STUDY OF EFFECT ON BURNING RATE COEFFICIENT OF COAL SLURRY FUEL AND FACTORS AFFECTING IT - A REVIEW

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Abstract—Researchers across the world carried out experimentation to find alternative fuels. The alternative fuels in this paper are basically, mixture of two or more liquid and solid fuels. This paper focuses on the coal liquid fuel slurry i.e. pulverized coal mixed with different liquid fuel. There are various liquid fuels mixed like oil, water, methanol, tar, industrial waste, Nano fluids, organic waste, chemical waste, solvent refined coal. Every researcher has identical experimental set up design. There is a strong need for alternative fuel. This paper will give brief importance review of coal fuel slurry and its effectiveness which is measured by calculating its various burning rate coefficient and also factors affecting the burning rate coefficient. Experimentation is majorly carried in China, USA, Russia and Japan. Results from there experimentation are purely based on or carried on the coal and liquid fuel of their land. Each of the paper has its own results and reading, may differ from each other.

Keywords—coal, coal combustion, coal fuel slurry, burning rate coefficient, coal fuel slurry, single droplet combustion component

I. INTRODUCTION

Coal is by far the largest indigenous fossil fuel resource which currently meets about 60% commercial energy requirements of India. Approximately 86% of the total reserves of Indian coals is non-coking suitable primarily for use in power generation. The power sector consumes about 70% of coal produced in the country. Power generation from coal is based on pulverised coal-fired technology. Environmental problems associated with the increased use of energy are going to attract greater importance in the coming years. Advanced coal utilisation technologies are developed/being developed to respond to the energy and environmental demand of 21st century and also to utilise the coal resources efficiently, economically and cleanly. The anticipated depletion of the world’s oil supply has given rise to greater use of coal, which is estimated to be more abundant than oil [7]. However, coal has some difficulties in its use, such as transportation, storage, pollutants, and ash. One of the effective methods to avoid these peak points is to mix coal particles with oil, that is, the adoption of coal-oil mixtures and many others [7]. It is possible to mix high concentrations of finely pulverized coal with water and a small amount of additive to produce a stable slurry fuel. The fuel can be burned similarly to heavy oil using combustion equipment of ordinary design.

Few alternate option for liquid fuels used in this review paper are CWS (Coal water slurry), COM (coal oil mixture), CMS (coal methanol slurry) and coal oil/water/methanol mixture and also some industrial waste in combination and Nano fluids. The major reasons for investigating the suitability of these fuels are that these fuel slurries can be stored without the danger of coal-dust explosion, pumped, transported in pipelines and combusted like residual fuel oil in an environmentally benign manner [1-4, 7].

Study of Combustion of single drop Coal slurry fuels has been carried by suspending emulsified coal droplet in combustion chamber of high surrounding temperature. The aim of experiment is to study the combustion ignition temperature and burning rate coefficient. And Comparison between combustion ignition temperature and ignition delay time of these coal slurries. Coal particle size varies as per the researcher also; percentage of coal content is different. From
experimental data expected outcome is coal slurry is more efficient than coal. Combustion of droplet undergoes three major stages i.e. first, evaporation phase combustion second, solid/surface phase combustion and third is residue. The micro explosion, during the combustion of a coal-oil/methanol/water mixture is the most violent of all the sample fuels and its apparent overall burning rate coefficient was maintained at the highest value.

II. LITERATURE REVIEW

A fuel droplet, suspended at the tip of a line Pt-Pt/Rh13% thermocouple of 0.1 mm wire diameter, was inserted into the high temperature wind tunnel (a porcelain tube) and then ignited spontaneously. The air temperature flowing through the porcelain tube was varied in the range 850 & 1000°C and was measured using a suction pyrometer. The rate of air flow was maintained at 0.76 kg mm2 s-1. The characteristic initial diameters based on the volume surface ratio were between 0.99 and 1.87 mm. 10 measurements were made for each sample for each set of conditions. Burning behavior was recorded by a BOLEX 16-mm motion picture camera and/or a video camera. Then, the burning times for each combustion process were measured. Figure (1) shows the schematic of experimental setup [1, 2, 4, 5].

The fuel is prepared from coal dust in two stages, in accordance with the recommendations [10-11]. First, a mixture of water and spent turbine oil is prepared for 3–5 min in the working volume (0.25 L) of an MPW-302 homogenizer. In the second stage, lignite dust is added to the resulting water–oil emulsion. The components are mixed for 5–8 min. The suspensions based on coal-enrichment wastes are prepared in a single stage, by mixing wet filter cake and the combustible liquid component [9].

The \( d^2 \) law is well established for the combustion of volatile fuel droplets. It states that during droplet combustion the square of the instantaneous droplet diameter varies linearly with the elapsed time. Kobayashi [10] has pointed out that this linear relation cannot be applied to the combustion of residual fuels because of the formation of residual carbonaceous substances, although the square of the initial droplet diameter is still approximately proportional to the volatile combustion period for the same fuel and under the same condition. This relation has been referred to as the "square law of initial diameter."

Two kinds of burning rate coefficient based on the square of initial droplet diameter were defined as:

\[
K_o = \frac{D_o^2 - D_n^2}{t_o} \quad \ldots [1, 2, 3, 5]
\]

Where:
- \( D_o \) = initial droplet diameter,
- \( D_n \) = diameter of the thermocouple bead,
- \( t_o \) = overall combustion time

The burning behaviour of 20%M-COM and 10%W-COM droplets were ignited spontaneously. In the case of M-COM, a micro-explosion was observed as soon as the droplet ignited. It was observed in the experiments that W-COM burned instantly with a micro-explosion occurring just after ignition. WCOM droplets which contained >20 wt% water did not ignite.
spontaneously at an ambient temperature of 850°C and only scattering or disruption of the droplet occurred [1].

It was noted from that a number of fine particles were scattered by the micro-explosion of the parent droplet in both M-COM and W-COM combustion. The Sauter mean diameters of the scattered particles were 96 and 105 pm for M-COM and W-COM, respectively. From this result, it was found that the effect of a micro-explosion on secondary atomization was fairly marked. In the case of combustion of a COM droplet, however, single agglomerate was produced after gas-phase combustion because the micro-explosion did not occur during combustion. Chart 1 shows the relationship between k, and ambient air temperature, Ta, for every sample fuel of M-COM. The value of ko, was 2-3 times higher than that of 50%COM. However, the k, of W-COM was 2-10 times higher than that of 50%COM, though the values varied widely depending on water content and ambient air temperature. Furthermore, it is noticeable that the ko of 10%W-20%M-COM showed the highest value within the range of Ta= 850 & 1000°C for all the sample fuels tested in this experiment [2]. Chart 2 shows the effect of the ambient air temperature, Ta, on k, for CMS, methanol and the sample coals. In the case of combustion of a methanol droplet, &, increased with ambient air temperature because the rate of vaporizing combustion was controlled by the heat transfer rate.

The scattering phenomena of a CMS droplet differ from the disruption of pulverized coal particles themselves. In the case of CMS combustion, the pulverized coal particles, scattered along the wake behind the CMS droplet, burned in the hot ambient air. The simultaneous combustion of methanol and coal volatile matter occurred as soon as the droplet ignited. At the same time the droplet temperature rose rapidly. Though the diameter decreased temporarily by volatilization just after ignition, the droplet swelled again due to thermal cracking of the coal at ~400°C.

Chart -1: Effect of ambient air temperature on apparent mean overall burning rate coefficient.

X, 50%COM; O, 5%M-COM; Δ, 10%M-COM; □, 20%M-COM; ▽, 30%M-COM; ●, 5%W-COM; ▲, 10%W-COM; , ▼, 20%W-COM; ■, 30%W-COM; +, 10%W-20%M-COM

Chart -2: Effect of ambient air temperature on apparent mean overall burning rate coefficient.
In the case of combustion of a methanol droplet, \( z \), increased with ambient air temperature because the rate of vaporizing combustion was controlled by the heat transfer rate. Although the temperature dependencies of \( z \) for CMS mixture and the coals were very small, large differences in \( z \) were recognized between the different fuel samples. The values of \( k \), for the combustion of coal particles were lower than those for the other fuels because the solid phase combustion time of the coal particles was very long\[2\]. At the moment of ignition \(( t = 7.764 \text{ s})\), an exothermic process is initiated inside the droplet (a visible dark border line between the droplet and air). This result can be explained by the fact that plasticizers affect the characteristics of high-temperature moisture evaporation by forming a thin film on the droplet surface. During the heating of the fuel droplet, the temperature of coal ignition is reached. After some time, the ignition is initiated inside the fuel droplet and then the flame spreads throughout the droplet \[4\]. Since heterogeneous burning occupies the bulk of the burning time, in the following a model is formulating describing burning during this period. Since heterogeneous burning occupies the bulk of the burning time, in the following a model is formulated describing burning during this period. It is also of interest to assess the relative influence of diffusion and chemical reaction in controlling the bulk burning process \[5\]. It may be pointed out that the water that is incorporated into the slurry represents a relatively small energy penalty to the fuel. This is apparent if one considers typical enthalpy values involved. \[8\].

III. CONCLUSIONS

The coal particles of the coal–water suspension drops are located irregularly. The fluid in the suspension combines the particular coal particles into bigger agglomerates. In the case of the coal–water suspension made of coal particles of various sizes, the tendency was observed to form groups of larger particles inside the suspension and smaller particles flow to the drop edge. The specificity of suspension combustion in the conditions of the fluidised bed, changes the mechanism and kinetics of the process. After water evaporation, located outside the agglomerate coal particles reach the melting temperature and stick with each other, forming a shell. \[3\]. The combustion of CMS is a sequential two-stage process, consisting of gas-phase combustion followed by solid-phase combustion. Scattering of pulverized coal occurred during the gas-phase combustion period. The effect of ambient air temperature on the apparent overall burning rate coefficient of CMS droplets was small \[1\]. The predicted results imply that the heterogeneous combustion of the char agglomerate is diffusion-limited except in environments of ultra-low oxygen concentration, within which the finite rate kinetics of the reaction of C with CO, and H2O appear to exert a stronger influence \[5\]. The overall burning rate coefficient is approximately equal to that of the solid burning rate because the solid combination period occupies a major portion of the total combustion period. The overall burning rate coefficients for slurry fuel droplets are about 1/4 to 1/2 times those of the residual heavy fuel oil. They depend on the residual carbon content in the slurry fuel \[6\]. The slurries were found to burn satisfactorily, and the many variables associated with the burner, furnace, etc., were investigated and optimized in preliminary tests. The burning performance was characterized by measuring combustion efficiency and examining this dependent variable as a function of air/fuel ratio \[8\]. Stable ignition of individual suspended droplets of coal–water slurry based on lignite, coal-enrichment wastes, and spent turbine oil is possible at oxidant temperatures of 820–860 K. Such low threshold temperatures illustrate the great promise of droplet suspension for different fuel compositions \[9\].

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