 20% of the power of the first chamber, at the same production level, while doing almost the same work outside the mill to produce the feed for the second chamber.

To illustrate the point, a case may be considered as given below:

4.1.1. Clinker mill feed granulometry: Curve A in Fig. 2

Before addition of VSI

100% passing:	40 mm
80% passing:	18 mm
50% passing:	12 mm
15% passing:	3 mm
Clinker Bond Index:	16
Mill Production, open circuit:	100t/h
Mill Absorbed Power	2960kW
First Chamber Power	1010kW
Output	OPC 2800 Blaine
Specific Power Consumption	29.6kWh/t

After addition of VSI

VSI power @ 100t/h mill feed	300kW
Total Power, Mill + VSI	3260kW
Specific Power Consumption	23.28kWh/t
Mill Production	140t/h
Specific Power Saving	29.6-23.28 = 6.32kWh/t
Saving in Mill only	8.5kWh/t
Increase in Mill Capacity	40%

4.1.2 The effect of the pregrinding operation in terms of benefits and capacity enhancements depend on several factors. Given that the changes necessary in the separator (in case of closed circuit grinding), mill internals, ventilation, charge mix, capacity balancing of the whole circuit including transfer lines, etc. are taken care of, and there are no operational bottlenecks, the quantum of benefits will depend on the Bond Index of the material and particle size distribution of the feed.

4.1.3 While the particle size distribution of the screen underflow from the VSI circuit may show a high order of consistency, the mill feed prior to installation of VSI may vary over a wide range, due to various reasons from plant to plant or even in the same plant at different times. In raw mill circuits, for instance, the wear condition of the primary crusher will give rise to fluctuations in VSI circuit feed, as may varying characteristics of the run-of-mine material itself. For the mill referred in the case in 4.1.1 above, the projected performances before and after VSI are tabulated below for materials of different Bond Index. Curves ‘A’ and ‘F’ of Fig. 2 represent the mill feeds before and after introduction of a VSI.

	Bond Index	*Pre-VSI*	*Post-VSI*	*%+/-*
Mill Production	10	173	223	+28.9
	12	138	185	+34
	18	87	123	+41.3
	20	77	112	+45.4
Absorbed Power, kW	All			
Mill only		2960		
Mill + VSI			3260	
Spec. Power Cons. kWh/t	10	17.11	14.62	-14.5
	12	29.6	23.28	-21.3
	18	34	26	-22
	20	38.44	29.1	-24.3
Saving in Power, kWh/t	10		2.49	
	12		3.83	
	18		7.5	
	20		9.33	

*Note: No power losses are assumed in the motor control circuit

The above performance figures are projected for the mill referred to in 4.1.1, corresponding to particle size distributions shown in Fig. 2. For production of OPC at 2800 Blaines, the figures will change with variations in Bond Index and particle size distribution, but the trend will persist.

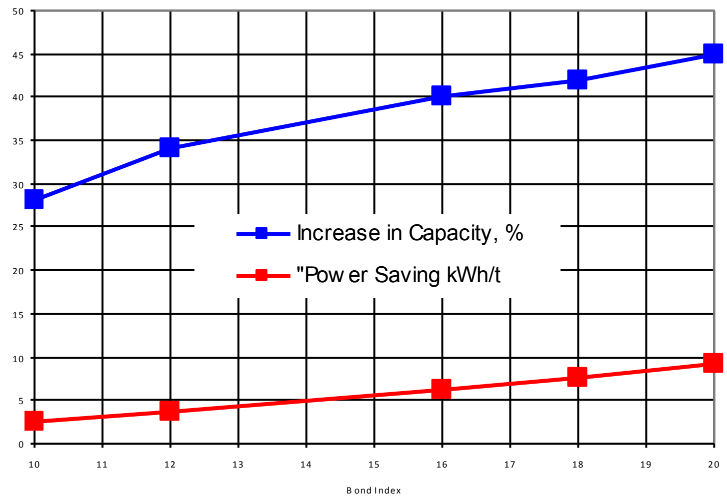

Fig.3

4.1.4 Though the above figures are worked out for OPC production, the trend will be the same for all material under defined conditions. It can be observed that the harder the material, the greater are the benefits from pregrinding with a VSI. With increasing Bond Index of material, the production from the mill and attendant specific power savings increase steadily. This is illustrated in Fig. 3.

5. ADDITIONAL BENEFITS RESULTING FROM UNIQUE FEATURES OF VSI

5.1 Conservation of hot gases used for drying, and further enhancement in capacity:

5.1.1 Limestone comes from the mines generally with appreciable level of moisture content. Large amounts of hot flue gases from the kiln are passed through limestone mill for drying the limestone feed. Due to the drying effect of the crushing process in a VSI, the requirement for these hot gases may be much reduced. The high speed of the rotor creates a strong turbulent airflow inside the crusher, resulting in moisture content of up to about 3% in the material being driven off while in circulation in the crusher. In many cases, the material is expected to appear quite dry as it comes out of machine, rendering the drying chamber in the mill redundant. The drying chamber may be effectively converted into a grinding chamber and the extra milling space so created can be used to improve the milling capacity still further, in addition to the enhancement possible from the existing grinding chamber.

5.1.2 Should there be any evidence that power losses in the motor control circuit due to the inductive load can be saved for use as additional process power (by installing adequate capacitor banks), a larger portion of the drying chamber could be converted to grinding chamber without over loading the motor. In any case, it may be appropriate to retain a small drying chamber, as the limestone particles, especially the finer ones, are somewhat hygroscopic in nature and may absorb some moisture from the ambient while travelling to the mill from the VSI plant.

5.1.3 The total increase in production capacity of raw mills, therefore, as revealed by a survey, can be anything from perhaps 20% upwards over existing levels depending on operating conditions.

5.2 Reduced enhancement due to constraints in auxiliaries:

5.2.1 Even if the milling capacity can be enhanced greatly by installing a VSI crusher as pregrinder, the constraints of auxiliary equipment in the milling and transportation circuits, as well as capacity constraints of down-stream equipment, may not permit the mill to work at fully enhanced capacity. The VSI plant can be configured appropriately to address such situations. It is possible to produce mill feed of different top sizes, to achieve different levels of production from the same mill by adjusting variable factors in the VSI circuit.

5.3 Process stability and reduction of media wear:

5.3.1 In limestone raw mills, the feed comes from primary crushing equipment, via stock pile. As the crusher grate bars or cage wear, the product gradation displays less reduction. After replacement of grate bars with new ones, the crusher discharge becomes finer. Since this is directly used as mill feed, there is a wide variability in particle sizes from time to time, depending on the condition of the crusher grate bars. Therefore, the mill may periodically get upset, and the ball charge mix may be inappropriate, thereby causing inefficient grinding. This will result in waste of power and loss of production. This situation is not likely to arise after installation of a VSI pregrinding circuit, since the mill feed gradation will remain consistent.

5.3.2 The screen underflow from a VSI plant will have a high order of consistency in particle size distribution, irrespective of the variability of the input caused by primary/secondary crusher grate wear. Because of the uniform gradation of the mill feed, it is possible to maintain an optimal charge mix for total stability of the process, and close to ideal performance can be achieved from the mill and sustained.

5.3.3 With pregrinding, the mill feed particle sizes become very much smaller and consequently the grinding media sizes are also reduced. Therefore, the movement of the grinding media, even in the first chamber, changes from a cataract to a cascading action, resulting in substantial reduction in grinding media wear which may be considered an added advantage.

6. VSI AND ROLLER PRESS

6.1 A roller press is widely used as a pregrinder. The rollers exert a very high pressure on the material, often of the order of 130—140 bar. Unlike a VSI the roller press has no effect upon the moisture content of its product: The discharge from the roller press appears as cake, and a disagglomerator is needed to breaking this cake into its constituent particles. A VSI can be used as a disagglomerator, and in the process the moisture in the material can be reduced, improving the effectiveness of the roller press.

6.2 A VSI can take the place of a roller press and both the functions of pregrinding and drying the material can be performed. Mill production may improve beyond what is achieved from the ball mill and roller press in tandem. An improvement in power consumption is likely as the VSI plant may consume rather less power than that required for equivalent pregrinding with roller press and attendant disagglomerator.

.