OPTIMIZATION OF COMBUSTION IN PULVERIZED COAL FIRED BOILER

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Abstract— The demand of electricity is increasing nowadays and has raised the necessity of improved power generation technologies, especially in developing countries like India. Reduction of emissions of greenhouse gases is the need of hour and it could be achieved considerably by improving the efficiency of existing coal fired plants. Operation of non-optimized boiler can lead to reduced boiler efficiency, increased excess air requirements, delayed combustion, increased heat loss, high CO and NOx emissions and many other. Optimization of combustion in pulverized coal fired boiler is very important today for every thermal power plant. The aim of the paper is to optimize combustion using secondary air damper which leads to improved boiler efficiency with reduced heat losses.

Index Terms— Optimization, combustion, greenhouse gases, secondary air damper

I. INTRODUCTION

India is a seventh largest country and has a very large population. To maintain growth rate, rapid growth in energy sector is needed. About 70.6% of power generation comes from thermal power plants, in which 61.5% generation comes from using coal as fuel [1]. The demand of electricity is increasing day by day and has raised the necessity of improved power generation technologies or to improve the performance of existing power plants. Coal is the major fossil fuel in India and continues to play a prime role in the energy sector. The coal combustion process produces many pollutants, and in turn leads to acid rain and climate change like global warming. Operating a boiler that is not optimized further leads to increased levels of unburnt carbon, increased excess air requirements, incorrect primary and secondary air to fuel ratios, reduced boiler efficiency and increased slagging etc. Hence it is necessary for all thermal power plants to optimize the combustion. In this paper, combustion is optimized by the use of secondary air damper which reduces heat loss and increases boiler efficiency.

II. SECONDARY AIR DAMPER CONTROL (SADC)

The secondary air which is handled by the FD fan passes through the air heater and to the windbox connecting duct which supplies the secondary air to a pair of windboxes. The secondary air is divided into two parts, namely, fuel air and auxiliary air. Fuel air is that air which immediately surrounds the fuel nozzles. Since this air provides a covering for the fuel nozzles it is also called mantle air. Auxiliary air is admitted through compartments above and below the fuel nozzles. Dampers are provided in the windbox compartments so that the correct quantities of air to the individual compartments can be modulated to achieve the better combustion in the furnace.

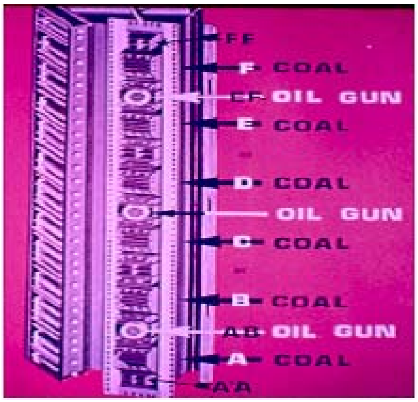

Fig 1. Damper Arrangement[2]

The secondary air dampers are named after the elevation on the boiler as follows:

Dampers A, B, C, D, E and F are provided at four corner of the furnace. These are also called fuel air dampers.

Dampers AB, CD and EF are placed between A and B elevation, C and D elevation, E and F elevation respectively.

Dampers AA, BC, DE, FF are auxiliary air dampers and placed between B and C elevation, C and D elevation and at bottom and top of furnace which provide the additional air required for combustion.

III. LITERATURE REVIEW

A method is presented by Benyuan Huang et. al.[3] to optimize coal combustion based on flame image processing technique and concept of introducing RES into combustion control circuit of coal fired power plant. It showed that by optimal control strategy, we can ensure stability of load and main steam pressure by adjusting secondary air for optimized A/F flow rate and thereby strengthened ad stabilized combustion conditions can be achieved in furnace. Also boiler efficiency increased and NOx emissions reduced at optimized operating conditions.

Ren Jianxing et.al. [4] studied a 300 MW Coal fired unit using three kinds of mixed coal A, B and C. Under the rated load conditions characteristics of coal and burning characteristics were studied. The objective was to optimize combustion and enhance boiler efficiency by undergoing experimental analysis based on parameters such as burning status, flame transparency, unburned combustible in flue gas and exhaust gas temperature. Based on results of experiments, the results showed that mixed coal A was found better than mixed coal B and C on above mentioned parameter and hence it helps to optimize combustion and boiler efficiency.

Ji Zheng Chu et. al. [5] proposed their study on new constrained procedure using artificial neural network as models for target processes. Information analysis based on random search, fuzzy c-mean clustering and minimization of information energy is performed iteratively in proposed procedure. ANN offer an alternative approach to model process behaviour. It is based on extracting imbedded pattern from data that describes the relationship between input and output in any process phenomena. Also, we came to know that there exists a best air ratio at which thermal efficiency achieves maximum for given fuel.

Risto V Filkoski et. al [6] applied a method for handling two phase reacting flow for prediction of pulverised coal combustion in large scale boiler furnace and to assess ability of model to predict existing power plant data. This paper presents principal steps and results of numerical modeling of furnace. The CFD/CTA approach was utilised for creation of three dimensional model, including platen super heater in upper part of furnace. Standard k epsilon model was employed for description of turbulent flow. Radiation heat transfer is computed by means of simplified P-N model. Simulation results concerning furnace walls, thermal efficiency and combustion efficiency shows good results corresponding with plant data.

IV. DIFFERENT LOSSES ASSOCIATED WITH EXCESS AIR

In practice, if a fuel is burned with only the theoretical amount of excess air present, then the combustion will be very poor due to incomplete mixing of the air with the fuel. Hence it is necessary to supply more air than theoretical air required and this is known as excess air [2]. If the amount of air supplied is higher than required, it will result into increase in dry flue gas loss, boiler efficiency reduction, erosion of heat transfer surface due to high gas velocity etc. If the amount of air supplied is lower than required, it will result into incomplete combustion, increase in unburnt carbon losses and soot formation.

The different losses mainly influenced by excess air are as follows:

A. Dry flue gas loss.
B. Incomplete combustion loss.

If above mentioned losses are added, then it results into combined heat loss. This loss decreases as excess air increases, reaches minimum and then increases as still more excess air is added. Thus there is only one quantity of excess air which will give the lowest loss for the combustion of a particular fuel.

V. ANALYSIS OF OPTIMUM EXCESS AIR

The analysis for finding an optimum air supply is found out at full load. By determining the percentage change in heat loss with percentage change in excess air, optimum quality of excess air supply is to be found. At optimal value of excess air, heat losses are minimum and efficiency is maximum. To find out the air supplied at which heat losses are minimum, design parameters of boiler were considered.

A. DRY FLUE GAS LOSS

This loss basically depends upon the mass supplied and the flue gas temperature. Figure 2 shows that as the amount of air supplied increases, the amount of mass supplied and the outlet flue gas temperature increases in other words dry flue gas loss increases.

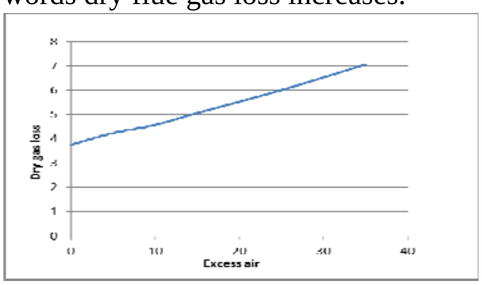

Fig. 2 Dry Flue Gas vs Excess Air

B. INCOMPLETE COMBUSTION LOSS

Incomplete combustion loss is formation of carbon monoxide instead of carbon dioxide during combustion.

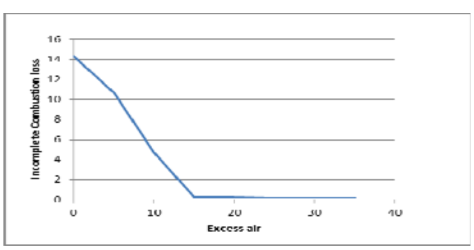

Fig. 3 Incomplete Combustion Loss vs Excess Air

As shown in Figure 3, when the amount of air supplied is higher than the optimal value of excess air, the incomplete combustion loss is very less and reduces at constant rate but when the amount of air supplied is lower than the optimal value of excess air than incomplete combustion loss increases very sharply.

COMBINED HEAT LOSS

Figure 4 shows result of combined heat losses. This loss is minimum when the amount of excess air supplied is 15% as shown in figure. With increase or decrease of the optimum value of excess air, heat losses increases. Thus after analysis, it is found that the optimum value of excess air at which heat losses are minimum and efficiency is maximum is 15%.

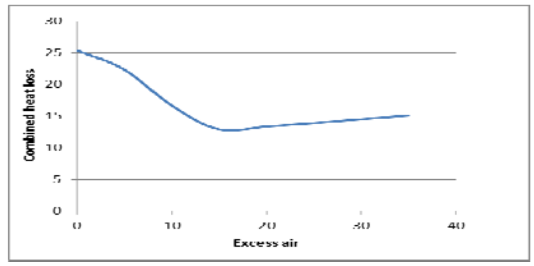

Fig. 4 Combined Heat Loss vs Excess Air

VI. BOILER EFFICIENCY BEFORE AND AFTER CORRECTING DAMPER

Using Coal analysis and operating parameters, the boiler efficiency and heat losses in boiler were calculated by "heat loss method" as per Bureau of energy efficiency booklet.

Table-I shows heat losses in boiler and boiler efficiency calculated according to "Heat Loss Method" before correcting damper position.

I. HL & efficiency in boiler before correcting damper

Calculated Parameters	Values
Theoretical air required (kg/kg of fuel)	5.82
Actual air supplied (kg/kg of fuel)	7.14
% Excess air	22.8
% Heat loss due to dry flue gas	7.34
% Heat loss due to evaporation of water formed due to H_2 in fuel	4.55
% Heat loss due to evaporation of moisture present in fuel	2.03
% Heat loss due to moisture present in air	0.19
% Heat loss due to unburnt in fly ash	0.46
% Heat loss due to unburnt in bottom ash	0.39
% Heat loss due to radiation	0.5

Boiler efficiency	84.52

As per analysis of optimum value of excess air done previously, it is known that to improve the efficiency and reduce the heat losses, secondary air dampers are needed to be set for 15% excess air. Since the excess air before correcting damper position is above 15% excess air, it is needed to close the dampers till optimum value is reached by keeping in view the amount of O_2 in flue gas outlet in DCS system. As we know the relation between percent of O_2 in flue gas at exit and excess air, we monitor the correction accordingly by gradually closing the dampers.

Table-II shows heat losses in boiler and boiler efficiency calculated according to "Heat Loss Method" after correcting damper position.

II. HL & efficiency in boiler after correcting damper

Calculated Parameters	Values
Theoretical air required (kg/kg of fuel)	5.81
Actual air supplied (kg/kg of fuel)	6.69
% Excess air	15
% Heat loss due to dry flue gas	6.52
% Heat loss due to evaporation of water formed due to H_2 in fuel	2.02
% Heat loss due to evaporation of moisture present in fuel	4.52
% Heat loss due to moisture present in air	0.16
% Heat loss due to unburnt in fly ash	0.48
% Heat loss due to unburnt in bottom ash	0.34
% Heat loss due to radiation	0.5
Boiler efficiency	85.43

VII. RESULT AND DISCUSSION

After correcting the damper position up to optimum value of excess air, it was found that total percent heat loss in the boiler reduced from 15.47% to 14.56% and boiler efficiency improved from 84.52% to 85.43%.

VIII. CONCLUSION

The effect of decreasing excess air to optimum value resulted into reduction in heat losses and improved boiler efficiency. Hence, using secondary air dampers, optimization in combustion was carried out.

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