PROCESS DIAGNOSTIC STUDIES
FOR
CEMENT MILL OPTIMISATION - CASE STUDY

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ABSTRACT

Grinding technology has been continuously improving with numerous innovations with a view to improve productivity and reduce power consumption. In order to reduce the manufacturing costs for cement, it is very important to optimise the existing mill installations as far as the grinding process is concerned and also to use high quality spare parts and consumables like grinding media .

Ball mills are predominantly used machines for grinding in the cement industry. Although ball mills have been used for more than one hundred years, the design is still being improved in order to reduce the grinding costs.

HOLTEC has undertaken Performance Optimisation of the cement grinding circuits by doing process diagnostic studies in many cement plants. The paper describes the approach for the process diagnostic study for the optimisation of a ball mill circuit and is supported with typical case study done by HOLTEC in a 1.5 mio t/a cement plant.

The paper also describes the principle of the mill load control system developed by the Holderbank Engineering Canada Limited (HEC), Canada for the optimisation of the performance of the ball mills for obtaining maximum production and minimum specific energy consumption.

1. INTRODUCTION

The need for process optimisation through diagnostic studies has been increasingly felt as production costs are shooting upwards in conjunction with increased competition in the market. In order to reduce the manufacturing costs for cement, it is very important to optimise the existing grinding installations.

Experience has shown that the potential for optimisation is greatest in the cement grinding process in a cement plant The benefits that can be achieved due to the optimisation of cement grinding system through process diagnostic study are:

- Reduction in specific power consumption
- Increase in production
- Stable and sustained operation
- Increase in availability of the equipment - Less down time
- Improved and consistent product quality

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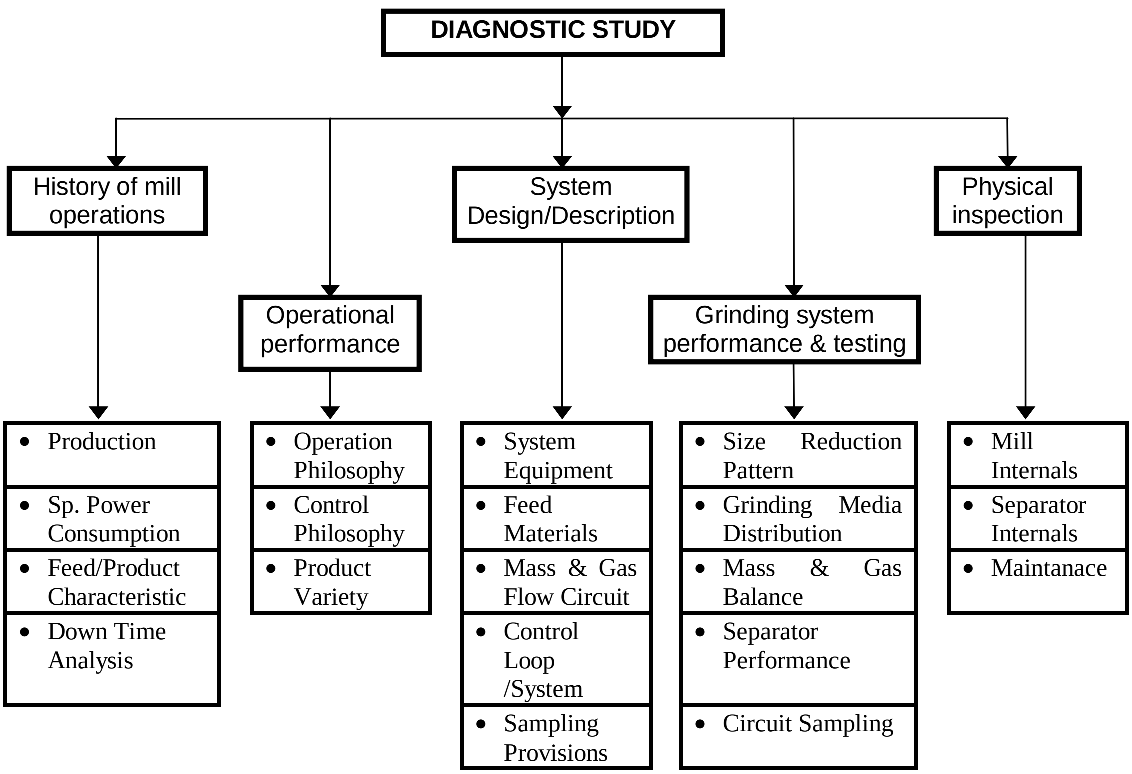
The various types of grinding systems currently being used for cement grinding in a cement plant are:

- Conventional tube mill - Open and Close circuit
- Tube mill with precrushing unit i.e. vertical shaft impactor (VSI) or horizontal impact crusher (HIC)
- Roller press in semi finish and finish grinding mode
- Vertical roller mill (VRM)
- Ring roller mill or Horo mill

Even though there are various types of systems available for cement grinding, ball mills are predominantly used machines for cement grinding in large number of cement plants. In this paper authors are covering the process diagnostic study of Ball mill for cement grinding.

2. METHODOLOGY FOR PROCESS DIAGNOSTIC STUDY : BALL MILL

The process diagnostic study for ball mill optimisation is carried out in following steps depending on the type of problem of the grinding system.



The mill performance is evaluated and recommendations are formulated based on the past history of the mill operations, inspections, process measurements, feed/product characteristics and grinding performance, in order to improve mill output and reduction in power consumptions in the ball mill system.

3. CASE STUDY

A 1.5 mio t/a cement plant is having a closed circuit ball mill for cement grinding: The mill has been operating with satisfactory performance in-terms of system availability and output, however power consumption was on higher side.

3.1 System Description

Mill Rated capacity	150 t/h OPC at 2800 blaine
Mill size	4.6 x 16.5 m
L/D ratio	3.58
Mill drive	5000 kW
Mill speed	15.2 rpm
Critical speed	76 %
Separator	Sepax 450M-222
Separator motor	300 kW
Separator Fan	248300 m^3/h 497 mmwg 500 kW
Bag Filter Fan	21720 m^3/h 185 mmwg 19 kW

I chamber liners	Stepped
II chamber liners	classifying
Diaphragm	Double blind plate
GM in I chamber	107 t
GM in II chamber	217 t
Separator Cyclone	4 nos.
ESP Fan	74100 m^3/h 375 mmwg 110 kW

3.2 Performance

The mill is designed to handle a total ball charge of 324.5 t at 100% loading with a percentage filling of 29.5% in both the chambers. Both the chambers of the cement mill were charged with 80% of the designed charge, which works out to 86 t in Ist chamber and 172 t in the IInd chamber.

The mill is utilised for production of OPC 33 grade, OPC 53 grade and PPC. The blaines for the cements of different grades are being maintained as given below:

Product	**Blaine Range(cm^2/g)**
OPC 33 grade	2600-2700
OPC 53 grade	3000-3100
PPC	3100-3200

The productivity of the mill system as observed from the plant data is given below:

Parameters		Month Average			
		A	B	C	D
Production rate	t/h	126	130	143	140
Sp. power consumption	kWh/t	44.18	43.56	41.20	42.00
Product blaine	m^2/gm	270	273	272	274

The mill was operating at an average output of 135 t/h OPC and specific power consumption of 42.73 kWh/t OPC.

3.3 Observations and Diagnosis

- The cement mill and the sepax separator were thoroughly inspected to observe internal condition of the mill and separator. During the inspection, mill and separator internal condition found in good condition and no coating on internals & material accumulation observed. However in Chamber I at a distance of 2 to 4 meters, around 5 broken/damaged liner plates were observed.

- Empty heights of both the chambers measured to calculate the ball charge, % filling and estimate the power consumption at mill shaft. Based on the empty height measurements, charging of grinding media in Chambers I & II calculated as equivalent to degree of filling of 22% & 21% respectively. The estimated power consumption at mill shaft with this charge as 4110 kW.

- Process measurements were conducted. The details and observations on process measurements are given below:

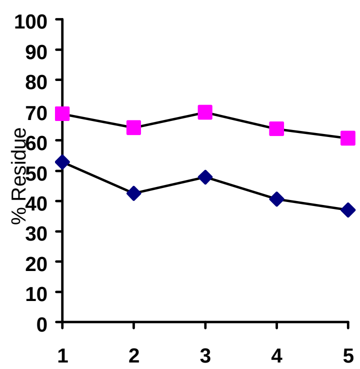
Mill vent flow	:	972 m^3/min
Separation air at separator outlet	:	5599 m^3/min
Separator vent air at bag filter outlet	:	210 m^3/min

  - The velocity of gases calculated through mill is 1.29 m/sec. This velocity is sufficient for OPC33 grade grinding.
  - The separation air at separator measured as 1.22 Kg material/m^3 at circulating load of 2.52, which indicates the availability of more classifying air in the system.
  - Due to high separation air, to obtain required blaine of the product, separator being operated at higher speed, which is contributing in higher circulating load and high bypass (High fines quantity in separator reject).
  - The low vent volume through the bag filter is mainly due to very high pressure drop across the bag filter (180-200 mmWG). The actual flow measured is only 4% of the total separator air.

- Mill was crash stopped for collection of chamber samples to evaluate size reduction progress in side the mill. The results of sieve analysis are depicted as below:

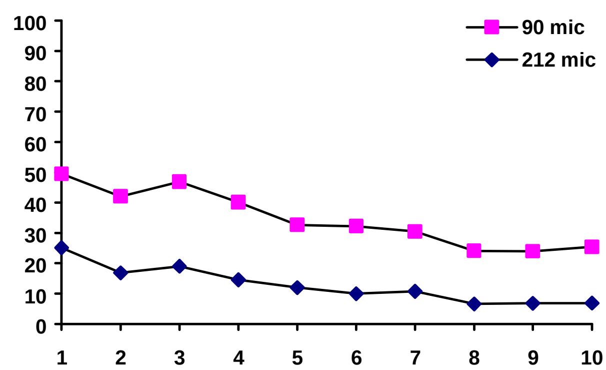
Size Reduction Progress

I Chamber



- More finer material at the mill inlet
- Size reduction rate for 90 microns is poor
- No significant grinding in the first 3 meters of the chamber
- Coarser particles size reduction is satisfactory

II Chamber



- No grinding taking place at the last two meters of the chamber
- Presence of the coarser particles at the inlet of the chamber
- Satisfactory size reduction rate on 90 microns sieve
- Coarse particle size reduction is not good

- To assess he performance of the separator, circuit samples were collected and the results and observations on the same are given below:

Residue of mill output on 90µ	:	12.80 %
Residue of separator reject on 90µ	:	32.20 %
Residue of separator product on 90µ	:	2.80 %

  - Fines are coming more in the separator reject
  - Higher Separation air at the separator outlet
  - Circulating factor works out to 1.52 on 90µ residue
  - Due to high air loading to the separator, separator being operated at higher rotor speeds
  - Separator vent volume is low due to excessive pressure drop of 200 mmWG across the bag filter
  - The efficiency of the separator is 73% based on the residue on the 90µ
  - Lower residues and higher blaines of separator reject material

- High variations in the mill feed size on +25 mm sieve observed, which shall result in variation in the mill performance.
- Observations on the Control philosophy of the mills are:
  - The mill is being operated in manual mode most of the time
  - For control of fineness, only separator speed is being adjusted and no action on air flow through the separator
  - Water spray is being done into the 2nd Chamber of the mill even though the cement temperature is only 97°C
- During the study and from the plant record data it was observed that idle running of auxiliary mainly separator fan and bag filter was on higher side and greatly contributing in higher specific power consumption of mill section.

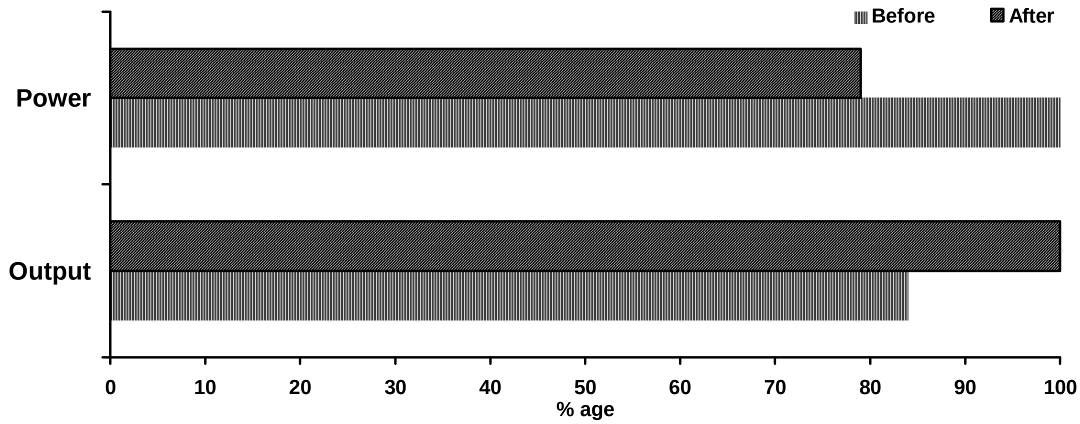
3.4 Recommendations

- ♦ Maintain uniform/consistent quality of feed as far as possible to mill by optimising the kiln and cooler operations
- ♦ Reduce the quantity of grinding media of 100mm size by 50% and increase the quantity of 80mm and 70 mm grinding media to improve the efficiency of Chamber I
- ♦ Broken/damage liners to be replaced in Chamber I
- ♦ Circulating load to be maintained around 1.00 by optimisation of the separator parameters i.e. reduction in higher air flow and speed of rotor
- ♦ Separation air at separator outlet to be maintained around 1.5 Kg/m^3
- ♦ Improve separator vent volume through the separator bag filter to about 10% of the total separation air by regular monitoring of pressure drop across the bag filter
- ♦ Cleaning of mill diaphragm to be done at regular intervals
- ♦ Operation of the mill in auto mode as far as possible
- ♦ Avoiding of water spray in the Chamber II when cement temperature is below $105^{O}C$
- ♦ Total feed (Fresh + Reject) to be kept constant

3.5 Results

After implementing the recommendations, an improvement in the performance of mill is observed. The output of the mill has increased to 160 t/h with an specific power consumption of 33.60 Kwh/ t OPC at blaine of 2700 cm^2/gm.

The percentage benefits for the above two parameters are depicted below:



4. MILL LOAD CONTROL- LATEST CONCEPT FOR CEMENT MILL OPTIMISATION

4.1 Concept

M/s Holderbank Engineering, Canada has developed a control strategy for ball mills which can maintain a mill production near optimum, with little operator intervention. The main principle of the concept is that maximum production is obtained from a ball mill when the mill motor power is at a maximum and consequently the specific energy consumption is at minimum. The maximum power point is dependent upon the feed material characteristics, mill liner conditions, grinding media charge and product size requirements.

4.2 Working principle

Experience over the years has shown that ball mill grinding circuit has a narrow load range in which optimum performance exists. Deviating from the optimum load range by under or overloading the grinding circuit causes the grinding power to change.

Mill Load Control strategy uses the traditional signals such as mill sound and recirculating bucket elevator power as well as the mill power to determine the mill load level. This load level is defined as the total of the grinding charge and material in the mill. The control strategy attempts to keep this load level as constant as possible. This load level is compared against the set point derived from the mill motor power. The concept of the mill load level helps the operator to visualise what is occurring in the mill.

The mill load level is calculated by using factors and comparing various signals, including the total fresh feed, the recirculating flow rate, the mill sound, and the discharge bucket elevator power as well as the mill motor power. The factors that are taken into account for determination of the mill load level are shown in **Annexure I**.

4.3 Control philosophy

The heart of the strategy consists of a standard PID algorithm for control, therefore it is not rule based or considered an expert system. Because of this, there is no requirement for special hardware or additional computers. The control strategy is integrated into the plant's existing control system.

The strategy is configured in the same control hardware as the rest of the mill circuit controls. Although it does require some complex calculations, the strategy is generally compact enough to be integrated into the same controller as the rest of the analog mill control. **Annexure II** depicts the control strategy showing the input signals that are required for the operation of the mill load control. A comparison of the mill load control logic with the conventional logic is given below:

Mill Load Control Logic	Conventional Logic
Uses PID and Algorithms	Uses PID only
Set point is derived	Set point is manual
Mill motor power has control function	Mill motor power has no control function
Correction is automatic	Automatic correction is not possible
Mill load is maintained based on the evaluation of various parameters	Mill control is based on some particular parameters only

4.4 Installations Commissioned

The strategy has been successfully implemented in 33 cement grinding mills and 6 raw grinding mills in a number of cement plants in America and Canada. The feedback received from the plants has shown increases in production and reduction in specific energy consumption. These improvements are usually of the order of 5 to 10% increase in the mill output and 3 to 5% decrease in the specific power consumption.

In addition to the improvements in production and power consumption, consistency in quality and less wear and tear of the grinding balls and liners are experienced by the plants due to stable running of the mills.