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Effect of Stack Temperature on Plant Efficiency in Coal-Fired Thermal Power Plant

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***Abstract*— The emissions of carbon di-oxide plays a significant role on the plant efficiency of a coal-fired thermal power plant. The dominant thermal energy source of thermal power plant will be the coal till the next decades. Efficient Combustion of coal on the furnace is very important to quantify the total heat input too the thermal power plant. At the same time, the efficient heat absorption of heat from the hot flue gases play an important role in the thermal efficiency of power plant. The amount of air given to burn the coal is a predominant factor in determining the plant efficiency. The temperature of the gas leaving the stack has an direct impact on the plant efficiency.**

***Keywords*— Stack Temperature, Emmission, Plant Efficiency, coal-fired, carbon di-oxide.**

I. Introduction

Coal is found to be dominant thermal energy source around 42% of the world power generation and is expected to continue till the year 2040. The development of coal-fired power with considerable efforts towards improvement of thermal efficiency is seen increasing with decades.

The small percentage of increase in power plant efficiency leads to reduction in the cost of power generation. Also the emission of carbon dioxide also plays an important role in the power plant efficiency and thereby has an effect on the stack temperature prominently.

II. Flow Of Flue Gas And Air Flow

The growing strategy of the green house gases encourages the efficiency enhancement of the thermal power plant [1]. Performance assessment and consecutive improvement measure can lead to large contribution in monetary terms, which can be further exploited for capacity addition [2]. Direct combustion of coal with respect to thermodynamic, technical and economic factors have a great impact on the efficiency of the power plant.

The chemical energy inside the coal is being converted to thermal energy by the process of combustion and the schematic of the air and flue gas movement is shown in Figure No.1.

Continuous efforts have been investigated to improve the plant efficiency by optimising the combustion process, and maximising the power production process.

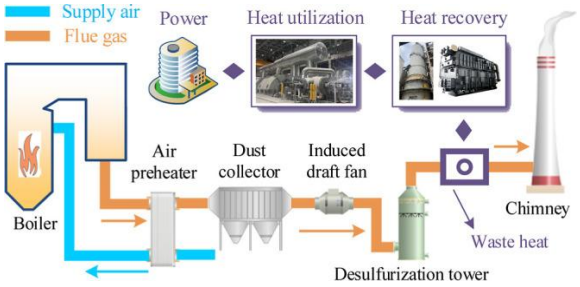


Figure No.1 Schematic of Flue gas and Air flow in a thermal power plant

III. Effect Of Stack Temperature On Plant Efficiency

The on-going research is done in various components of the thermal power plant like boiler, condenser, turbine etc., to provoke the energy boosters and thereby to improve the thermal efficiency of the power plant and among the various components, the boiler plays a vital role in primary energy conversion. The efficiency of the thermal power plant gradually decreases as time increases and retrofitting is done to increase the performance of those plants.

The maximum energy conversion could be made by properly monitoring and control of heat providing sources where the energy loss takes place casually [3]. The losses involved on the conversion of heat to power is made minimum based on the operating temperature limits. The various losses in the systems of thermal power plant are found to identify the irreversible process [4].

The Boiler has to be operated with optimal efficiency since primary energy conversion occurs by burning the coal at the furnace. Efficiency of the boiler is very crucial and any deviation from the norms are easily identified [5]. Different research works are proposed by thermal researchers to find the losses and improve the efficiency of the boiler [6]. The effect of flue gas temperature on the plant efficiency and consequently the unit cost of energy reduction (UCOE) is shown inf figure No.2.

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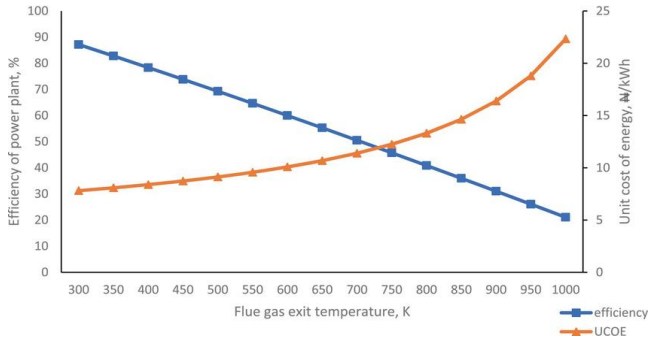


Figure No.2 Effect of flue gas temperature on plant efficiency and UCOE

A. Calculation of Excess Air:

Most coal reserve in India provides high ash content of 30 to 45 % and low sulphur content of 0.2 to 0.5 %. However, the calorific value of coal is very low ranging from 2000 to 4500 kcal/kg and hence conversion of this to useful heat is very complicated. The capture of cardon di-oxide by the process of post combustion, pre-combustion and oxy-combustion is very critical.

Considering a Flue gas composition of $CO_2 = 12\%$, $O_2 = 5.5\%$ and $N_2 = 82.5\%$, the percentage of air composition is calculated as below:

Atmospheric air contains 21% O_2 and 79% N_2

$\frac{N_2}{O_2}$ Ratio Equation 1

$$\frac{N_2}{O_2} = 3.76$$

The actual oxygen supplied is found as below by Equation 2.

$$Actual\ Oxygen\ Supplied = \frac{Nitrogen\ in\ Flue\ gas}{\frac{N_2}{O_2}\ Raio} \quad \text{Equation 2}$$

$$\frac{82.5}{3.76} = 21.96\ mol$$

The Consumed oxygen by coal is found by carbon reaction as below:

$$C + O_2 = CO_2 \quad \text{Equation 3}$$

By the above equation, the oxygen used for carbon burning is *12 mol.*

The oxygen available for hydrogen is the remaining O_2

$$Remaining\ O_2 = Actual\ Oxygen\ Supplied - O_2\ in\ the\ fluegas \quad \text{Equation 4}$$

$$Remaining\ O_2 = 21.94 - 12 = 4.4\ mol$$

The hydrogen Combustion reaction is as below:

$$H_2 + \frac{1}{2}O_2 = H_2O \quad \text{Equation 5}$$

Therefore, the Hydrogen present is *8.88 mol* H_2 and the Carbon-hydrogen ratio is calculated as below:

Carbon mass is *12 x 12 =144* and the Hydrogen mass is calculated as *17.76 C*

And therefore, the C:H mass ratio is *8.1 :1.*

The excess air is then calculated as below:

$$Excess\ Air = \frac{O_2\%}{100 - O_2\%}\ x\ 100 \quad \text{Equation 6}$$

$$\frac{21.94}{100-21.94} \text{x } 100$$

= 33.5% of Excess air

The operating furnaces will never attain this stoichiometric ideal case due to the practical limitations of the huge variations in the coal-air mixture in proportion with the load fluctuations. Operators make it a challenge to find the best operating point where the range of excess air is around 1% to 4% .

Flue gas analysis is very important in determining the combustion efficiency of a coal-fired boiler. Figure No. 3 shows the variation of the air-fuel mixture with respect to stochiometric point. The stoichiometric condition exists when all coal is burnt with the required amount of oxygen. After that point no unburnt coal remains and also no oxygen remain in the hot gases evolved during combustion. The air that was sent but not used for combustion is termed as excess air.

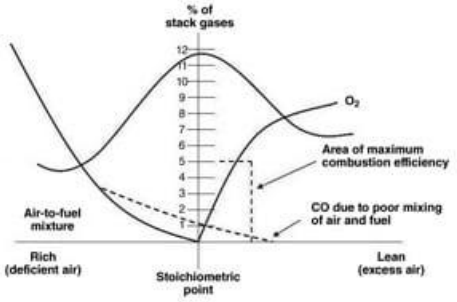


Figure No.3 Variation of the air-fuel mixture with respect to stochiometric point

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B. Upward drive of heat recovery Zone

The successful capture of sensible heat lies in the lowered exit temperature of the flue gas in the stack. The heat exchangers like economiser and air pre-heater will take the heat form the flue gases and transfer its heat to the feedwater and the air for combustion respectively. This reduces the amount of coal burnt in order the get the same steam thermodynamic parameters. Soot blowing in coal-fired boilers address the problem of ash and slag deposit by regularly removing them at fixed intervals, which adhere to the inner heat transfer surface. This increase the thermal efficiency and also reduced emissions. The effect of soot blowing with respect to flue gas temperature is shown in Figure No.4. below:

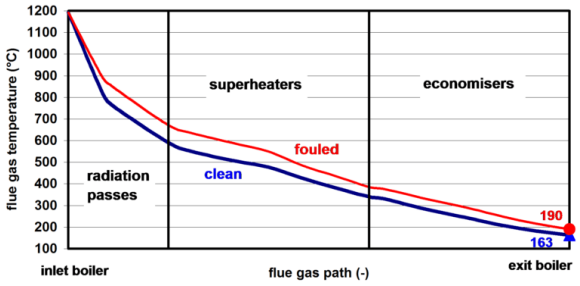


Figure No.4 Effect of Soot blowing on the Flue gas temperature

IV. CONCLUSION

The stack gas temperature directly has an impact on the thermal efficiency of the power plant as it represents the largest source of continuous heat loss from the thermodynamic system of boiler. It is said that every 10 to 15 degree decrease in the stack temperature improves the overall efficiency by 1% .

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