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Research in Varying Burner Tilt Angle to Reduce Rear Pass Temperature in Coal Fired Boiler

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Abstract. This research shows the investigation conducted on one of techniques that is used in Manjung 700 MW tangentially fired coal power plant. The investigation conducted in this research is finding out the right tilt angle for the burners in the boiler that causes an efficient temperature distribution and combustion gas flow pattern in the boiler especially at the rear pass section. The main outcome of the project is to determine the right tilt angle for the burner to create an efficient temperature distribution and combustion gas flow pattern that able to increase the efficiency of the boiler. The investigation is carried out by using Computational Fluid Dynamics method to obtain the results by varying the burner tilt angle. The boiler model is drawn by using designing software which is called Solid Works and Fluent from Computational Fluid Dynamics is used to conduct the analysis on the boiler model. The analysis is to imitate the real combustion process in the real Manjung 700 MW boiler. The expected results are to determine the right burner tilt angle with a computational fluid analysis by obtaining the temperature distribution and combustion gas flow pattern for each of the three angles set for the burner tilt angle in FLUENT software. Three burner tilt angles are selected which are burner tilt angle at (0°) as test case 1, burner tilt angle at (+10°) as test case 2 and burner tilt angle at (-10°) as test case 3. These entire three cases were run in CFD software and the results of temperature distribution and velocity vector were obtained to find out the changes on the three cases at the furnace and rear pass section of the boiler. The results are being compared in analysis part by plotting graphs to determine the right tilting angle that reduces the rear pass temperature.

1. Introduction

Generation of electricity through the combustion of fossil fuels in thermal power plants are widely implemented in many countries because it is very efficient in generating large portion of electrical energy to support the needs of the country. Most of the boilers in the thermal power plant are using tangentially fired coal fired boilers in power generating process. Basically coal is preferred to be chosen as the fossil fuel resources globally to run thermal power plant in power generation. A thermal power plant operates on the basic theory of converting heat energy produced through combustion of fossil fuels into mechanical work using working fluid. The mechanical work is further converted into electrical energy using generator. The main function of coal burning system is to convert chemical energy into heat energy by using boiler to convert water into steam which drives the turbine. The combustion element of fuel consists of carbon, hydrogen and small amount of sulphur. The exhaust gases released after combustion contains CO_2, SO_2 and CO [1].

The coal combustion process in thermal power plant consist of phenomena as turbulence, convection and radiation in heat transfer and chemical reaction in combustion of coal. Many factors that are involved in power generation through thermal plant such as furnace scale thickness, air velocity, mass

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flow rate and temperature of the heated air. The efficiency of the coal fired boiler is dependent to the thermal distribution that is effected by all the listed down factors.

1.1 Brief Description of the Boiler

Figure 1 shows the cross section of a boiler with furnace, cross over pass and rear pass sections in a boiler. The pulverised coal that is mixed with primary air is pumped from the four corners in the furnace section and ignited by injecting liquid fuel oil that starts the combustion. The injection of coal and air follows an imaginary line tangent to a small circle located in the centre of the furnace. The flow provides a rotation motion to the flame and creates additional turbulence for additional mixing of the coal and primary air. The flame spreads in the furnace and produce "fire ball". The system allows fuel particles to have sufficient time for residence in the furnace for the combustion.

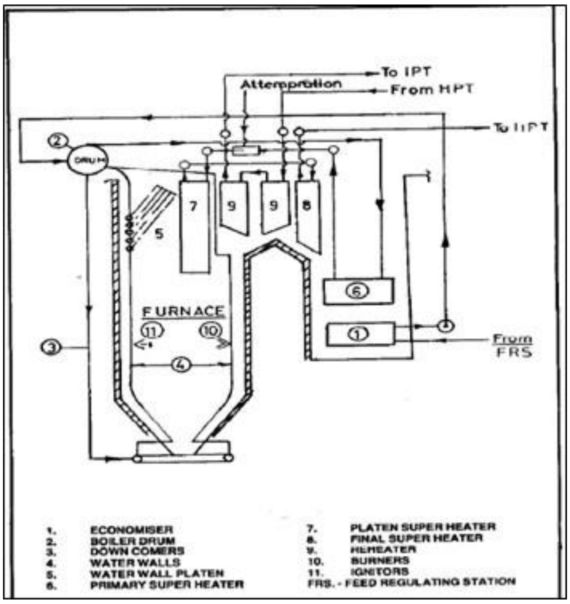

Figure 1: Cross Section of Boiler

Coal is pulverized into fine powder particles. Coal is blown in to the boiler by mixing with primary air in the furnace through a series of burner nozzle that is located at four sides as tangentially in the boiler. Combustion temperature of the furnace can reach up to 1300°C-1500°C.

1.2 Problem Statement and Scope of Study

In the boiler, all the burner nozzles can be tilted at the same time. All the nozzles can be tilted in a vertical direction up to certain angle from the horizontal axis to adjust the reheated steam temperature for the varying fouling conditions of the furnace. The tilting of the burner controls the vertical position of the fireball and also the size of the fireball to produce a uniform temperature distribution to all boiler tubes. The inaccurate tilting angle can lead to high rear pass temperature, imbalance left and right rear pass temperature and hot spots forming on water well that make the tubes to burst. The main aim is find out the right tilting angle for the burner to produce a perfect fireball that creates uniform temperature distribution in the boiler when heat transfers through radiation from the fireball to the tubes. The right tilting angle of the burner also can increases the efficiency of the boiler because the tilting angle can change the temperature of the superheat and reheat temperatures of steam.
The main reason to reduce the rear pass temperature is because to increase the efficiency of the boiler and reduce formation of hotspots on water well that leads to tube burst. Computational Fluid Dynamics has to be used to run the cases by varying the tilting angles at the boundary conditions. The effect of the varying tilting angle of the burners at the rear pass is identified by obtaining flow pattern and temperature distribution at the contours of rear pass. Analysis on the results has to be conducted

and plots have to be drawn to compare all the cases. The right angle tilting angle that reduces the rear temperature will be discussed and determined.

1.3 Summary of Researches Conducted on Boiler Models

The main idea of tilting the burner is to obtain a stable flame that creates an even distribution of thermal flow in the boiler as explained by William Brockman in his research [2]. The stable flame influences the temperature distribution in various sections of boiler as explained by Syed Mujtaba Umair and P.T.Borlepwar in their research on varying the burner tilt as one of the parameters to obtain a stable flame [3]. The research conducted by Masoumi H. and Abroshan H. proves that burner tilting causes changes in different part of the boiler such as upper furnace, crossover pass and rear pass temperature [4]. Other than that, it is proven that tilting angle of the burners influences the slag production in the burner as being explained by Zhou Hao, Cen Kefa and Sun Ping in their research [5]. They prove that slag decreases the efficiency of boiler.

The common method used in many research to determine the results are by running simulations using Computational Fluid Dynamics. The parameters can be tested in actual boiler situations through this software. Other than that, numerical method is also very important in conducting calculation for the data to be used in CFD. Most of the research done identified the temperatures at exit by reading temperature profile graph that obtained through CFD.

2. Methodology

2.1 Development of 700 MW Boiler Geometry

The Computational Fluid Dynamics investigation was done along the furnace path of the boiler and the rear pass of the boiler model which is situated on the other side of the boiler model. Planes and lines are created in the base model to observe the contours on the planes to determine the results such as temperature distribution and flow pattern at different cross section of the boiler. The base model was created according to the full scale furnace that as similar dimensions as the 700 MW coal fired boiler in TNB Janamanjung Power Plant. It has dimensions of 72.58 m height and 35.504 m widths. The base model is consisting of super heaters, burner inlet, furnace outlet, main furnace and bottom ash hopper. The geometry was created using SOLIDWORKS CAD software. The meshing process was done by using GAMBIT software. The meshing done on the boiler model was a fine meshing which enhance a more accurate flow of particles during the simulation in Computational Fluid Dynamics. The model drawn is shown on Figure 2.

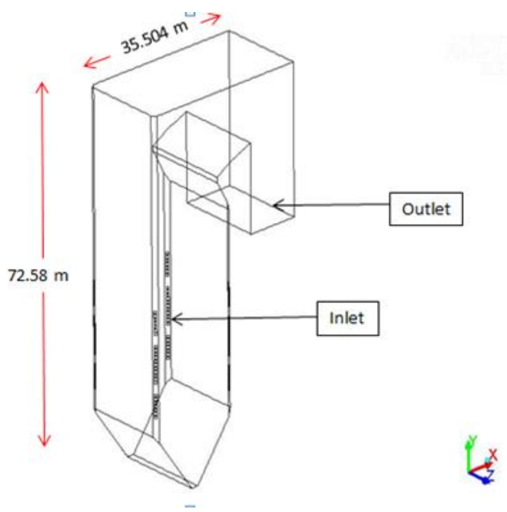

Figure 2: Layout of boiler model

2.2 Planes to Obtain Results

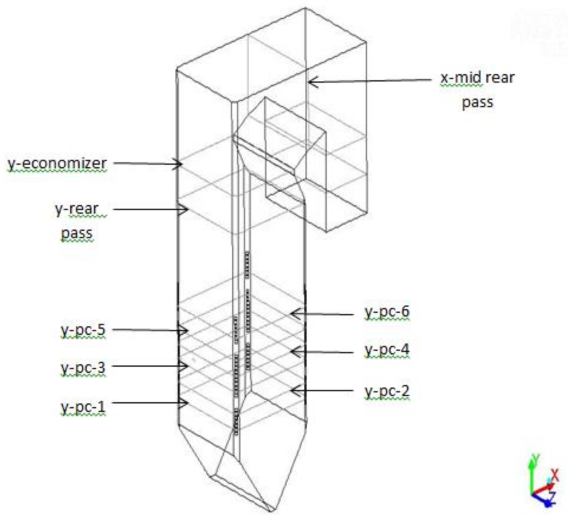

Figure 3: Mesh display of planes

The planes shown on figure 3 were drawn in FLUENT software to measure the changes occurs in the contours as the results when the boundary condition which is the tilting angle of the burner is changed during analysis. The plane y-pc-1, y-pc-2, y-pc-3, y-pc-4, y-pc-5, y-pc-6 are drawn at the inlet part where pulverized coal inlet located. The contours such as temperature distribution, velocity vector of the combustion flow are obtained on these planes in FLUENT. The planes are located at the furnace segment of boiler. These planes are mainly used to obtain contours to observe the fireball formation at the furnace. There are 6 planes drawn because the changes done on the tilting angle in boundary condition will change the position of fireball. The planes 6 planes drawn at the furnace that covers the lower furnace, middle furnace and the upper furnace to observe the formation of fireball for all the three cases tested. The middle rear pass section is used to measure the changes in contours at cross-over segment of boiler for example to observe temperature distribution of the flue gas at the segment. The y- economizer and y-rear pass plane is used to measure the changes in contours in rear pass segment of boiler for all the three cases. The contours on these planes will determine the changes occur at the rear pass from the variation of burner tilt angle.

2.3 Simulation of the Real Cases in Fluent

The analysis were done by selecting three angle for the burner which are case 1(0°), case 2 (+10°) and case 3 (-10°). The burner is at the center for case 1, lifted upwards for case 2 and lifted downwards for case 3. The value that is entered for y-component of flow direction under the burner's boundary condition on FLUENT software is the value obtained from the sin of the angle of the elevation set for the three cases. For example, the value of sin 10 is entered in y-component in all pc inlet and secondary air inlet under boundary condition to run the analysis for the case which that the burner is tilted at (+10°). For the case that the burner is tilted at 0° the value of sin 0 is entered for y-component of flow direction and the value of sin -10 is entered in y-component direction flow the case that the burner is tilted at (-10). The mass flow rate of pulverized coal was set at 32.319 kg/s and it is constant for all the three cases. For all the three cases is then initialized with 0 m/s velocity at x, y, z component and the temperature is set at 300 K for the initialization.

The Rosseland radiation for all three cases is used because this radiation gives out a stable simulation during the calculation running and also quite fast compared to P1. Initially P1 radiation was use when conducting the test run simulation for the test case and find out that the results obtained was not satisfying. The simulation for the real cases were run again using Rosseland radiation type and found out that Rosseland is more stable and takes shorter time for the iterations to run compared with P1 radiation type.

3. Results and Discussion

3.1 Formation of fireball

The formation of fireball on each case is confirmed before analysing the results at the rear pass section of the boiler for all the three cases. Fireball formation can be seen on all at the three cases but the position of the fireball formed varies in each cases. The fireball formation can be observed on different elevation of planes for all the three cases.

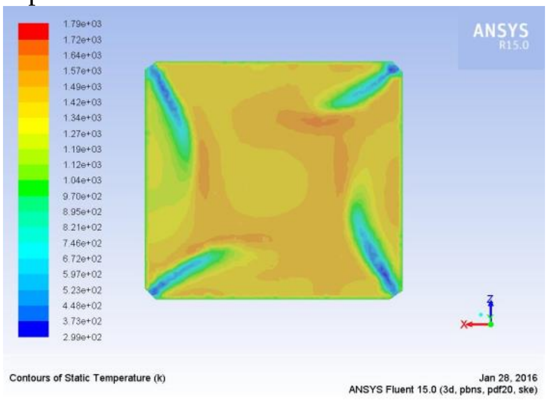

Figure 4: Plane y-pc-3 for (0°)

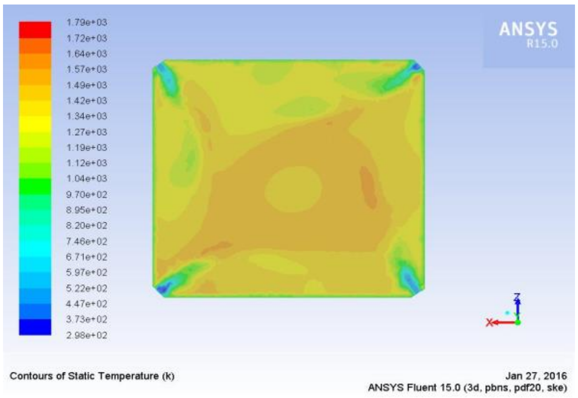

Figure 5: Plane y-pc-6 for (+10°)

The figure 4 shows the fireball formation is about to form on plane y-pc-3 if all the 6 planes at the furnace were being compared for test case 1 which is burner tilt angle at (0°). The plane y-pc-3 figure shows that a fireball is about to form with a surrounding of orange colour that proves higher temperature. Fireball formation occurs at plane y-pc-3 which is considered at the center of the furnace. This is because the burners were set at (0°) tilting angle which is not tilted at all and placed at the center of the furnace.

Fireball formation can be seen clearly on plane y-pc-6 shown in figure 5. The temperature contour proves that fireball formed at the top of the furnace. This is because the burner was tilted upwards for the angle of (+10°) which causes the fireball to be lifted upwards as well.

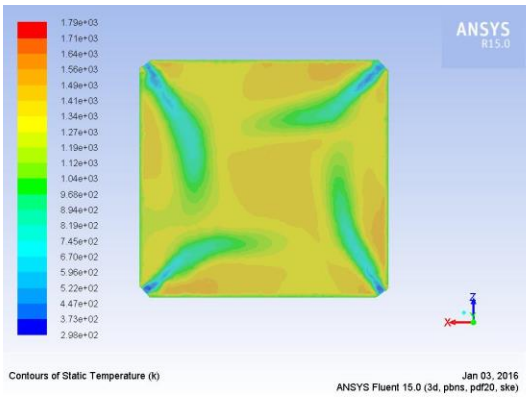

Figure 6: Plane y-pc-1 for (-10°)

The fireball shaped figure can be seen on plane y-pc-1 which is in figure 6. The figure of y-pc-1 which is in figure 6 showing that the fireball formed is not exactly like a ball shape but the shape is sufficient to prove the formation of fireball occurs for (-10°) burner tilt angle case. The other planes can be said that they are showing the flow of flue gas that is rising up from the bottom of furnace to the top part of the furnace on their contours. The result proves that the fireball formed at the lower part of the furnace because the fireball is lifted downwards when the burner is tilted downwards for test case 3 [6].

3.2 Rear Pass Analysis

Two graphs were plotted to show the comparison on temperature distribution at the rear pass section of boiler for all the three cases. The lowest temperature and the highest temperature at the rear pass section of the boiler can be observed on this graph. The distribution on of flue gas from the left hand side rear pass wall and right hand side rear pass also can be analysed through the graphs plotted. The first graph is drawn based on the relationship between temperature distribution at the rear pass and curve length of the rear pass. It is plotted along the line drawn at the mid rear pass of the boiler section. The second graphs show the relationship between temperature distribution at the rear pass and direction vector of the rear pass. The graph plotted on the line along the rear pass is drawn by at the front part of the rear pass section of the boiler following the x position of the mid rear pass line.

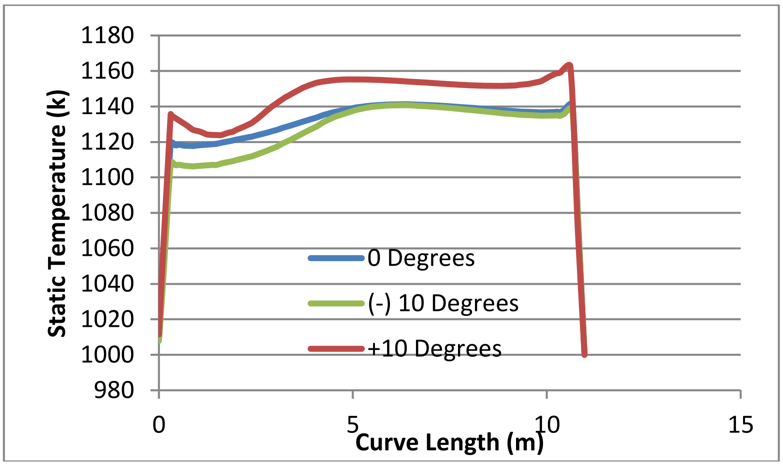

Figure 7: Graph of Rear Pass Temperature with Different Tilt Angle

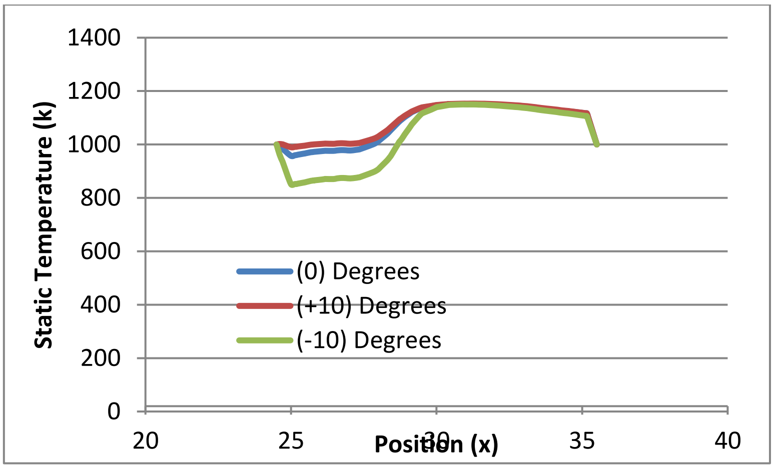

Figure 8: Graph of Rear Pass Temperature with Different Tilt Angle

The graphs on figure 7 and 8 shows that the temperature distributions from the wall of the rear pass at the left hand side until the wall on the right hand side is quite different for all the three cases. The change of temperature distribution from left hand side to the right hand side for test case 2(+10°) shows a lot of difference compared to other two cases. There is also a difference can be seen on the temperature distribution for test case 3 (-10°) when compared with test case 1 (0°). Test case 1 has a stable temperature distribution from left hand side to the right hand side compared to the other two cases. This proves that tilting the burner causes the changes at the rear pass of the boiler. Test case 2 has more difference in the temperature between left hand side and the right hand side of the rear pass section based

on the first graph at figure 7. This shows that as the burner is elevated upwards there is more difference of temperature between left hand side and the right hand side. The temperature distribution on the right hand side of the rear pass is higher compared to the temperature on the left hand side of the rear pass for all the three cases. This is because the temperature distribution from the flue gas that flow at the rear pass are being absorbed more on the left hand side of the rear pass section of the boiler. Other than that, the flow of flue gas is supposed to be at the center because the fireball is produced at the center of the furnace but the flow of the flue gas is disturbed when the flue gas has to rise up until the cross over section from the furnace. This causes the temperature difference between left hand side and right hand side on the graphs. Both graphs prove that the rear pass temperature is the highest for test case 1(+10°) and lowest for the test case 3(-10°). This can be also said that tilting the burner downwards reduces the rear pass temperature and tilting the burner upwards increases the rear pass temperature.
Tilting the burner downwards makes the fireball to be positioned at the lower furnace and tilting the burner upwards raise the fireball to the top of the furnace. The flue gas formed through the fireball produced at the furnace will travel to the cross over section of the boiler where it is located at the top of the boiler and finally travel to the rear pass section. The heat absorption from the flue gas temperature by the furnace wall occurs in that situation. The flue gas takes longer time for it to reach the rear pass when the fireball is located at the bottom of the furnace because the distance for the flue gas increases in that case. Based to that, more heat absorption from the flue gas occurs as the distance of the rear pass and fireball increase in the burner. This causes the temperature of rear pass is at the lowest for test case 3. The distances of the flue gas to travel to the rear pass from the furnace is shorter if the burner is lifted upwards as in test case 1. In this situation, the heat absorption from the flue gas by the furnace wall will be lower and causes the rear pass temperature to increase because all the heat that is not absorbed by the furnace wall.

4. Conclusion and Recommendation

Changes occur at the boiler rear pass when different burner tilt angle were set at the furnace section. This is because the position of fireball changes as the burners tilt angle is changed. The temperature difference between the left hand side and right side at the rear pass also changes as the burners tilt angle is changed. The combustion flow pattern at the furnace also changes when the burner tilt angle is varied and leads to the difference in temperature at the rear pass section of the boiler. The temperature distribution at the rear pass is only analysed as the fireball formation is seen at the temperature and velocity vector contours. The fireball formation can be seen on temperature contour and velocity vector contours on y-pc-3 for test case 1, y-pc-5 and y-pc-6 for test case 2 and y-pc-1 for test case 3. The right tilt angle that reduces the rear pass temperature of the boiler is identified through the graphs and contours. The graphs clearly prove that the rear pass temperature is the lowest when the burner is tilted at angle of (-10°) and highest when the burner is tilted at angle of (+10°). The rear pass temperature is low for test case 3 because more absorption of heat by the furnace wall from the flue gas occurs as the time taken for the flue gas to flow from the fireball at the furnace to the rear pass is longer due to the longer distance.
The recommendations that can be done for this research is more changes can be observed at the boiler such as determine the unburned carbon contain in the boiler when the burner tilt angle is changed. This is because unburned carbon also reduces the efficiency of the boiler because high carbon contained in the flue gas produces more NOx emission that can pollute the environment. Other than that, the ash deposition in the boiler also can be determined based on changes on burner tilt angle. This is because the ash deposition leads to the formation of slag that can actually reduce the efficiency of the boiler. Moreover, the changes of temperature occurs at the rear pass section of boiler can also be investigated by varying the type of coal being used for combustion.

5. References

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