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Investigations on Combustion of Coal by Static Pressure and Volume Fraction of Ash In CFBC Boiler Using CFD

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ABSTRACT

Objective of this study is to develop a two-dimensional Circulating Fluidized Bed Combustion (CFBC) Boiler with cyclone solid separator using ANSYS Fluent Computational Fluid Dynamics (CFD). The numerical simulation model presented in this study is aimed at combustion of lignite coal in boiler. The simulations were done using different approaches for how the flow is driven through the CFB system. For agglomeration phenomenon contours studied static pressure and volume fraction of ash. This study is more concerned about finding the location of formation of ash agglomeration and pressure of these areas. CFD modeling is used to find out the location the ash agglomeration phenomenon in the Circulating fluidized bed combustion boiler.

Keywords : Ash Agglomeration, CFD, Fluent, CFBC boiler, Lignite coal, Pressure, Volume fraction

I. INTRODUCTION

Availability wise Coal is the major energy source in India, Lignite is an alternate source of fuel for power generation. In India the total lignite potential is 4177 million tonnes. The varieties found in India (Gujarat & Rajasthan region) have moderate to high sulphur content. It has become economically necessary to use this lignite for power generation [1]. Considering the high ash and high reactivity of Indian coals fluidized bed gasification technology pretend to be up-and-coming in Indian scenario [2]. Due to its advantages like, high combustion efficiency, fewer feed points, wide variety of solid fuel, good turndown, lower pollutant emissions, load capability and smaller combustor cross section smaller Circulating Fluidized Bed Combustion has been given more attention in the last decades [3]. In CFBC boiler part of furnace is smaller and is often tapered in cross section. This geometry of furnace helps to maintain good fluidization, even with excluded particles. Above the secondary air entry furnace is regular in cross section and larger than the lower part. The gas solid separator means cyclone and the non-mechanical valve for solid recycle are located outside the furnace [4]. CFBC boiler consistently deteriorated from a major operational inconvenience caused by the ash agglomeration, which is very much detrimental and often undergo to the close down of the plant. Several researchers observed ash agglomeration related issue in their studies with using different feed coal [2]. Granting all this the main reason that caused the severe ash sintering characteristics have been investigated widely, the broad perceptive and prediction of the particle collision and sticking activity, and the importance of the respective ash agglomeration mechanism on the ash deposition formation or growth is still inadequate [5]. Ash agglomeration is interrelated with fusion and phase transition of the ash particles during combustion, come up when particle temperatures are high enough to invoke partial melting [6].

II. LITERATURE REVIEW

Ash agglomeration is provoked by heat up of various elements like alkali metals (Na and K), alkali earth metals (Mg and Ca), Sulphur and chlorine. These alkali compounds play a deprecative role in bed ash agglomeration because some of the compounds have low melting points. C. Tangsathitkulchai et al. [7] used laboratory techniques for ash sintering predictions. To determine the sintering behavior of coal ashes Barnhart and Williams [8] used ash pallet compressive strength measurement. C. Tangsathitkulchai et al. [9] resolved that glass material in the as received fly ashes was the element that sum up most to the formation of hard deposits. Brown et al. [10] found that the interaction between the viscid ashes with other ash or bed material caused ash agglomeration. Manzoori [11] reported the problem of growth in the size of bed material particles during fluidized bed combustion of lignite having prominent ratio of sodium and sulfur. Steenari et al. [12] found that the agglomerates comprised of prevalent unformed phase and other crystalline phases. Bhattacharya [13] studied coals having high percentage of sodium and sulphur feed in boiler for combustion a slight crystalline phase to be sulphates of sodium, magnesium and calcium found. In consonance with these past researches ash agglomeration formation in boiler bed result of inaugural adherence between viscous ash particles and deposition of boiler bed materials. This initial adhesion and agglomeration of bed ash particles inhibited by the low melting phase formed from ash particles. Xin Yang et al. [5] recently, only a limited number of studies have investigated the ash deposition growth through a dynamic CFD simulation. Kaer et al. [14] developed a dynamic CFD model to predict the ash agglomeration formation and heat transfer rates and the research focused on straw combustion and studied the ash deposition rate caused by different sintering mechanisms.

III. MODELLING OBJECTIVE

Aim of this study to develop a CFD model of CFBC boiler in this Indian coal (lignite) use as a fuel and setup the mathematical Model of CFBC boiler with cyclone separator then using actual boundary condition by Ansys (fluent) software tools. Vikram Cement power plant Neemuch it has captive power plant of 2 x 23 MW having Circulating Fluidized Bed boiler using lignite coal and pet coke as a fuel. Boiler bed, combustor, cyclone, standpipe and return leg dimension taken from there drawing. In present work we will evaluate static pressure and volume fraction of ash to find out ash agglomeration conditions.

IV.GEOMETRY MODELLING AND MESHING

Based on the dimensions taken from the Vikram cement power plant model of the selected boiler is prepared using ANSYS workbench. The different parts and relative locations are labelled in figure 1(a) while the model with meshing depicted through figure 1(b). The model comprises of two broad groups of component viz. ‘Combustor’ and ‘Cyclone’ which are connected through ‘Return Leg’ and ‘Loop Seal’ from bottom and through a broad passage from the top.

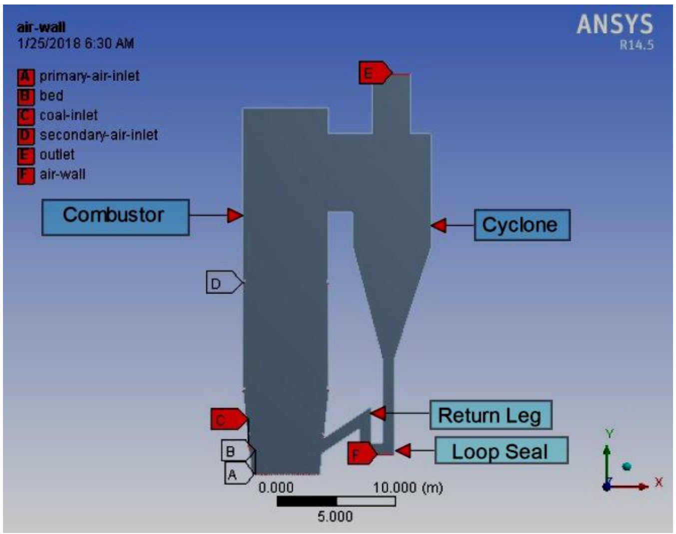

Fig. 1(a)

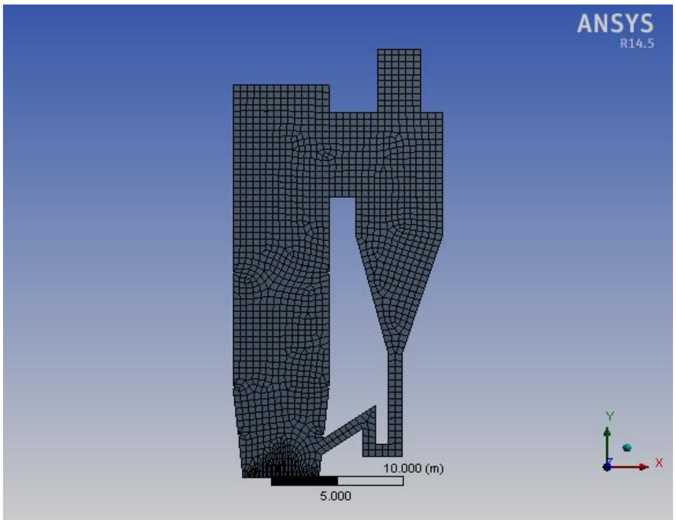

Fig. 1(b)

Fig. 1(a), (b): Geometry modelling and meshing of CFBC Combustor with Cyclone.

V. NUMERICAL STUDY

Numerical study done on the basis of CFD analysis method that is based on the combustion of coal and the circulation of flue gases has been developed and used for predicting the ash agglomeration propensities in the selected utility boilers supported by the data collected from vikram cement captive power plant. Standard k- ε models for CFD analysis is used for the simulation. In present case, discrete phase model interface with 10 number of continuous Phase iterations per DPM iteration is used. Both mean and RMS values are used for contour plots for DPM variables. Maximum number of steps 500 and step length factor 5 are used for tracking parameters. Four parameters viz. coal mass flow rate, coal particle size, Primary air velocity and Secondary air velocity are taken as input parameters while Bed pressure as performance parameter. Based on the literature and information gathered from boiler operation industrial practices three level values have been selected for each input parameter. Nine experiments have been carried out using simulated environment for lignite volatile coal.

VI. CASE OF LIGNITE VOLATILE COAL

Combustion behavior of Lignite volatile coal is analyzed using nine different sets as given in table 1. The properties of Lignite volatile coal are taken from fluent database which are also matching with the actual values of coal used in CFBC Boiler of M/s. UltraTech Cement Limited. Contours of distribution of static temperature and mass balance are obtain using these nine simulated cases and sample results are represented through figure 2, 3, 4, 5, 6, 7, 8 and 9 respectively.

TABLE I

INPUT PARAMETERS FOR SIMULATION OF LIGNITE VOLATILE COAL COMBUSTION BEHAVIOR

S.No.	Input Parameters			
	Coal Mass flow (kg/s)	Coal particle size(m)	PA velocity (m/s)	SA velocity (m/s)
1	10	0.004	3	10
2	10	0.006	4.5	15
3	10	0.008	6	20
4	14	0.004	4.5	20
5	14	0.006	6	10
6	14	0.008	3	15
7	18	0.004	6	15
8	18	0.006	3	20
9	18	0.008	4.5	10

A. ***Experiment 1***: Contours for Coal mass flow rate-10kg/s, 0.004 m particle size of lignite coal, primary Air -3 m/s, secondary Air -10 m/s

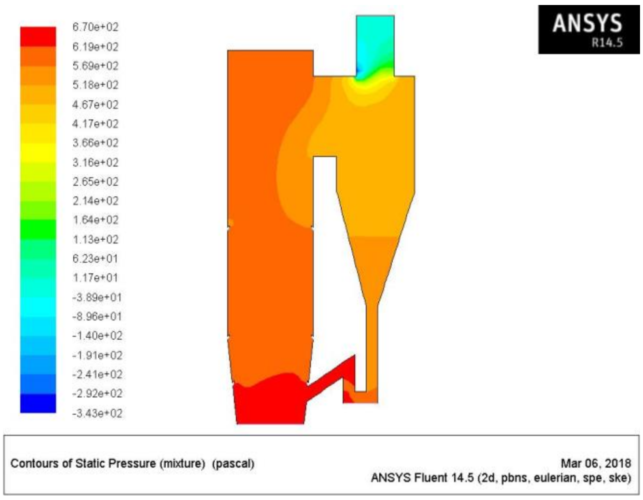

Fig. 2 (a)

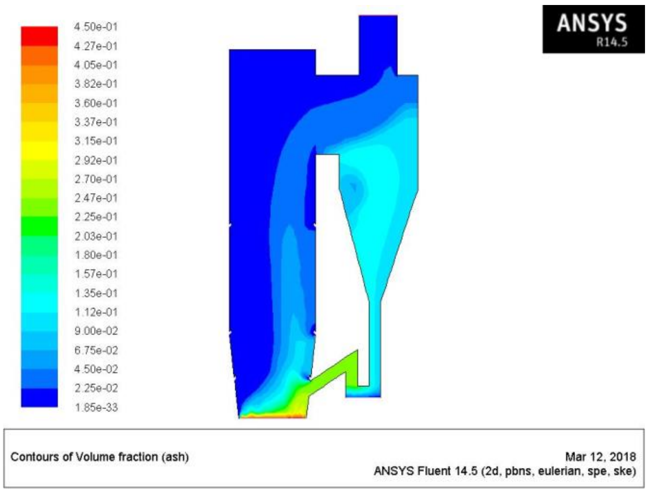

Fig. 2 (b)

Figure 2 (a) contours of static pressure (b) contours of volume fraction of ash

Analysis of result: From Fig. 2 (a) Visualized boiler bed average pressure observed 594.97 Pa this is normal pressure of boiler bed possibility of ash agglomeration is low. Fig. 2 (b) shows volume fraction of ash is maximum at bed and return leg.

B. **Experiment 7:** Contours for Coal mass flow rate-18kg/s, 0.004 m particle size of lignite coal, primary Air -6 m/s, secondary Air -15 m/

Fig. 3 (a)

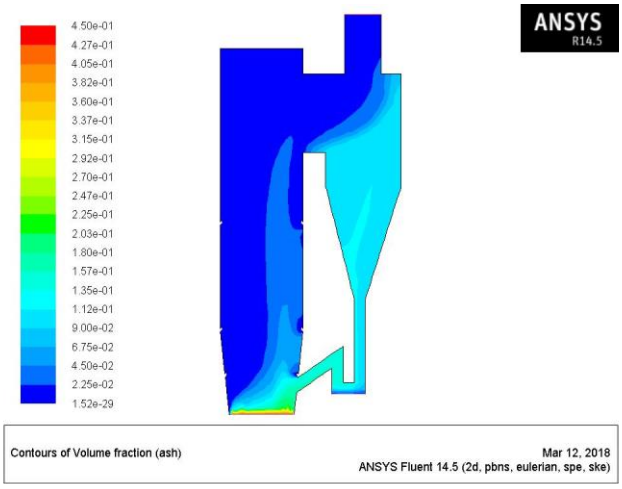

Fig. 3 (a)

Figure 3 (a) contours of static pressure (b) contours of volume fraction of ash

Analysis of result: From Fig. 3 (a) Visualized boiler bed average pressure observed 1412.8 Pa this is first stage alarming temperature of boiler bed. From fig. 3 (b) shows volume fraction of ash at bed and cyclone

C. **Experiment 8:** Contours for Coal mass flow rate-18kg/s, 0.006 m particle size of lignite coal, primary Air -3 m/s, secondary Air -20 m/s

Fig. 4 (a)

Fig. 4 b)

Figure 4 (a) contours of static pressure (b) contours of volume fraction of ash

Analysis of result: From Fig. 4 (a) Visualized boiler bed average pressure observed 1292.19 Pa this is higher than alarming pressure of boiler bed more possibility of ash agglomeration. From fig. 4 (b) shows volume fraction of ash is maximum at bed. So possibility of ash agglomeration in bed area because bed average pressure is also higher than alarming stage.

D. Analysis of Lignite Coal Combustion Experiments

TABLE 2

LIGNITE VOLATILE COAL MODELLED COMBUSTION RESULT

	Lignite coal result					
S.NO.	Coal Mass flow (kg/s)	Coal particle size(m)	PA velocity (m/s)	SA velocity (m/s)	Maximum Pressure (Pa)	Average pressure
1	10	0.004	3	10	669.93	594.97
2	10	0.006	4.5	15	1102.18	981.12
3	10	0.008	6	20	1632.78	1453.35
4	14	0.004	4.5	20	1601.23	1348.02
5	14	0.006	6	10	1125.21	978.57
6	14	0.008	3	15	1060.66	880.99
7	18	0.004	6	15	1692.88	1412.8
8	18	0.006	3	20	1609.71	1292.19
9	18	0.008	4.5	10	1118.27	926.87

1. Experiment 1,5,7 and 9 shows favorable condition for boiler if boiler runs in these parameter there is no possibility of ash agglomeration.
2. Experiment 2,3,4,6 and 8 give alarming bed temperature shows these operating conditions is not suitable for boiler. There is very much possibility of ash agglomeration

VII. CONCLUSION

Following conclusions are drawn from the computational analysis in this present work. It is observed that the lignite volatile coal requires different operating conditions for maintaining boiler bed average pressure. It is also observed that coal mass flow rate and coal particle size have less effect on the boiler bed average pressure while primary air velocity and secondary air velocity show significant effect on boiler bed average pressure. To avoid ash agglomeration in case of lignite volatile coal the primary air flow should be 4.5m/s and 6 m/s, and the secondary air flow should be maintained between 10 m/s and 15 m/s. For BIL coal the primary air flow should be 3 to 6 m/s with secondary air flow should be in the range of 20-30 m/s to avoid ash agglomeration. In case of SIL coal the preferable values to avoid ash agglomeration are primary air flow should be 3 to 6 m/s and Secondary air flow should be 10 to 15 m/s.

This CFD model of CFBC boiler helps to predict best input parameters values for a particular coal quality. It is very easy for the operator and practicing engineer to maintain favourable boiler bed average temperature for any coal quality using this model. This model also helps to predict the best operating conditions for any type of coal quality by which ash agglomeration can be minimized.

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