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A Study on 500 MW Coal Fired Boiler Unit's Bowl Mill Performance through Coal Sampling and Characterization: CPRI's Experience

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Abstract

Coal-fired thermal power stations presently account for nearly 52 % of the total power generation in India's power generation sector. There is a constant need to monitor the performance of the coal-fired power plant auxiliaries/ components and ensure maintenance of these to optimum levels of operating parameters to achieve the trouble-free generation of quality and consistent electric power output. Coal's mineralogical content and its physical parameters decide the performance of the coal pulverizer in terms of optimum ground coal output and the life of the grinding elements in the coal mills/ pulverizers. The grinding media in the pulverizes are subjected to high erosion rates owing to the presence of abrasive minerals like pyrites, alumino-silicates and hard minerals like α quartz, which are attached to the coal mass as contaminants during mining. A study was undertaken along with the Pulverizers Division of M/s. BHEL for evaluation of Coal Bowl Mill, for guaranteed performance at a 500 MW capacity NTPC thermal power plant. The study was conducted to assess the effective performance of the pulverizers of this 500 MW boiler unit for its maximum capacity of 60.9 t/hr for guaranteed coal condition and assess optimum output in terms of fineness of the crushed coal during continuous loading under the designed operating parameters. The study was also carried out to ensure that the pulverizer grinding efficiency and the effective output of the finely crushed coal were achieved by proper optimization of the mill mechanical auxillaries and their operating parameters.

Keywords: Coal Abrasives, Coal Pulverizers, Grinding Elements, Hardgrove Grindability Index, Iso-Kinetic Coal Sampling, Pyrites

1. Introduction

Coal is the most dominating energy source with abundant coal reserves available throughout the world. It is cheap and transportable over large distances. Pulverised form of coal has made modern steam generating units highly thermally efficient, reliable and safe.

Pulverised form of coal has also made efficient use of low-grade coals. Pulverised coal provides proper coal-air ratio fuel control, flame stability and effective utilisation of carbon. It provides a reduction in cost and flexibility of operation.

Indian coals used for power generation are low-grade high ash coals having a GCV of about 2600 kcal/kg with ash content as high as 45 to 50% with Pyrites of about 1-2% and alpha quartz to an extent of about 8 to 18%.

Bowl Mills are one of the major components of a coal-fired thermal power station. These are used for grinding the raw coal so that the pulverized product at the desired fineness can be fed directly to the furnace and fired for steam generation.

The major function of the Pulverizer is to grind the lumped coal and to the desired fineness and drying of coal. Transportation of the coal powder is carried out by the primary air to the furnace chamber for effective combustion.

There are four major mechanisms that happen during the coal crushing in the mills viz., size reduction in the coal, drying of the coal, transport of the crushed coal and the classification of coal in terms of its fineness[1]. The comminution or size reduction of coal depends upon its bond strength, breaking energy and force required

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for size reduction effectively. The broken size and shape of the coal particle are related to the material's response to applied breakage strength and force. There exists a relationship between the fineness of the crushed coal to that of the bowl mill's capacity. The overall circulation rate of the coal in the mill, its retention time in the mill and the resistance to flow depending on the fineness of the crushed coal.

The mineralogical content and the physical parameters of coal decide the performance of the coal pulverisers in terms of their output and the life of the grinding elements. The grinding media in the pulverisers are subjected to high erosion rates due to the presence of abrasive minerals like pyrites, alumina-silicates and quartz which are attached to the mined coal mass as contaminants during mining[2].

The physical processes occurring inside the mill such as grinding, pneumatic transport, drying, heat transfer, and classification of pulverized coal have a bearing on the life of the pulverizers. The following factors that affect the mill's performance and they are:

1.1 Size of the Coal

Matters since the work done per unit mass of coal increases if the size increases. Too big lumps of coal affect the mill capacity which varies inversely with the size of the coal. Smaller size coal chokes the coal bunkers and feeder pipes which aggravates the increase in moisture content. Storing, transportation, dust hazards, and fire also need to be considered when choosing the size of coal. An optimum size of 25 to 50 mm of coal is preferred for the efficient performance of the pulverizer.

1.2 Coal Grindability Index (GI)

Indicates the degree of ease given coal can be pulverized. Softer coals have a higher index of coals. Coal Grindability Index is itself not an inherent property of coal but only represents the relative grindability of a given test coal with that of a standard coal having a known Grindability Index. The HGI or Hardgrove Grindability Index method is employed to determine the grindability of coal. The HGI method involves placing a 50 g of air-dried sample of -16+30 mesh (+1.18 mm - 600μm) size coal in a miniature vertical spindle ball mill's mortar along with 1-inch steel balls. A weighted upper race is placed on the coal sample and the steel balls and the ball mill is made to rotate for 50 revolutions. The crushed coal samples are then removed and sieved. The quantity of the crushed coal passing through 200 mesh (75 μm) is weighed and the HGI is derived from the empirical equation:

$$\mathbf{HGI = 6.93W + 13}$$

where W is the weight of crushed coal passing through 200 mesh (75 μm). Indian bituminous types of coal have an HGI ranging between 45 to 70. Moisture content and volatile matter in the coal also affect the HGI values.

1.3 Moisture Content

Raw coal produces agglomerates from the pulverized coal and reduces the capacity of the bowl mills. Drying is carried out by injecting hot air into the mills while grinding. The temperature of the air is dependent on the moisture content in the coal and usually varies between 65 to 80°C.

1.4 Pulverized Coal Fineness

The degree of fineness to which the coal needs to be pulverized depends upon many factors. Coals behave differently in the boiler depending upon factors like their swelling nature, and volatile and fixed carbon content. High volatile coals with less fixed carbon require less fine pulverization. High volatile coals require a fineness of about 60% passing through 200 mesh.

For low volatile coals, the fineness passing between 80-85% through 200 mesh is suitable to avoid carbon loss due to improper combustion. Excessive fineness will lead to wastage of mill power since mill output varies inversely with mill fineness. Hence it is recommended that periodic analyses of coal samples and the proper adjustments of the classifiers at the coal mill inlet thereof need to be

Figure 1. 1003 XRP coal bowl mill.

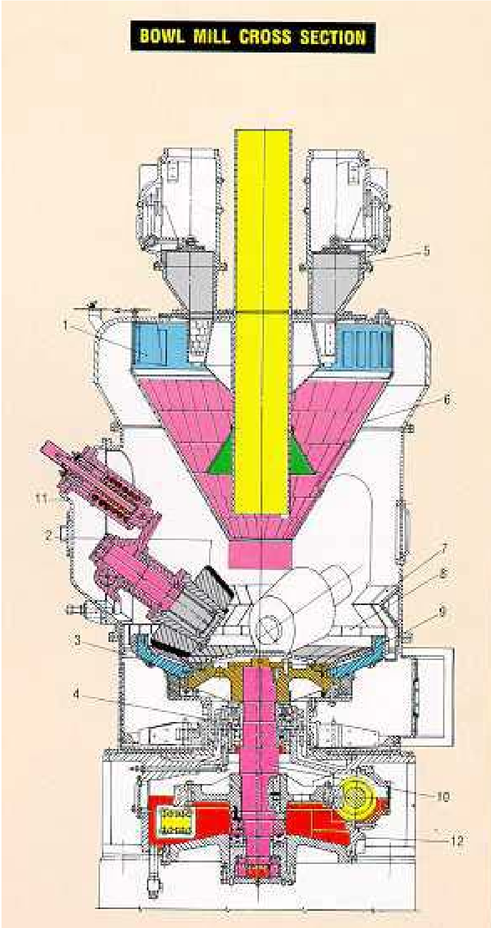

Figure 2. Section of coal bowl mill.

carried out as this will lead to effective mill operation. Standard ASTM Sieves of 200, 100 and 50 mesh size were used for the study.

1.5 Mill Wear and Ash Content in Raw Coal

The coal is abrasive in nature due to the presence of hard materials like pyrites, α quartz etc., Due to the grinding nature and abrasiveness of coal, the mill parts tend to wear depending on the hours of service and wearing property of the metallic parts.

High wear-resistant materials are used in the mill parts to mitigate wear problems and consequent maintenance work thereafter. It is considered that wear increases due to an increase in ash content in the coal. Ash contains Silica (SiO_2) as *α* quartz and Alumina (Al_2O_3) as Corundum which is an abrasive material. The presence of ash also adversely affects the Gross Calorific Value of the coal (heat content) and therefore indirectly the mill output.

2. Field Work

A study was undertaken by CPRI along with the Pulverizers Division of M/s. BHEL for evaluation of coal pulverizer *1003* XRP Bowl Mills shown at Figure 1, for guaranteed performance at a 500 MW capacity NTPC thermal power plant. The cross section of the coal bowl mill is shown in Figure 2.

The study was conducted to assess the effective performance of the pulverizers of this 500 MW boiler unit for its optimum output in terms of the fineness of the crushed coal during continuous loading under the designed operating parameters. The study was also carried out to ensure that the pulverizer grinding efficiency and the effective output of the finely crushed coal were achieved by proper optimization of the mill mechanical auxiliaries and their operating parameters. Guaranteed coal conditions for mill performance parameters are as follows[3]:

Table 1. Guaranteed coal conditions for mill performance evaluation

Coal Moisture %	**20**
Coal HGI	**55**
Mill Outlet Temperarure °C	**80**
Mill Air Flow T/hr.	**102**
Coal Fineness (% passing trough 200 mesh)	**70% passing through 200 mesh and 90% passing through 50 mesh**
Differental Pressure	**300 mmwc**
Coal Output from Mill	**60.9 t/hr**

2.1 Preparation of the Bowl Mill and Accessories

Before the performance study of the bowl mills is undertaken, an initial survey about the condition of the mill and its assembly is ascertained. The mill running hour data pulverized coal fineness report, coal data, grinding roll wear depth, preventive maintenance data etc., from the plant, are collected.

The service checks, overhaul and necessary checks of the operating conditions of certain important components of the mill listed below are undertaken, to ensure the specified/optimum operating conditions are met. This would help to evaluate the actual mill performance vis a vis specified operating conditions.

2.1.1 Servicing of Journal Assembly

The following service checks/overhaul of the journal assembly was done:
- Changing of rolls, oil seals and lubricating oils.
- Setting bearing clearances or replacing bearings.
- Changing trunnion bushings.
- Cleaning and greasing.

2.1.2 Servicing of Spring Assembly

The following service checks were carried out:
- Dismantling and cleaning.
- Resetting springs with hydraulic compression kit.

2.1.3 Servicing of Mill Discharge Valve Assembly

The following service checks were carried out:
- Servicing of air cylinders.
- Repair/replacement of valve body, multiple port outlet body, liner plate, flaps.
- Assembly and testing for proper operation.

2.1.4 Servicing and Checking of Scraper Assembly

The following repairs/ replacement were done:
- Replacing/ repairing scrapper, scrapper guard, scrapper pins, scraper assembly, cover plate, and mill side liner if necessary.
- Checking clearance of scrapper and scrapper guard with cover plate and mill side bottom liners.
- Check for scrapper-free movement.

2.1.5 Overhaul of Classifier and Venturi Assembly

The following overhauling was done:
- Changing all worn-out classifier blades.
- Patch repair of venturi and Ceramic lining.
- Repairing or replacing classifier cone and Ceramic lining.

2.1.6. Servicing and Checking of Mechanical face Seal Assembly

The following service checks were carried out:
- Check the condition of the seal runner, seal assembly, shoulder screws, flexible hoses, Air seal housing oil seals, etc and replace the same if necessary.
- Ensure the required gap between the Air seal housing and seal runner and no gap between Viton seals and seal runner.

2.1.7 Servicing External Lube Oil System (if applicable)

The following service checks were done:
- Check and change if required the following gauges/ switches
  - Temperature gauges/switches
  - Different pressure gauges/switches
- Servicing of Lube oil pump, relief valves, etc.

2.1.8 Servicing Mill-Motor Coupling

The following service checks/overhaul of the mill motor coupling was done:
- Check and ensure proper Greasing
- Alignment of the coupling to be checked and done properly. Refer Erection manual for the procedure and values.
- The Journal assemblies are provided with large diameter grinding rolls (43") in HP 803 instead of normal (37") given for XRP 803 mill.
- Similarly, for higher size Mills, bigger rolls are provided. This improves the life of the rolls and loading on the coal for pulverization.
- Additionally, the Classifier is provided with a Tall Top Separator top for better classification and for removing moisture. This is specially provided when the coal is with high moisture content.

2.2 Procedure for Evaluating Mill Performance

The following procedures were adopted to evaluate the mill's performance:
- Conduct a Hot Traverse test to measure the quantum of hot air flow through the mill and verify the control room air flow quantity meter with measured air flow through the coal duct.
- Calibrate the raw coal feeder before the test.
- Check pulverized fuel fineness and adjust to get the required fineness
- Check raw coal HGI and Total Moisture.

- Load the mill to the maximum possible condition with rated mill outlet temperature and coal fineness.
- Run the mill at this condition for 2 hours (as per ASME PTC 3.5 clause) and record every 15 minutes the Mill outlet temperature, Mill inlet temperature, PA Header Pressure, Mill Differential Pressure, Unit Load, Mill air flow and Coal Flow.

2.3 Coal Sampling Methodology

Initially, raw coal sampling needs to be done once for evaluating Total Moisture and Hardgrove Grindability Index as per ASTM/IS standards. Mill rejects samples are also collected every one hour for analysis. The following steps were carried out to assess the Bowl Mill's performance:

- Pulverized fuel sampling was done by the Iso-Kinetic method of Sampling using Dirty Air Pitot and Multipoint Rotary Probe as per ISO: 9931.
- PF fineness analysis was carried out in the laboratory using standard sieve sets which were calibrated.
- The average values of mill parameters were collected from the Unit Control Room of the thermal power plant at 1-minute intervals during the PG test for two hours as per Log Sheet.
- Mill rejects were collected below the mill through the mill reject exit port, for every one hour during the test duration and were quantified in kg.
- Raw coal samples were collected from each Raw Coal Feeder and the sample lot was prepared using Coning and Quartering Method as per IS: 436 (Part I/Sec1)-1964 (RA 2019).
- The coal samples were analyzed for HGI as per IS:4433-1979 standard and the remaining raw coal samples were taken up for estimating the Total Moisture content on As Received Basis and Proximate Analysis on air dried basis both as per ASTM D 5142-02a Standard.
- Venturi Differential Pressure measurement at the Feeder floor and Hot Primary Air Temperature were measured locally at the Duct and was cross-checked for the air flow value displayed in the Unit Control room, before proceeding for a pulverized coal sample collection from the coal flow ducts.

Initially, the Bowl Mill was fully loaded (around 60.9 TPH) and was adjusted to the maximum possible tonnage to take care of the variation in HGI and Total Moisture (TM). The Classifier setting was done suitably and the open position was kept at 7, which is done normally. The Feeder Calibration was done and ensured before conducting the PG test. Obtaining pulverized coal samples from a direct-fired system is difficult since the sample is collected online from a fuel-carrying duct. A sampling device as stipulated in 'BHEL Testing Procedure and Manual for PG on Bowl Mills', which consists of a small cyclone collector, a sampling jar and a sampling nozzle with a connecting hose is used for collecting the sample. It is essential to ensure that the sample collected is representative one and that all required care is taken during sampling.

The sample should be collected from the straightest possible line and far from bends or offsets as the piping layout will allow, and should be obtained at one point in the pipe at right angles to each other, both points being in the same plane perpendicular to the axis of the fuel line. If possible, the samples should be taken ahead of any distributors, which might be in the system. The sample is obtained by traversing the pipe across its entire diameter, and the rate of movement must be uniform. Samples in both directions must be taken for the same period of time, and also from all the four PF pipes emanating from the mill being tested.

Figure 3. ISO kinetic coal sampling from coal duct.

During the study coal samples from A, B, C, D and E mills were collected from the 500 MW unit and was analysed for various test parameters which are tabulated in Table 2 for determining the performance of the Bowl Mills. The coal test results obtained are tabulated in Table 3 and the same has been used and anlayzed for determining the performance of the bowl mill[3].

3. Coal Test Results and Performance Analysis

Table 2. Test parameters

Mill No.	Coal Flow (t/h)	Air flow (t/h)	Mill current (A)	Unit load (MW)	PA Header pressure mmwc	Bowl DP mmwc	Mill inlet temp (°C)
A	62.4	114.3	126.0	454	832.4	384	275
B	63.1	115.0	97.4	489	827.5	232	314
C	62.7	113.2	111.4	451	829.8	310	311
D	62.9	116.3	106.5	412	828.7	289	304
E	68.8	119.2	118.6	473	835.2	298	317

Table 3. Test results

Mill No.	SIEVE ANALYSIS (%)			TOTAL MOISTURE (%)	HGI
	+50	-100	-200		
A	0.20	93.3	75.1	44.9	70
B	0.32	93.8	75.8	45.3	69
C	0.38	93.2	77.2	48.3	57
D	0.32	93.4	78.2	46.1	60
E	0.26	92.5	74.9	47.2	58

4. Conclusions

From the study, it was found that the coal mill operating parameters such as coal flow, airflow, mill current, bowl mill DP, mill inlet temperature etc., were well within the design parameters. The pulverizer coal samples collected by the Iso-kinetic sampling method and then tested showed values matching the design parameters. This indicates the satisfactory performance of the pulverizer mill at rated capacity even after running the same for the required hours as per the PG Test conditions. Pulverizer mill performance optimization needs to be carried out for its effective operation and successful combustion optimization in the boiler.

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6. References

1. L. Juniper, G. Schumacher. Advances in pulverised fuel technology: Understanding coal comminution, combustion and ash deposition. The Coal Handbook: Towards Cleaner Production: Coal Utilisation; 2013. https://doi.org/10.1533/9781782421177.3.312
2. Rai AK, Pandey M, Baredar P. Pulveriser mill performance analysis and optimisation in super critical thermal power plant using imported coal. International Journal for Research in Engineering Application and Management. 2018; 4(3).
3. M/s. BHEL Testing Procedure and Manual for PG on Bowl Mills.