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A Review of Literature on Flame Intensity of Pulverized Coal Combustion

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Abstract: The combustion efficiency is the calculation of how effectively the combustion process takes place. To achieve highest level of combustion efficiency complete combustion should take place. Complete combustion takes place when all the energy in fuel is extracted and none of the hydrogen and carbon compound is left. Completecombustion will occur when proper amount of fuel and air are mixed for correct amount of time under the appropriate condition of turbulence and temperature. Flame intensity is the direct indication of completeness or incompleteness of combustion. Stability of flame intensity is of upmost requirement for safe and efficient working of pulverized coal thermal power plant. Authors present the review of literature available on said subject.

Keywords: coal combustion, pulverized coal, flame intensity, combustion efficiency**.**

I.INTRODUCTION

1.1 Scope of coal fired power plants:

Reliable, efficient and clean energy supply is one of the basic needs of humankind. Today, our energy supply system is under-going a long-term transition from its conventional form to a more sustainable and low carbon style, especially addressing greenhouse gas (water, carbon dioxide, methane, nitrous oxide, chloro-fluoro-carbons and aerosols) emissions into the atmosphere. Strong evidence suggests that both the average global temperature and the atmospheric CO2concentration have significantly increased since the onset of the industrial evolution, and they are well correlated. Concerns over climate change have led to mounting efforts on developing technologies to reduce carbon dioxide emissions from human activities. Technological solutions to this problem ought to include a substantial improvement in energy conversion and utilization efficiencies, carbon capture and sequestration (CCS), and expanding the use of nuclear energy and renewable sources such as biomass, hydro-, solar, wind and geothermal energy. Coal has been and will continue to be one of the major energy resources in the long term because of its abundant reserves and competitively low prices, especially for the use of base-load power generation. For instance, the share of coal in world energy consumption was 29.4% in 2009, as opposed to 34.8% for oil and 3.8% for natural gas. In terms of power generation, coal continues to be the dominant fuel, contributing about 45% of the total electricity in the US in 2009, and about 80% in China. Several technologies have been proposed for reducing CO2 emission from coal-fired power generation, namely post-combustion capture, pre-combustion capture and oxy-fuel combustion capture.

1.2 Stabilization of coal combustion flame:

The challenges to maintaining oxy-coal combustion stability have been reported in early pilot scale experimental studies. These challenges stem from the lower adiabatic flame temperature, the delayed ignition and the lower burning rate of coal particles in a CO2diluted environment, among other fundamental issues discussed above.

Two criteria for flame stabilization:

(1) The composition of the fuel/oxidizer mixture must be within the flammability limits.

(2) The local flow velocity must be near the premixed laminar burning velocity (SL).

In this section, the flammability constraints as measured by the preheat temperature and dilution ratio under N2and CO2diluted combustion conditions are investigated using a simplified WSR model. Possible region of stable

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combustion in O2/CO2 combustion are calculated and compared with that under O2/N2conditions. Regarding the second criterion of stability, the characteristics of laminar burning velocity in oxy-fuel combustion is also reviewed, as well as its implications on practical operations. Recent studies and measures taken to improve the stabilization of oxy-coal combustion are introduced.

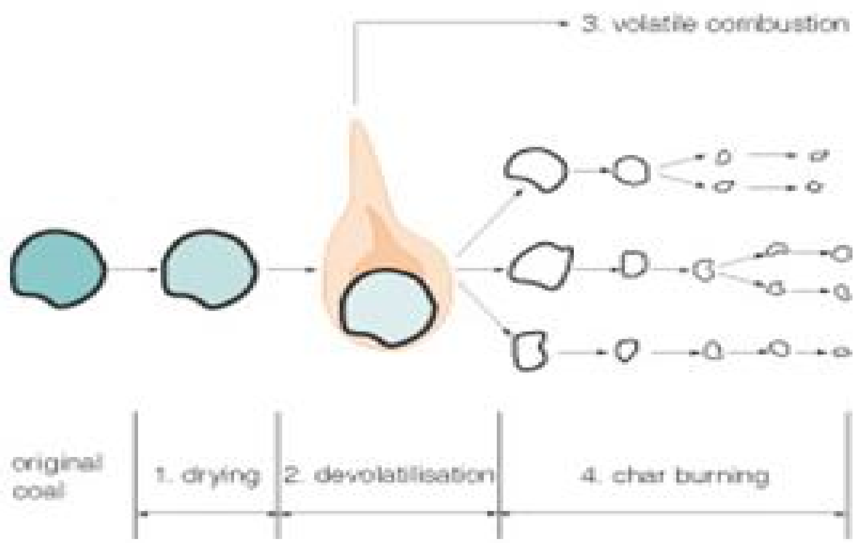

Fig.1 Phases of Combustion

1.3 Phases of Combustion:

As shown in the Fig.1 phases of coal combustion may be described as follows.

- The first phase is associated with moisture evolution and occurs at very low temperatures at about 373 K.
- The second phase at a heating rate of 1273 K/sec begins at about 723 K.
- This is associated with a large initial evolution of carbon dioxide and a small amount of tar.
- The third phase involves evolution of water chemically formed in the range 773-973K and carbon dioxide as the other significant product.
- The fourth phase involves a final rapid evolution of carbon-containing species such as carbon oxides, tar, hydrogen, and hydrocarbon gases in the temperature range 973-1173 K.
- The fifth phase is the high temperature formation of carbon oxides.

II.LITERATURE REVIEW

In this area of research only limited literature are reported, hence the research in this area finds a lot of scope which will enable the researchers to develop an indigenous technique for flame stability improvement.

Zadiraka et al (1996) proposed a method to control the emissions of SOx and NOx content in the flue gases. If coal was to be used as the fuel, the new power plants need to be very clean, with higher efficiency and economical.

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Sensors and control techniques are being developed to permit the accurate measurement and control of the individual burner air and fuel flowsas they are introduced to the time-temperature-turbulence combustion process in the furnace.

Flame Doctor, a burner flame monitoring system was developed by Timothy et al (2004) to reduce NOx emissions and to improve the overall performance. The signals from an optical flame scanner diagnose the operation of the burners. Continuous monitoring by flame doctor makes it possible to analyze the flame color thereby optimizing the overall performance of the furnace load changes, fuel quality variations, and equipment modifications. This article describes the status of an ongoing EPRIBeta Test Program and the results from combustion tuning service work which offers specific challenges encountered during Flame Doctor Installation and start up. Demonstrated performance improvements include reductions of20% in NOx, 70% in CO, and 70% in LOI. These improvements are sustainable and translate directly into significant cost savings in the expenditure of the power plants.

Circulating Fluidized Bed (CFB) boilers are widely used for multi fuel combustion of waste and bio fuels. When several non-homogeneous fuels, having varying heat values, are burned simultaneously, the boiler control system can be affected by various control challenges, especially since it is not feasible to reliably measure the energy content of the multi fuel flow. In order to fulfill the energy production needs and maintain the ability to burn low grade fuels, co-firing with high heat value fuels such as gas, oil or coal is needed. Fuzzy Logic Control (FLC) has been successfully used for solving26control challenges by Timo Hyppanen et al (2000), where the operator's process expertise can be transformed into automation. Real life control objects are often nonlinear because the dynamics change with the operating point, or there might be other essential nonlinearities in the combustion process.

The thermal characteristics of propane air diffusion flames using high temperature combustion air are presented in this work by Ashwani Gupta et al (2000). Global flame characteristics are presented using several different gaseous fuels. A specially designed regenerative combustion test furnace facility, built by Nippon Furnace Kogyo, Japan, has been used to preheat the combustion air to elevated temperatures. Stable flames were obtained at remarkably low equivalence ratios, which would not be possible with normal temperature air. The global flame features showed flame color to change from yellow to blue, bluish-green and green over the range of conditions examined using propane as the fuel. In some cases hybrid color flame was also observed. Under certain conditions flameless or colorless oxidation of the fuel has also been observed for some fuels. Some fuels provide purple color flame under similar operational conditions. Information on the flame spectral emission characteristics, spatial distribution of OH, CH and C2 species and 24emission of pollutants has been obtained. Low levels of NOx along with negligible amounts of CO and HC were obtained with high temperature combustion air. Experimental results have been complemented with numerical simulations. The thermal and chemical behavior of high temperature combustion flames depends on the fuel property, preheat temperature and oxygen. The challenges and opportunities with high temperature-air combustion technology are also described.Oxy-fuel combustion has generated significant interest since it was proposed as a carbon capture technology for newly built and retrofitted coal-based power plants. Research, development and demonstration of oxyfuel combustion technologies has been advancing in recent years; however, there are still fundamental issues and technological challenges that must be addressed before this technology can reach its full potential, especially in the areas of combustion in oxygen-carbon dioxide environments and potentially at elevated pressures.

Ahmed F Ghoniem et al 2011 found that when operating under elevated pressure, the gas phase flow field and coal particle residence time may change significantly. The effect of pressure on the characteristics of mass and heat transfer, char and gas phase combustion kinetics and dynamics, etc, are also still relatively unknown. Research on the characteristics of oxy combustion at elevated pressures is needed.

While swirling flows and their impact on mixing via the establishment of inner recirculation zones near burners and injectors are important in all combustors, they take on a more significant role in the case of oxy-combustion. Better predictive models for rotating and swirling flows are thus needed, especially for the more economical approaches, such as RANS. Due to its complexity; the combustion technology is still heavily dependent on experiments and operational experience, especially in its application in coal-fired power plants. Therefore, successes in pilotand demonstration-scale tests such as the Vattenfall project should provide practical knowledge and experience for the operation, heat transfer, combustion dynamics and stability, as well as pollutant formation and control.

Pulverized coal tangentially fired furnaces are used extensively in power generation worldwide due to a number of their advantages, like uniform heat flux to the furnace walls and NOx emission lower than in other firing types. Further study of the furnaces is needed by both experiments and simulations. While full-scale measurements are restricted by considerably high expenses, numerical simulation provides a cost-effective and powerful engineering tool,

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complementing experimental investigations. Because of the peculiar aerodynamics of the tangentially fired furnaces, the flow inside the furnaces, as well as the combustion processes were found to be complicated for modelling.

S Belosevic et al 2006 presented selected results of numerical simulations of processes in utility boiler pulverized coal tangentially fired dry-bottom furnace. The simulations of the processes are based on a comprehensive 3D differential mathematical model, specially developed for the purpose. The model offers such a composition of sub models and modelling approaches so as to balance sub model sophistication with computational practicality. A 3D geometry, Eulerian–Lagrangian approach, k–e gas turbulence model, particles-to-turbulence interaction, diffusion model of particle dispersion, six-flux method for radiation modelling and pulverized coal particle combustion model based on the global particle kinetics and experimentally obtained coal kinetic parameters are the main features of the model.An essential characteristic of the tangentially fired furnace aerodynamics is the central vortex. As suggested by authors, the vortex is moved toward the switched off burner, effecting the flame position and temperature field in the furnace and the heat fluxes distribution at the furnace walls.

M Habermehi et al 2012 investigated the effect of burner on flame stabilization. Starting from an existing burner design for a bench scale burner, a new burner concept based on aerodynamic stabilization of an oxy fuel swirl flame was developed. For this development process, CFD was intensively used as a design tool. Adapted models for homogeneous and heterogeneous reactions were integrated into the CFD code to take the different conditions for Oxy fuel combustion into account. As a result a burner able to operate in air and oxy fuel conditions was developed and its functionality was demonstrated in experiments. By these experiments, it was proven that applying the measures for oxy coal swirl flame stabilization an oxycoal flame can be stabilized aero-dynamically at an oxygen concentration down to 18 vol.-% for wet and dry recirculation. Based on the successful demonstration of the developed burner design, the stabilization measures and the CFD models were applied to industry scale furnaces leading to a possible design of a 70 MW burner. Based on this design, simulations for a furnace of a power plant steam generator were conducted showing a possible way to operation with similar heat transfer parameters as existing air based steam generators.

Swirl plays an important role in mixing the air–fuel stream and bringing about combustion. Swirl has a great impact on combustion and subsequently on emissions and, hence, was investigated by K Khanafer et al 2011 in this study. All results shown in this section were for a wall temperature of 540K. Results show the effect of swirl velocity on the temperature along the centreline and the exit plane of the burner,respectively.Results shows that in the absence of swirl the mixing between the air and fuel streams is slow (mostly due to diffusion),and hence the combustion is slow. This effect is seen in the sluggish temperature rise along the centreline forS= 0. Introduction of swirl greatly enhances the mixing of the fuel–air stream, bringing about a sharp rise in temperature. Increasing the swirl velocity reduces the lift-off length (distance for the air and fuel stream to rapidly ignite). This result is to be expected because a higher swirl velocity leads to increased mixing between the air and fuel streams, which in turn results in a shorter delay in combustion.

The requirements of actual combustion-circle diameter for a tangentially fired boiler and flame centre for an opposed wall fired boiler under different loads and the disadvantages of burners presently used by these boilers are reviewed. An adaptive PC-fired burner to loads, which is based on a torsion-spring incorporated damper, is proposed. With the damper installed nearby the burner's exit, the axis of air-jet at the exit can be completely self-adjustable without any other drivers. Therefore, the actual combustion-circle diameter and the flame centre can automatically follow variable loads, which will consequently improve ignition, combustion and overall thermal performance.
The structure and principle of this burner are introduced. The effects of structural parameters of the burner on angle deflecting characteristics of the damper and that of the jet are experimentally investigated by Donglin Chen et al 2007.

Donglin Chen et al concluded that The deflected angle of a torsion-spring incorporated Damper and the air-jet at BWD exit is approximately a linear function of air velocity inside burner nozzle and simultaneously affected by the damper's length, installation distance and the spring's mechanical constant. With a proper combination of the spring's mechanical constant k, the damper's length l and installation distances, satisfied deflecting characteristics for the jet of BWD can be obtained.

In UK boilers the video camera probes are mounted on the rear wall to observe the oil gun flames during the start up for safety purpose. When the boiler is on load the large flames are close to the rear wall and there will be dust and ash deposits near the rear wall. This causes variation in the color of the fire ball which is utilized to observe the combustion conditions. A video monitoring system was developed to monitor the combustion activities. A Euclidean distance classifier was used for identifying the combustion conditions along with the CO emissions. Principal Value

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Decomposition (PVD) and Euclidean classifier were used for classification of flame images based on their combustion status by Abdul Rahman et al (2006)

III.CONCLUSION

This paper reviewed the literature on flame intensity of pulverized coal combustion. The discussion focused on the factors that affect the coal combustion flame stability. The various factors that affect the flame intensity are reviewed and it was found that there is scope available for flame intensity improvement at low load condition in coal based thermal power plants and to optimize the operation of combustion chamber of boiler.

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