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# Erosion Failure Analysis of CFBC Boiler

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**Abstract**
This work is concerned about erosion failure analysis of CFBC boiler, in which gas–solid two-phase mixtures flowing upwards through the fast beds. We know that boilers are used for steam generators in power plants as well as in process industries. Failure of tube leads is huge loss in terms of production, so in this paper we analyze main causes of erosion in CFBC boiler. Erosion mainly caused due to improper design of boiler, improper erection, Misoperation, and due to poor maintenance. Using CFD we can predict fluid flows inside the furnace.

**Keywords:** Fluidized bed combustion, Erosion, CFD

## 1. Introduction

### 1.1 Erosion

Erosion is a process in which material is removed from the surface layers of an object impacted by a stream of abrasive particles. Erosion is localized in a small volume of the target material that is eventually removed. The magnitude of the wear is quantified by the volume or mass of the material that is removed by the action of the impacting particles. The following process and materials parameters are considered for predicting erosion rate in the boiler components [1, 2].

- Ash particle velocity.
- Ash particle impingement angle.
- Mass fraction of silica contained in the ash sample.
- Average density of ash particle.
- Density of the steel component.
- Yield stress of the steel component and
- Temperature of the steel component.

### 1.2 Main causes of erosion

Erosion is associated with solid fuel fired boilers. In advanced stages of erosion, the components get perforated, and may fail once they lose their structural integrity. Such erosion, together with the processes of blocking, fouling and corrosion, shortens the service-life of boiler components. Once this happens, the power station unit has to be shut down in order to replace the damaged components. The resulting penalty is not only the cost of replacing the components but also the cost of stoppage of power production. It is desirable, therefore, to be able to predict the rate of erosion of the coal-fired boiler components in order to plan systematically for the maintenance or replacement of these components and avoid forced outages.

- Causes attributed to design
- Causes attributed to erection
- Causes attributed to operation
- Causes attributed to maintenance.

## 2. CFBC Boiler

In these fluidized bed principal the particles are suspended in a stream of upwardly flowing air which enters from the bottom of the furnace through air distribution nozzles. High velocity air 4-6 m/s is used in these for fluidization of bed. Hot primary air from PA fan is used for this. The balance of combustion air is admitted above the bottom of furnace as secondary air obtained from SA fan. Fluidized bed is extended throughout the furnace. So, some solid bed material along with some Uncombusted fine fuel particle and ash is escaped from bed or carried over and passed with flue gas. These solid particles are then collected by a solid separator (Cyclone separator). In Cyclone the heavier particles are separate from the gas and falls to the hopper of the cyclone and circulated back to the furnace through Loop seal.

It consists of CFBC boiler of 88kg/cm2 operating pressure and 510 $^0$C superheated steam temperatures. Steam from the boiler used to drive double extraction turbine for power generation as well as paper production. The boiler is a new kind mixed fuel boiler with high efficiency and low pollution; it adopts circulating fluidized bed combustion technology with wide range of many kinds of fuel, such as bituminous coal, anthracite, lignite and others with lower calorific value. Its combustion efficiency is as high as 82-85%, especially it can burn high sulfur-bearing fuel. By feeding limestone into the boiler, it can obviously reduce the discharge of sulfur dioxide and NOx, and reduce corrosion of sulfur on devices and pollution of flue gas. Ash residue is active enough to be used as aggregate of materials such as cement. The boiler is a natural circulating water-tube boiler and adopts circulating combustion system formed by vortex cyclone separator. Its furnace is of membrane wall structure; its separator is of high-temperature adiabatic type. The super heater system is composed of screen, high and low temperature ones, between which two-grade vertical spray desuperheater is arranged. At the back-end surfaces, two grades of economizer, primary and secondary air preheaters are arranged.

### 3.1 Problem definition

It consists of CFBC boiler of 88kg/cm2 operating pressure and 510 $^0$C superheated steam temperatures. Boiler Commissioned in 2007 and it is mainly designed for Indian coal. After 2 years of safe operation erosion found in Water wall tube at kick off zone as shown in figure. And from these frequently tube failure occurs due to erosion. So in this context we determine root causes of erosion to avoid tube leakages. For these we analyze various coals used in past days also Caculate flue gas velocities and temperature counters along the furnace using FLUENT.

**Fig 1:** Shows erosion found in kick off zone

## 4. Coal analysis

**Table 1:** Ultimate analysis of coal

| Carbon (C) | % | 30.09 | 48.49 |
|---|---|---|---|
| Hydrogen (H) | % | 3.9 | 0.88 |
| Sulphur (S) | % | 2.55 | 0.6 |
| Oxygen (O) | % | 6.58 | 5.88 |
| Moisture (M) | % | 40 | 12 |
| Ash | % | 16.88 | 32.15 |
| GCV | (Kcal/Kg) | 3850 | 3520 |

### 4.1 Nature of Indian coal

As per ultimate analysis of Indian coal it contains high ash. So, the ash input to furnace is high. Indian coals have high amount of ash and stones as compared to lignite this calls for frequent bed draining in order to control the stones. Usually +3 mm particles are more and they fail to burn completely as the oxygen cannot diffuse in to the coal particle. Stones are harder in nature and cause more erosion. The loop seal sealing is easily achieved in Indian coal due to high ash generation. The air flow required at loop seal is more in order to have higher transfer rate to main furnace. The ash has to be drained from loop seal also in case the fly ash is very high. Stones can cause high erosion rate.

### 4.2 Nature of Lignite

Lignite does have high iron. It has alkalis as well, which brings down the ash fusion temperature. Bed temperature has to be less than 874 deg C. Otherwise fusion and deposition on furnace refractory will be experienced Lignite cause fouling of final SH, secondary SH and economizer. Lignite poses flow problems at bunker. Lignite is known to slag due to its iron content. Fused ash causes high erosion rates. The ash fusion temperature of lignite is low in general.

## 5. CFD Analysis

Erosion is mainly observed in furnace kickoff zone so lower furnace is considered for analysis. We know that CFD is a research tool used now a days to predict the fluid flow in boiler. In this case study we have to calculate velocity, Static pressure and Temperature distribution of flue gas along furnace using FLUENT software. And meshing done with the help of GAMBIT, After analysis we have to compare Velocity, Pressure and Temperature distribution along the furnace for two types of coal used i.e. Lignite and Indian coal. For this two mixed flow model is used. The grids are selected for all the meshes for doing CFD analysis. As the furnace for which analysis is carried out, quadrate type mesh is selected. This specifies that the mesh is composed primarily of quadrate mesh elements. The qualities of the created mesh are checked.

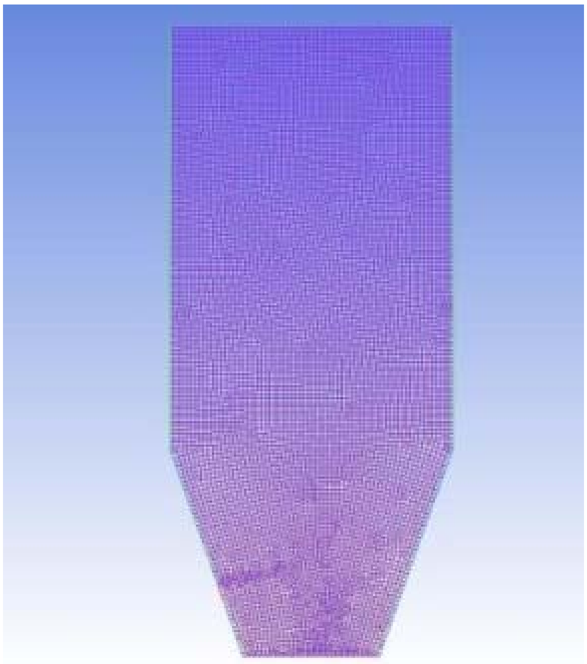

**Fig 2:** Meshing

### 5.1 Analysis for Indian coal

**Table 2:** Boundry conditions for Indian coal

| Sr. no | Parameter | Value |
|---|---|---|
| 1 | Primary air velocity | 5 m/s |
| 2 | Secondaryair velocity | 2 m/s |
| 3 | Mass flow rate | 5 kg/s |
| 4 | Coal particle size | 8- 10 mm |

When we fire Indian coal, theoretically the volume of flue gas generation in lower furnace is 351180 $m^3$/hr and for Lignite it is 464040 $m^3$/hr. Flue gas generated in lignite is around 25% more than Indian coal also As per the fuel analysis of lignite, the sulfur in fuel is more than 1%. LC cartable Refractory would be subject to depletion of binder cements – CaO in reducing atmosphere with presence of sulfur. Due to refractory failure flue gas path gets disturbed and it also major cause of erosion.

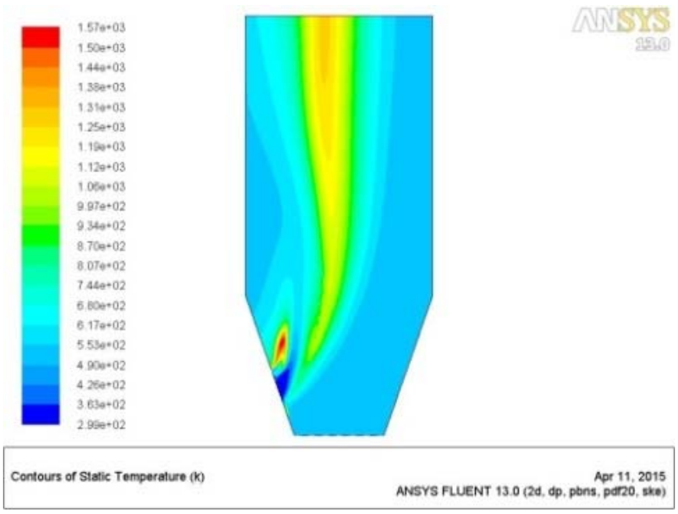


**Fig 3:** counters of Temperature (K)

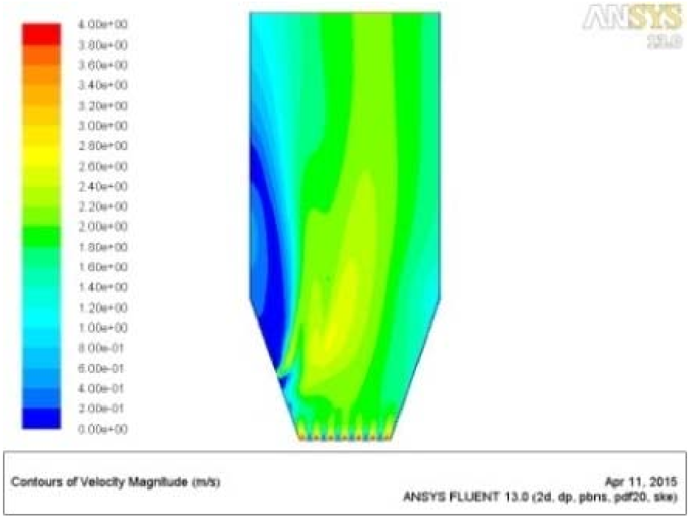


**Fig 4:** counters of Velocity Magnitude (m/s)

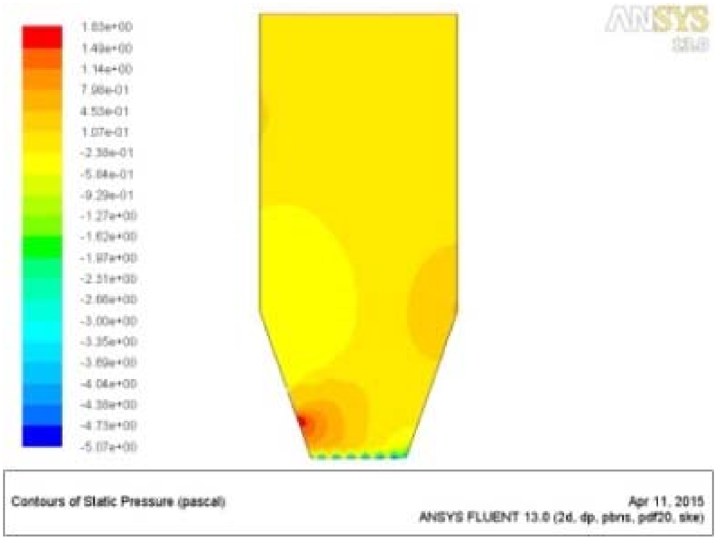


**Fig 5:** counters of Pressure (Pa)

### 5.2 Analysis of lignite coal

**Table 3:** Boundry conditions for Indian coal

| Sr. no | Parameter | Value |
|---|---|---|
| 1 | Primary air velocity | 5 m/s |
| 2 | Secondaryair velocity | 2 m/s |
| 3 | Mass flow rate | 4 kg/s |
| 4 | Coal particle size | 8- 10 mm |

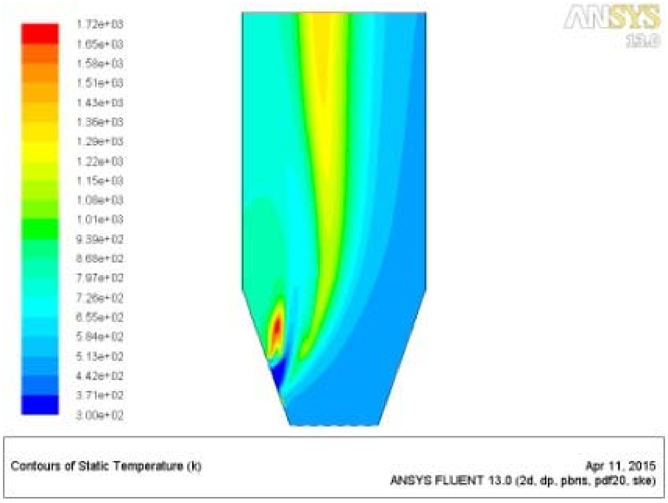


**Fig 6:** counters of Temperature (K)

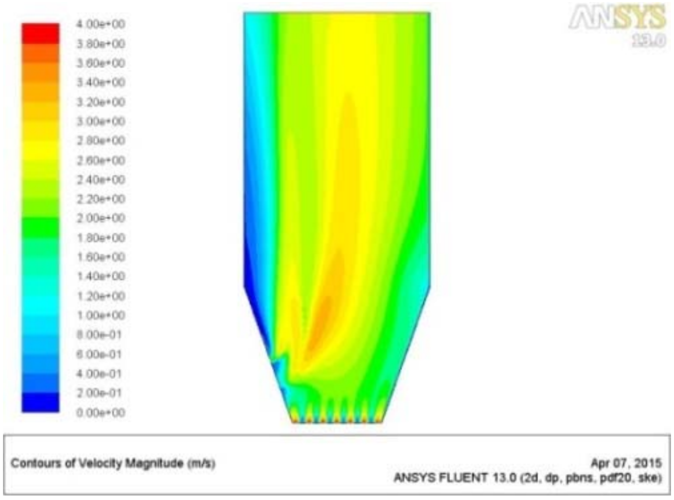


**Fig 7:** counters of Velocity Magnitude (m/s)

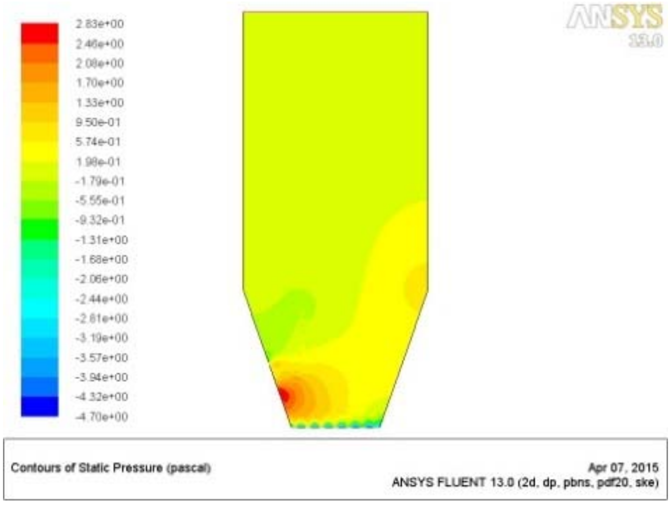


**Fig 8:** counters of Pressure (Pa)

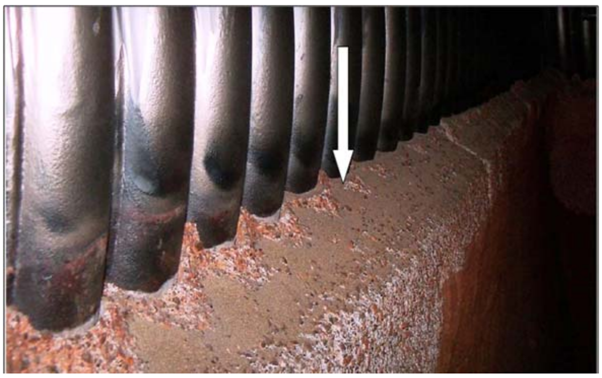

**Fig 9:** Shows excess refractory at kick off zone

**Fig 10:** Shows Butt joints of fin are not ground flushed

## 6. Results and Discussions

The no uniform bed temperatures along the furnace height indicate the inadequate upper bed Inventory. When the inventory is less, the gases do not flow in equal velocity at the entire cross section. It can cause gas flow one sided and can cause dust to fall back on other side. This is called internal Circulation within the furnace. No uniform bed temperatures are in the indications for uniform wear out of the tubes at kick off zone. If a loop seal is not having a sufficient material at the down leg side, the gas flow partly takes place through the loop seal the loop seal temperature will be close to furnace bottom temperature. The material transfer rate is a function of the air flow to the riser section. High ash coals need more air. Low ash coals need less air. Once the loop seal is not proper, furnace inventory is reduced and the bed temperature increases. The situation can happen due to failure of air nozzles loop seal. There are many air nozzle failures seen in the bed.

The causes of localized erosion can be categorized seeing the failures in many installations. In CFBC boiler, the bed ash slips back to bed because, the operating regime is fast fluidization and not pneumatic transport.

- When the panel tubes have a butt joint the joints are to be ground flush. If not flushed the tubes erode due to diversion of the flowing material towards the fin to tube area
- When the fin to fin joint is not flushed ground, the bed material gets diverted towards the tube.

- When the boiler tube dia is higher, the bed ash flows more towards to the fin to tube valley area.
- When the tubes are out of verticality in water wall plane itself, it erodes in one sided manner.
- When the tubes are projected towards to the furnace, the tubes erode on both sides of the fin -tube valley.
- Localized large weld beads due to manual welding process cause diversion of bed ash towards the fin-tube valley area and cause erosion. Fin to fin longitudinal weld bead at field joints cause diversion of bed material towards to the tube to fin valley area.
- Short kick off bends are seen to erode the tubes faster. Long distance between kick off bends are better.
- The kick off zone refractory shape is important. Extra projections cause fast erosion of the tubes.
- Hard refractory is good for protecting the tubes. But when the shape is not properly maintained by templates / shuttering, this can cause faster erosion.
- Corner tubes erode due to preferential downward flow of particles along the corner.
- Less upper furnace inventory can cause high rate of attrition. It is this factor that leads to high erosion of furnace tubes.

## 7. Conclusion

In this work, we study about case study of CFBC boiler whose tube failure frequently due to erosion. We find out its causes, as we know Lignite contains 2.55% sulfur it breaks bond between refractory and it breaks so, erosion is mainly found due to refractory failure. When we fire lignite internal circulation within furnace so back flow occurs. And furnace bed temperature not maintained it causes uniform erosion pattern at kick off zone. There are many more solutions available to avoid erosion; anti abrasive coating is one of them. Also in this case it is required to remove excess refractory from kick off zone as shown in fig.9 and at time of erection of panel butt joints of fin are not properly ground flushed shown in fig 10, due to these flow of material gets diverted and tube eroded.

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