

Effect of Air-Fuel Ratio in Combustion Efficiency of Coal – Fired Subcritical Boilers

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Abstract— The air – fuel ratio is a critical parameter in the combustion efficiency of any boiler of a thermal power plant. The boiler performance can be improved by changing the fuel- air ratio. An optimized air-fuel ratio is crucial with respect to efficiency reduction in the emissions. This also leads to lowering of operational cost of the boiler. The air fuel ratio in a thermal power plant is the ratio of the combustion air provided to burn the fuel to the mass of fuel burnt. The ratio of primary to secondary air has an impact for the combustion process and thus the overall performance of the thermal power plant. By sending the correct percentage of oxygen, the complete combustion is achieved. The complete combustion require oxygen than the designed value which is termed to be the excess air. The air flow provided should be optimum ensuring the peak efficiency which also reduces the emissions to environment considerably.

Keywords— Air-fuel ratio, Combustion efficiency, emission, operating cost, carbon di-oxide

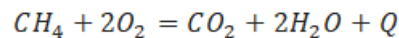
I. INTRODUCTION

The increase in population growth leads to high demand for electricity. The activities of the human life have an increasing impact on the climatic system since the fossil fuel burning releases huge amounts of carbon dioxide to environment. The increased pace of depletion of coal demands the improvement of efficiency of exiting thermal power plant. The depletion of coal is due to the unbalance between production and consumption of coal and is forecasted to decline by 2040s [1]. Coal-fired power plant comprises of several major components which includes boiler, turbine, condenser, and Feed water pump. The energy stored in chemical form in coal is released by combustion process in close chamber known as furnace. The heat released is transferred from hot gases to water and thus water gets converted to steam. The steam thus produced is superheated and is made to run a steam turbine and mechanical energy is produced which runs a generator to produce electrical energy.

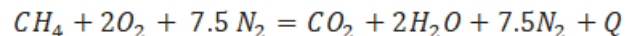
II. AIR-FUEL RATIO

Boilers in coal-fired are operated by burning the coal in a closed chamber called as a furnace. In the burning process, the heavy loss occurs at the stack.

Hence the management of the air flow is very essential for the efficiency of the furnace. As coal gets burnt in the presence of oxygen, it gets converted to carbon di-oxide, heat and water.



The complete combustion involved is as below:



The stoichiometric air –fuel ratio ensures complete combustion of coal in boilers as shown in Figure No.1. below:

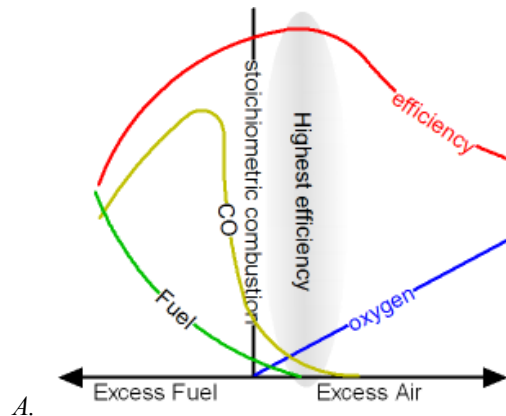


Figure No.1. Excess fuel and Excess air on the stoichiometric combustion of coal

The combination of primary and secondary air flow rate is to be managed for efficient combustion as shown in Figure No.2. The primary air is initially split into two streams letting inside the coal to the furnace. The secondary air enters the secondary sector of air preheater and after getting heated by flue gases, the hot air enters the furnace. The primary air is forced into the bottom part of the boiler which ensures the general flow circulation [2]. The purpose of the primary air is to transport the coal powder into the combustion chamber.

Various efforts have been investigated to reduce the coal usage and air preheating is the prime method to increase the efficiency of the overall plant which reduces coal consumption since the time of combustion gets shortened.

The air pre-heater is equipment which is basically a heat exchanger designed to heat the atmospheric air entering the combustion chamber. This directly improves the thermal power plant efficiency and also conserves energy [3].

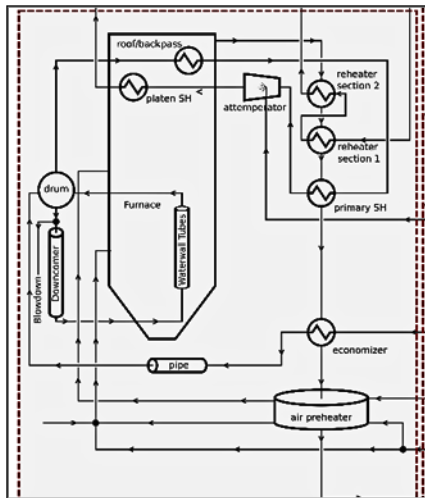


Figure No.2 Primary and Secondary air flow in a coal fired boiler

The pressure of the primary air is normally high since it has to travel through several components [4]. The use of secondary air is to ensure complete combustion reaction [5]. The boiler operating with more air than the theoretical air to be supplied ensures complete combustion of coal. This reduces the formation of harmful pollutants reducing the emissions dissipated to the atmosphere. But if excess air is provided, the results in high fuel consumption and lowers the thermal efficiency. A balance is needed for the complete oxidation of coal in the boiler.

Depending upon the chemical composition of the coal, the theoretical range ranges from 8.6 to 11.2 kg of air per kg of coal. The release of thermal energy during the burning of coal is the main process in the combustion chamber of the sub-critical boilers.

The theoretical amount of air required for evolving same intensity of heat during a combustion will be the same irrespective of the type of coal. The theoretical volume can be said on the basis of the calorific value of coal and is equivalent to 2.63 Nm³ per 10 MJ [6]. The composition of the dry air is 0.209 O₂, 0.009 Ar, 0.781 N₂ and other gases and have an average molecular weight of 28.99 with a density of 1.3 kg/Nm³ at standard atmospheric pressure.

III. CONCLUSION

When the rapid increase of burning coal in thermal power plants, the depletion of coal is a major factor to be noted for. The complete combustion of coal conserves the coal to be used at a optimum level. For obtaining this, the use of excess air in the process of combustion is very important. The combustion reaction in a ideal case is said that is should balance the stoichiometric equations. But the amount of air is just sufficient for burning the coal. The complete combustion is possible by the use of excess air sent during combustion.

REFERENCES

- [1] J. A. Ordonez, "Coal vs. renewables: Least-cost optimization of the Indonesian power sector" *Energy for Sustain Development*, vol. 68, pp. 350–363, 2022.
- [2] P. Basu, *Circulating Fluidized Bed Boilers*. Springer International Publishing, Canada, 2015.
- [3] L. Wang, et al, "Thermal deformation prediction based on the temperature distribution of the rotor in rotary air-preheater" *Applied Thermal Engineering*, vol. 90, 5 November 2015, pp. 478–488, 2015.
- [4] H. Chen, et al, "Performance evaluation of a new conceptual combustion air preheating system in a 1000 MW coal-fueled power plant" *Energy*, vol. 193, 15 February 2020, p. 116739.
- [5] R. Yan, et al, "Influence of inner and outer secondary air ratio on flow and combustion characteristics of a swirl burner in a 29 MW pulverized coal boiler" *Energy*, vol. 237, p. 121625, 2021
- [6] Chen P. et al, "Study on the distribution characteristics of sulphur in Chinese coals", *Fuel*, 1986, 65, 1305 - 1309