IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 54-59

Influence of air flow temperature on Isolated Coal Water/Oil/Methanol Mixture Droplet

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Abstract: *- Experimental investigation of sample fuels coal-water/methanol/oil mixture. Every liquid fuel was added to pulverize coal in percentage weight. For every fuel Combustion temperature, time is noted and burning rate coefficient is calculated. Great impact of air flow temperature is observed on combustion temperature and burning rate coefficient. 50% and more Oil in Coal Oil Mixture achieve highest temperature and moderate burning rate coefficient as compare to other fuels. Due to presence of low grade coal in India, immense and expensive coal is imported in India. The aim of this project is to find alternative fuels replacing oil in industries and utilization of low grade coal. By varying air flow temperature in the process of fuel combustion, improvement in results i.e. combustion temperature and burning rate coefficient is observed.*

Keywords: *- Air flow temperature, burning rate Coefficient, Coal-Water Mixture, Coal-Oil Mixture, Coal-Methanol Mixture, Combustion Temperature, isolated droplet.*

I. Introduction

India has become a power surplus country with huge power generation capacity idling for want of electricity demand. The issue of coal availability assumes significance because the commodity accounts for more than half of the country's energy mix. To sustain the growth rate of 8-9 per cent over the next few decades, the country has invariably to depend on coal. The country has increasingly to rely on imports, which are set to grow to 142 million tonnes next fiscal, from 83 million tonnes this year. The utilization of coal has recently attracted special interest as an alternative energy source in place of petroleum [4].

Coal liquid slurry was initially developed in Russia about 80 years ago, and the technology was further refined in Europe in 1950. Coal-oil mixtures have been investigated for over a century, and during World War I attempts were even made to use the fuel in submarines. Interest has fluctuated with coal and oil prices. Much work was carried out in the USA with the aim of eking out the dwindling oil reserves, but the price differential between coal and oil was too small to encourage development [32].

Single droplet combustion of coal-oil/methanol/water mixtures was investigated. A micro explosion occurred during the gas-phase combustion period of emulsified fuels and caused secondary atomization of fuel droplets. Appropriate addition of water and/or methanol in COM improves combustion characteristics of mixtures [7]. The effect of ambient air temperature on the apparent overall burning rate coefficient of CMS droplets was small [4] whereas, MW-COM shows noticeable high burning rate coefficient among all [7]. The combustion is a sequential two-staged process, consisting of gas-phase combustion of the volatiles followed by combustion of the solid residue, which is mostly carbon. The duration of combustion of the solid residue agglomerate was several times longer than that of the volatiles and therefore constituted a major part of the total burning time. The gas-phase burning time as well as the total burning time was found to vary linearly with the square of the initial droplet diameter, thus obeying the "square law" of initial droplet diameter [5]. Water from the coal–water suspension clearly intensifies the combustion process, causing the lowering of ignition temperature and the highest combustion temperature has the suspension made of coal dust of the lower type, and its combustion time is the lowest [2]. Positive effects of staged firing were reduction in volume and velocity of flue gases lowered heat losses, increase in boiler efficiency and reduce NOx products. CWM combustion is carried on in three different ways firstly, CWM combustion using oxygen enriched air. Second CWM combustion using staged firing; third one is combination of above two [8].

In this experimental investigation, single isolated droplet combustion of coal-water (CWM), coal-methanol slurry (CMM), and coal-oil mixture (COM) which consists water, methanol, oil and pulverized coal, by varying there weights has been examined. Effect on Combustion Temperature and burning rate coefficient is calculated for increasing air flow temperature.

II. Experimentation

The Pulverized bituminous coal of particle size <100 µm, three samples for each three type of liquid fuel are experimented by suspending isolated droplet in the middle of combustion chamber made of Quartz glass by the means of fine wired thermocouple i.e. Generic K-Type Digital Thermometer/Thermocouple Sensor. The tip holding droplet has 1mm diameter. For example, 25% of water is added to pulverized coal. This is done by measuring weight of both the elements on Digital Portable Weight Machine with LED Weighing Scale Display. Air Flow temperature is varied from 6000C to 8000C to note down effect on combustion temperature. The fuel drop undergoes combustion with it is ignited by force ignition method. The temperature and time of combustion is recorded. Then water content is raised to 50% and 75% in coal fuel slurry and its readings are noted down and same procedure is followed for rest type of fuel. As per the burning rate coefficient formula, the diameter of tip of K type thermocouple holding droplet and the diameter of droplet is measured and time is recorded for all types and contents. Using this data, burning rate coefficient is calculated. Ambient temperature is varied by increasing heater temperature. In case of coal water mixture, additive naphthalene oil is added.

During the attainment of coal-water slurry of high-coal concentration, the viscosity of the slurry increases with every increase in the particle-particle interaction, thereby leading to severe adverse effects on the storage as well as on the transportation properties of the slurry. Since a significant region of the coal is hydrophobic, the inter-particle association can be controlled by masking the hydrophobic sites of the coal or by rendering the coal surface with sufficient dispersant such that coal-water interaction will be promoted instead of coal-coal interaction. Thus, the dispersant/additive/agent plays an important role in the preparation of concentrated CWS systems.

Fig. 1: Experimental setup

1. Quartz glass cylinder, 2. Exotic Thermocouple Probes, 3. Manometer, 4. Vertical Heating Oven, 5. Heater temperature indicator, 6. Exotic Thermocouple indicator, 7. Oxygen cylinder. 8. Supporting stand

Fig. 2: Generic K-Type Digital Thermometer/Thermocouple Sensor

2.1 Burning Rate Coefficient

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. Burning rate coefficient is ratio of difference of square diameter of initial droplet and diameter of thermocouple bed to the overall time of combustion. Assumptions incorporated into the d^2-law of droplet combustion: Spherical symmetry, Isolated droplet in infinite medium, Isobaric process, Chemical reaction infinitely fast with respect to diffusion, Constant gas phase transport properties and heat capacity, Gas phase quasi-steadiness, Constant, uniform droplet temperature, Neglects Soret effect, Dufour effect and radiation, Unity Lewis number for all gaseous species, Negligible buoyancy, Negligible radiation. The justification of this assumption is based on the relatively slow regression rate of the liquid fuel droplet as compared to gas phase transport processes [5].

$K_o = (Dn^2 - Do^2) / to$ ………………..(1)

Where, Ko= burning rate coefficient, mm2/sec
Do= initial droplet diameter, mm
Dn=diameter of thermocouple bead, mm
to= overall combustion time, sec

III. Results

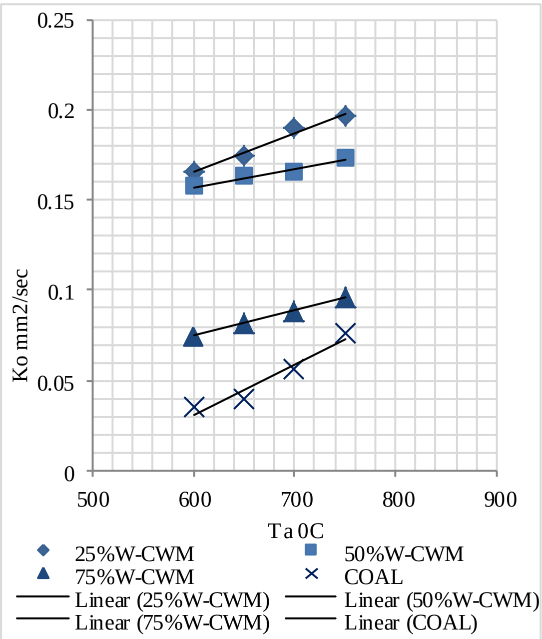

Fig.3 Effect of air flow temperature on burning rate coefficient of CWM

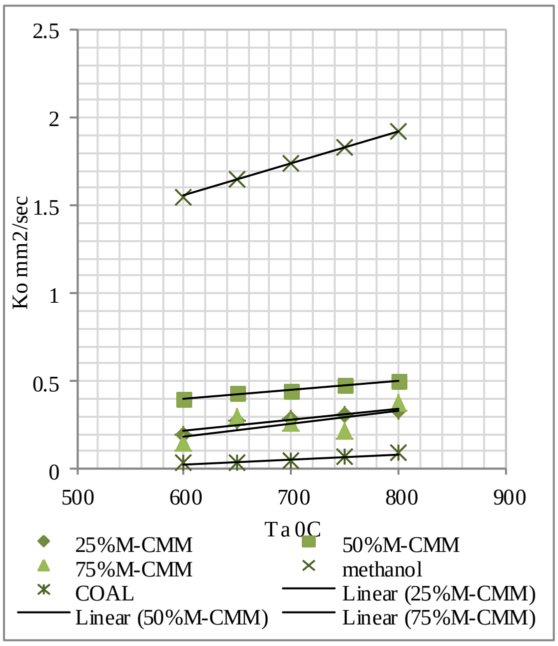

Fig.4 Effect of air flow temperature on burning rate coefficient of CMM

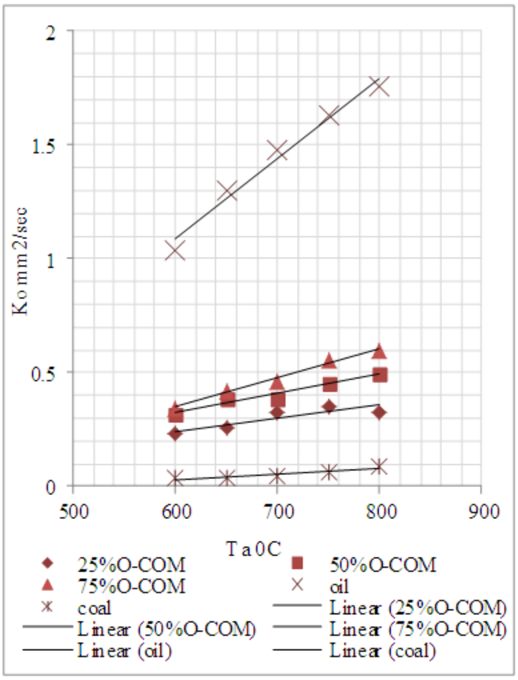

Fig.5. Effect of air flow temperature on burning rate coefficient of COM

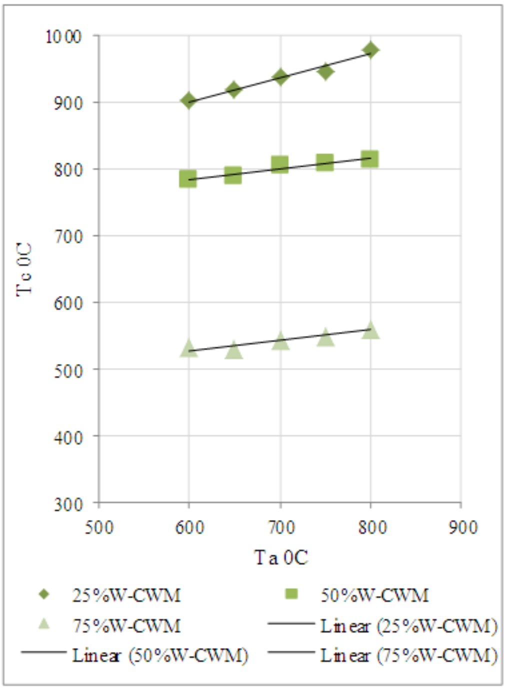

Fig.7. Effect of air flow temperature on combustion temperature of CMM

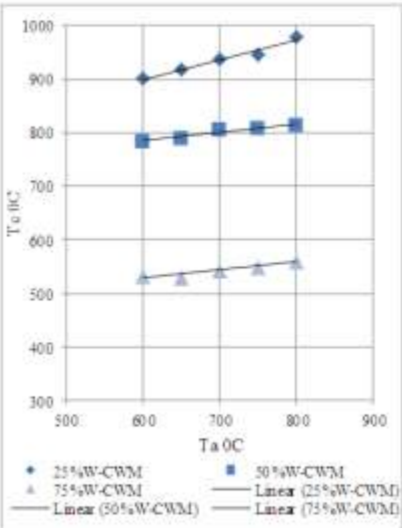

Fig.6. Effect of air flow temperature on combustion temperature of CWM

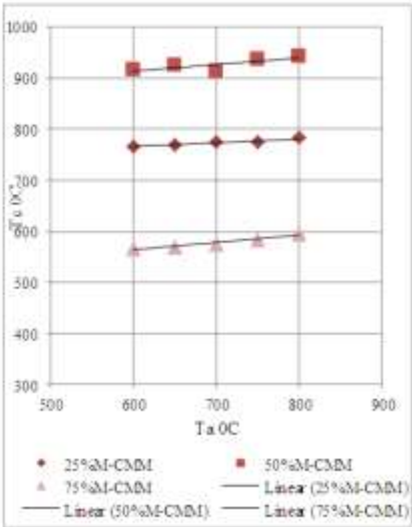

Fig 8. Effect of air flow temperature on combustion temperature of COM

IV. Conculsion

A From the results we can state that increasing the air flow temperature or combustion temperature increases fuel burning rate coefficient and combustion temperature. The advantage of coal slurry fuel is low grade fuel can be utilized and adding liquid fuel enhance coal property. Among the three sample fuels, Coal oil mixture highest burning rate coefficient and combustion temperature. Air flow temperature or combustion chamber temperature was restricted to 900^0C for safe side is the limitations. There is possibility that coal liquid mixture can attend more temperature and burning rate coefficient, if more than 1000^0C air flow temperature is attended. Coal slurry fuel is intended to use as alternative of oil. Use of coal liquid mixture can significantly reduce the import of coal. Liquid fuel used was in 25%, 50% and 75% proportion. Further work can be done for coal water slurry for water below 25% in coal water mixture and adding more different additives. Application of coal slurry fuel in petroleum industries, oil and gas industry, oil fired power plant, automobile etc

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