Pulverizer Plant O&M Aspects

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Contents

- Coal characteristics, fineness, combustion interrelationship
- Mill operational issues
- Constructional features and maintenance
- Performance issues and case studies
Diagram of a coal-fired power plant:

- Coal bunker
- Pulverizing mill
- Fuel and primary air
- Secondary air
- Windbox
- Evaporator
- Superheaters + reheaters
- 700-800°C
- 1300-1400°C
- 1500-1700°C
- Ash hoppers
- Economizer
- 300-400°C
- Rotary air-heater
- 120-150°C
- Induced-draught fan
- Stack
- Forced-draught fan
- Electrostatic precipitator
- 120°C
The Three Ts & One S Practice

<table>
<thead>
<tr>
<th>Technology</th>
<th>Time</th>
<th>Temperature</th>
<th>Turbulence</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoker</td>
<td>large</td>
<td>Medium</td>
<td>Low</td>
<td>Big</td>
</tr>
<tr>
<td>Pulverized</td>
<td>Short</td>
<td>High</td>
<td>Medium</td>
<td>Tiny</td>
</tr>
<tr>
<td>Cyclone</td>
<td>Short+</td>
<td>V High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Fluid Bed</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Size the Coal and Add the Air !!!
Coal – an organic complex polymer
Sequential events

- Devolatilization (Pyrolysis)
  - Heating causes its structure to decompose
  - Weaker chemical bonds break at lower temperatures
  - Stronger ones at higher temperatures
  - Volatile yield can be up to 50% greater than indicated by proximate analysis

SEM of a de-volatilizing coal particle
• Burning of volatile matters
  
  − Homogeneous gas phase reaction around the particle

• Char burning
  
  − Heterogeneous combustion
  
  − Occurs at the char surface and pore surfaces (porosity~0.7; surface area ~100 m²/g)
  
  − Guided through competing effects of heat and mass transfers to the char surface and chemical reaction
Coal Combustion

Coal particle
p-coal, $d=30-70\mu m$

Heating

De-volatilization

$\text{t}_{\text{devolatile}} = 1-5\text{ms}$

$\text{t}_{\text{volatiles}} = 50-100\text{ms}$

$\text{t}_{\text{char}} = 1-2\text{sec}$

Temperature, Turbulence, **Time** and Size
VM, Fineness, Combustion & Residence Time

- Vol. combustion intensity, \( I_v \) is in the range 150-250 kW/m\(^3\).
- FEGT<IDT
- For a desired \( I_v \), one can select \( t_r \) (~ 2 sec)
- The combustion time, \( t_c \) (~ 1 sec) <\( t_r \) by a significant margin.
- Low VM coal; more fineness required
Gravimetric Feeder
Gravimetric Coal feeder
Internals of coal feeder
Classification - As per Speed

Types of Mills

Low Speed
- 17 to 20 Rev/min
  - Tube and ball mill

Medium Speed
- 30 to 100 Rev/min
  - Bowl Mill, Ball and Race mill

High Speed
- 500 to 1000 Rev/min
  - Beater Mill, Impact Mill
# BOWL MILL

<table>
<thead>
<tr>
<th>Model no.</th>
<th>Base capacity (T/Hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>623XRP</td>
<td>18.4</td>
</tr>
<tr>
<td>703XRP</td>
<td>26.4</td>
</tr>
<tr>
<td>763XRP</td>
<td>33.8</td>
</tr>
<tr>
<td>803XRP</td>
<td>36.5</td>
</tr>
<tr>
<td>883XRP</td>
<td>51.1</td>
</tr>
<tr>
<td>903XRP</td>
<td>54.1</td>
</tr>
<tr>
<td>1003XRP</td>
<td>68.1</td>
</tr>
<tr>
<td>1043XRP</td>
<td>72.0</td>
</tr>
</tbody>
</table>

**BASE CAPACITY (T/HR)**
- AT HGI -55
- Total Moisture -10%
- Fineness -70% THRU 200 MESH
Types of pulverisers

- Based on principles of particle size reduction
  - Impact
  - Attrition
  - Crushing
- Pulverisers use one, two or all the three principles.
### Types of pulverisers

<table>
<thead>
<tr>
<th>Speed</th>
<th>Low 10 to 20 rpm</th>
<th>Medium 40 to 70 rpm</th>
<th>High 900 to 1000 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Ball tube mills</td>
<td>Bowl Mill Ball &amp; race Mill</td>
<td>Hammer mill, beater mill or fan mill</td>
</tr>
<tr>
<td>Dominating Principal</td>
<td>Attrition</td>
<td>Crushing</td>
<td>Impact</td>
</tr>
</tbody>
</table>
HORIZONTAL BALL TUBE MILL
A Cross Section View

Tube mill
Medium speed
40 - 70 rpm
Ball & Race Mill

Key Features

1. Raw Material Inlet
2. Product Outlet
3. Adjustable Classifier Blades
4. Oversize Particles Return Chute
5. Hollow Balls
6. Rotating Lower Grinding Ring
7. Primary Air Inlet
8. Loading Cylinders
9. Spider Guides
10. Stationary Upper Grinding Ring
11. Throat Plate
12. Gearbox
13. Reject Box
Nomenclature-Bowl Mills

- 583 XRS / 803 XRP Bowl mills
- 58,80 stands for bowl diameter in inches
- If the number is even then its shallow bowl mill.
- If the number is odd then its deep bowl mill
- 3 - number of rollers three nos.
  - X - frequency of power supply 50 cycles. In USA ‘x’ means 60 cycles.
  - R- Raymond, name of the inventor
  - S- suction type with exhauster after mill
  - P- pressurised type with P.A. Fan before mill.
Factors affecting Mill performance

- Moisture in the coal.
- Coal grindability index.
- Mill inlet and outlet temp.
- Mill differential Pr. (DP)
- Mill loading.
- Air Flow in the Mill.
- Mill Motor current.
- Coal Mill fineness

- Grindability
- Moisture content
- Fineness
- Pri air quantity & temp
Effect of Grindability

- The grind ability of the coal is an empirical index
- It is not an inherent property of coal
- Relative ease of grinding as compared with standard coal
- It is determined in laboratory using 50 g of air dried sample of properly sized coal in a miniature pulveriser which is set to rotate exactly 60 revolutions grinding the coal sample.
- The hard grove Gindability index is calculated
  - G.I. (hardgrove) = 13 + 6.93W
  - Where W = weight of dust passing through 200 mesh sieve.
Effect of Grindability

- Higher the HGI more is the capacity
- Normally mill capacity is indicated at 50/55 HGI.
- Actual Mill capacity varies with HGI
Effect of Grindability

Maximum mill capacity vs HGI at coal moisture of 12 %

Output (TPH)

Output at coal fineness of 70 % passing through 200 Mesh
Output at coal fineness of 75 % passing through 200 mesh
Moisture in Coal

- Moisture: Inherent and surface
- Inherent moisture locked up within the structure
- Inherent moisture is constant for a particular seam
- Surface moisture varies
- Coal must be dried to remove the surface moisture totally before grinding
- Beside drying primary air also
  - Create circulation
  - Transport coal
  - Provide initial oxygen for combustion
- PA quantity is 15 to 28% of total air
Moisture in Coal

**Graphs:**

- **Grinding Capacity Limit**
- **Capacity with average mill outlet temperature**

**Figure 2(a) & 2(b):** Variation in mill output with total moisture content in raw coals.

- **a) Vertical Spindle Mills**
- **b) Tube-Ball Type horizontal Mills**
Effect of Moisture

Maximum mill Capacity vs coal moisture at coal HGI 100-110 and PF Fineness of 70% passing through 200 Mesh
The temperature of pulverised coal and air mixture at pulveriser outlet should be maintained at least 15 °C Above the dew point of air at pulveriser pressure to avoid condensation and consequent plugging of the coal pipes.

The pulveriser mill outlet temperature should be maintained above 65 °C.

The higher limits are 90 °C For high volatile (above 24%) coals and 110 °C for low volatile coals (below 20% VM).
Effect of Fineness

- Fineness of pulverised coal
- More the fineness less is the capacity
- 70% through 200 mesh
- Number of opening per linear inch.
- 50 mesh sieve will have 2500 openings per square inch
- Volatile content below 16% would required higher degree of fineness i.e. 75 to 80% through 200 mesh sieve, whereas the higher volatile coals (above 24%) will ignite and burn with ease with lower fineness of 60% through 200 mesh sieve.
Effect of Fineness

Fig. 4(a) Variation in mill output with fineness of mill product

Fig. 4(b) Variation in power input and mill maintenance with fineness of mill product
Effect of fineness

Maximum Mill capacity vs PF fineness at 12% Raw coal moisture and at Coal HGI 100-110

Mill output at raw coal moisture and at Coal HGI 100-110
## Fineness Requirement

### Sizing Range of Coals for PC Firing

<table>
<thead>
<tr>
<th>Coal rank</th>
<th>Passing 200 mesh, wt %</th>
<th>Retained on 50 mesh, wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subbituminous C coal and lignite</td>
<td>60-70</td>
<td>2.0</td>
</tr>
<tr>
<td>High-volatile bituminous C, subbituminous A, B</td>
<td>65-72</td>
<td>2.0</td>
</tr>
<tr>
<td>Low- and medium-volatile bituminous C, high-volatile bituminous A and B</td>
<td>70-75</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Roller Setting

1/4" Clearance - Parallel from bottom to top of roll

BULL RING

1/4"

1/4"
Throat Velocity

Velocity must be 7000 FPM to maintain coal particles in suspension and eliminate coal dribble.

Velocity @ throat – 7,000 to 7,500 FPM

Minimal (¼") required here

Rotating throat with angled outered rim to direct flow toward pulverizer &

Roll

Bull ring

Air flow
to overcome the ingress rate of most applications. The high-viscosity
Mill Gear Box
Mechanical face Seal

- SEAL RUNNER
- AIRSEAL HOUSING
- SEAL (BRONZE)
- MILL BOTTOM COVER
- SUPPLY SEAL AIR HOSE (4 NOS)
- EXHAUST AIR HOSE (2 NOS)
- DUST GUARD
- SHOULDER SCREW (2 NOS)
- AIR SEAL
- OIL SEALS
- UPPER BEARING HOUSING COV.
Various modifications

- Split type seals in journal and vertical Shaft
- Spring loaded mechanical face seal
- Ceramic tiles at separator body
- Tall separator top
Tall Separator Top
Tall Separator Top

Annexure - A

SEPARATOR TOP (TALL TYPE)
Split type seal
Effect Of Mill Internals On Mill Fineness

- Classifier blades opening
- Holes in classifier blades
- Holes in innercone
- Improper gap between inverted cone and inner cone
- Spring tension
- Clearance between grinding roll & brs
- Wear out of grinding elements
Factors Affecting Mill Performance

- HGI
- Fineness
- Moisture
- Size of raw coal
- Mill wear (YGP)
- Maintenance practices
Coal particle size distribution

- If 1-2% is +50 in BS mesh sieve (300 μm), most of this coarse coal will not burn and end up in C in BA
  - It also frequently causes slagging around the burners
- If -200 mesh (75 μm) fineness is poor, results in high C in FA
- If the coal is not properly ground, the distribution to the burners may not be even
  - Resulting in air-fuel imbalances at one or more burners
Fuel line balance

- Mill discharge pipes offer different resistances to the flows due to unequal lengths and different geometry/layouts.

- Fixed orifices are put in shorter pipes to balance velocities, dirty air / PF flows.
  - The sizes of the orifices are normally specified by equip. supplier
  - Variable/adjustable orifices

- Dirty air flow distribution should be within +/- 5%

- Coal distribution within +/- 10% of the mean value
Interrelationship of parameters

- Each line can rotate about the pivot point
- The arrow head can move laterally along the line it touches
- The area swept by the arrow head line increases or decreases depending upon the direction of swing
- The parameters represented by the area increase or decrease as the area changes
Combustible in Ash Loss

- Measure of effectiveness of Combustion process and Mill performance

- Loss in kJ/kg of fuel: \( \frac{cA}{100} \times 33820 \)

- \( c \) = % of carbon in ash

- \( A \) = Mass of ash kg/kg of fuel

- Carbon burnt to \( \text{CO}_2 \) = 33820 kJ/kg (8077 kcal/kg)

- Compute Boiler efficiency loss % due to \( c \) in Ash
The Diagnostic Tests

- Representative & accurate performance data
- RCA, Identify reasons for inefficiency
- Verify online FB

- **Dirty Airflow Tests**
- **Iso-kinetic Coal Sampling**
- **PA Flow Calibration**
- **Clean Airflow Tests**
  - HVS
  - Furnace Exit HVT
  - Air In-Leakage survey
  - Insulation survey
  - Furnace temperature survey
- **Boiler Efficiency Tests**
- **AH Performance Tests**
  - **Boiler Tuning & Optimization**
    - Turbine Cycle Heat Rate Test
    - Turbine Cylinder Efficiency Test
    - Condenser Performance Test
    - Condenser Air in-leak Test
    - Heater Performance Test
Factors Affecting Mill Performance

- HGI
- Fineness
- Moisture
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- Maintenance practices
Pulverizer Capacity vs. Moisture in Coal

- Design Coal: HGI = 50, Total Moisture in Coal = 12 wt%
- Worst Coal: HGI = 47, Total Moisture in Coal = 15 wt%
- Best Coal: HGI = 52, Total Moisture in Coal = 11 wt%

Moisture Content of Coal (%)

- Pulverizer Capacity (tp/hr)
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- Coal distribution within +/- 10% of the mean value
Clean Air Flow Test

- Clean Air flowing through the fuel lines at normal operating temp and pres.
- Indicative of the transport energy
- Clean air vel. should be within +/- 2% of the mean.
Dirty Air Flow Test

- PF air mix flowing thro fuel lines with mill in service
- To determine coal & air flow in each line
- Dirty air vel. should be within +/- 5% of the mean
Sampling grids
ASME PTC 4.2

FIG. 7 SAMPLING DIRECT-FIRED PULVERIZED COAL-SAMPLING STATIONS
DIMENSIONS ARE "PERCENT OF PIPE DIA."

5 ZONES
10" & 11" PIPE

8 ZONES
12" & LARGER
## Dirty Pitot Survey - Summary Data (Mill X)

<table>
<thead>
<tr>
<th>Description</th>
<th>Corner</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Mean</th>
<th>Desired</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity m/s</td>
<td></td>
<td>24.3</td>
<td>22.9</td>
<td>16.0</td>
<td>17.4</td>
<td>20.2</td>
<td>&gt; 18 m/sec</td>
</tr>
<tr>
<td>Air Flow T/hr</td>
<td></td>
<td>13.1</td>
<td>12.4</td>
<td>8.7</td>
<td>9.4</td>
<td>10.9</td>
<td>----</td>
</tr>
<tr>
<td>Dev. From Mean %</td>
<td></td>
<td>20.2</td>
<td>13.8</td>
<td>-20.2</td>
<td>-13.8</td>
<td>---</td>
<td>&lt; +/- 5%</td>
</tr>
<tr>
<td>Mill Out Temp ºC</td>
<td></td>
<td>56.0</td>
<td>55.0</td>
<td>53.0</td>
<td>55.0</td>
<td>54.8</td>
<td>~ 85ºC</td>
</tr>
<tr>
<td>Coal Flow T/hr</td>
<td></td>
<td>7.9</td>
<td>5.8</td>
<td>5.6</td>
<td>6.9</td>
<td>6.6</td>
<td>&lt; +/- 10%</td>
</tr>
<tr>
<td>A/F Ratio</td>
<td></td>
<td>1.7</td>
<td>2.1</td>
<td>1.0</td>
<td>1.4</td>
<td>1.6</td>
<td>1.8 to 2.5</td>
</tr>
</tbody>
</table>

- Operating PA flow is lower by almost 4 - 5 T/h than design
- Mill Outlet temperature is low in all the pipes.
- Low mill outlet temperature coupled with low PA flow could be the reason for the choking observed in Pipes 3 & 4.
Iso-kinetic PF sampling

The velocity of dirty air entering the collection nozzle is equal to the velocity of the flow in the fuel line.

More fines are drawn to the sampler. Allow fine particles to escape.
Variation of coal flows in the four corners in Unit 2

Sample Weight (grams)

- Mill A
- Mill C
- Mill D
- Mill E
- Mill F
- Average

Corner 1  Corner 2  Corner 3  Corner 4
Case studies

- Mill outlet temperature measurement
  - Cold Junction Temp. Compensation Error
  - Temp. monitoring in each pipe

- PF sampling point and sampling method
Case studies

- Leakage in central feed pipe
- Poor fineness in particular line
- Holes in classifier vanes
- Poor fineness
High Unburnt in Fly Ash

Fineness or Air distribution problem?

PLACE 20 GRAMS OF ASH ON STACKED 200 MEASH AND PAN AND SHAKE FOR 20 MINUTES.
DETERMINE UNBURNED OF RESIDUE ON 200 MESH SCREEN AND IN PAN
Higher Unburnt in the pan indicates Air distribution problems while higher Unburnt in the sieve would indicate milling system problems.

In one case 53% of the ash retained on a 200 sieve was coarse & high in carbon (8%), while the -200 was soft, fluffy and had less unburnts (1%). This is indicative of poor fineness & problems in milling system.
Unburnt Carbon Loss (Controllable)

- $C_{\text{unburnt}}$ is a measure of effectiveness of comb. process
- $C_{\text{unburnt}}$ includes the unburned constituents in FA and BA
- +50 PF fineness fractions to be < 1%
- Focus to be on FA due to uncertainty in repeatability and representativeness

FA sampling (HVS)

![Diagram of FA sampling setup](image)
Factors - Unburnt C Loss

- Type of mills and firing system
- Furnace size
- PF fineness (Pulverizer problems)
- Coal FC/VM ratio, coal reactivity
- Insufficient excess air in combustion zone
- Air damper / register settings
- Burners design / condition
- Burner balance / worn orifices
- Primary Air Flow / Pressure
Thanks

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