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STUDY ON COMBUSTION BEHAVIOURS OF BRIQUETTE FUEL PRODUCED FROM CROP RESIDUES

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ABSTRACT : This study examines the effect of combustion properties of briquettes produced from different crop residues. The densification of biomass changes the combustion characteristics, in view of that the system was designed to determined combustion characteristics of different crop residues briquette using a specially design combustion chamber. In this experiments air is blown around the combustion chamber. The maximum specific rate of combustion achieved 92.8kg/h-m^2 with airflow rate 63. 6m^3/h. The higher biomass consumption was observed that mix briquette 17.7 kg/h. with air flow rate 63.6 m^3/h. The result indicates that as the airflow rate increase, the rate combustion and temperature of combustion both increase simultaneously. Oxidation temperature and flame temperature in the combustion chamber as depend on a function of airflow rate.

Keywords : *Biomass, crop residue briquettes, combustion chamber, combustion properties, electric blower.*

Renewable energy sources is becoming increasingly necessary and thrust towards wider application of renewable energy devices at domestic, commercial and industrial levels not only resulted in greater awareness but also significant installed capacities. On a rural level in developing nations, typically about 3-5 tons of agricultural residues are produced per acre (Stanley, 9).Residues however, are often small in size when compared with solid biomass, burn rapidly with fluctuating power output and produce more emission products resulting from incomplete combustion. They also have problems associated with their transportation and storage. Since biomass is the only carbon-based renewable fuel, its application becomes more and more important for climate protection. Thermo chemical conversion technologies i.e., combustion, gasification, and pyrolysis are the proven technology for heat and power production.

There is a growing network of people manufacturing them on both rural and industrial scales. The result has been the establishment of many small scale briquetting enterprises that generate income and provide an alternative fuel for rural village community's .The selection or choice of agro-waste briquettes for domestic and industrial cottage applications depends on the fuel properties. Biomass residues from agriculture and industry can provide an alternative to solid wood fuel. They can be found in abundance in many parts of the world. In this way the energy density of the fuel is increased, and handling characteristics are improved transportation is made more feasible and burn rate can be controlled (Olorunnisala, 6). Ever increasing energy demand and the polluting nature of existing fossil fuel energy sources demonstrate the need for other none polluting and renewable sources of energy (Natarajan *et al.,* 4). Biomass is widely considered as an important potential fuel and renewable energy resources for the future. The common usage of biomass is in low capacity boilers or furnaces, local house hold cooking or farm heating, which is the simplest and cheapest way, but inefficient for extensive energy production (Jankes and Milovanovic, 2).

This paper is part of a study in which the combustion behavior of biomass briquettes is being experimentally investigated. The aim is to more carefully understand the role of biomass briquette combustion and to develop a simple cylindrical combustion chamber that will predict the briquette burn rate. The concept of biomass waste or residue utilization will continue to be a topical issue in developing countries of the world. Large quantity of crop residues and forestry based residues are generated on yearly basis. The major agro based residues come from rice husk, coffee husk, maize stalk and husk, sugarcane bagasse, jute sticks, silk cotton

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pods, groundnut shells (Shri, 8). The biomass residues generated by the wood based industry in most developing countries have potential to replace energy sources such as firewood in domestic energy need (Suarez *et al.,* 10). Briquetting is the process of compact the biomass residue into a uniform solid fuel called briquettes. It has higher density and energy content and less moisture compared to its raw materials. Briquetting of biomass can be done using various techniques, either with or without binder addition. In the developing countries, biomass briquettes are mainly for household usage only. Briquettes made from crop residues can reduce forest degradation and deforestation to mitigate these problems. Among several kinds of biomass, agricultural residues have become one of the most promising choices. Some agricultural wastes such as wood can be directly utilized as fuels. Nevertheless, a majority of them are not suitable apparently because they are bulky, uneven, and have low energy density. All these characteristics make them difficult to handle, store, transport, and utilize in their raw form. Hence, there is the need to subject them to conversion processes in order to mitigate these problems. One of the promising solutions to the problems unutilized crop residues is the application of briquetting technology. The technology may be defined as a densification process for improving the handling characteristics of raw materials and enhancing volumetric calorific value of the biomass (Oladeji, 5).

MATERIALS AND METHODS

System description

Biomass combustion chamber was fabricated at the department of agriculture energy and power (AEP) division, workshop at CIAE, Bhopal. To meet the determine characteristics of biomass briquette. The schematic diagram of biomass combustion chamber is shown in (Fig. 1). The biomass combustion chamber consists of well insulated cylindrical reactor, cast iron grate and five air nozzles at diameter were 15 mm each. Air supplied to five air nozzle each air channel supplies air to provide a circular pipe connected to air nozzle around the combustion chamber. Air nozzle is placed at 10 cm above the grate. The diameter of the grate was 50 cm. The grate was positioned at a distance of 10 cm above the bottom end of the combustion chamber. The reactor is a mild steel (IS 2062) cylinder having outer diameter about 55 cm, height about 50 cm and inner diameter 50 cm. Heat is transferred by conduction through the walls of the combustion chamber. Consequently, by improving the insulation of the combustion chamber, a higher combustion chamber temperature can be achieved. In order to minimize heat losses critical insulation at inner side of combustion chamber with 2.5 mm thickness of insulate 11 insulating refectory castable (from Ace calderys Ltd.) was held by mild steel anchors welded to the inner shell of the combustion chamber.

Studies on Combustion Characteristics of Briquette

The densification of biomass changes the combustion characteristics, in view of that the combustion characteristics of different type of briquette was studies in a specially designed biomass combustion chamber at different air fuel ratio. In this study, the burning characteristics of crop residues briquettes were studied using a vertical cylindrical combustion chamber. The combustion chamber is an attempt to simulate the actual combustion situation for determines different characteristics of biomass. The combustion chamber was tested with three different crop residues briquette with diameter of about 60 mm i.e. soybean briquettes, pigeon pea briquettes, mix briquette of (soybean+ pigeon pea). The combustion characteristics such as rate of combustion, temperature profile of combustion characteristics, air supply, burning time, fuel consumption were determined. There used different crop residues briquette i.e soybean briquette, pigeon pea briquette, and mix briquette, the feed stocks analyze for physical and chemical parameters included bulk density, moisture content, volatile matter, ash content and fixed carbon, Ash fusion temperature, Calorific value (Mahadeo *et al.,* 3) as shown in (Table 1).

Table 1 : Physical and Chemical properties of crop residues briquette

Characteristics	Soybean briquette	Pigeon pea briquette	Mix biomass briquette (soybean+pigeon pea)
Diameter (mm)	60	60	60
Length (mm)	60-85	70-95	65-80
Bulk density (kg/m^3)	618	625	598
True Density (kg/m^3)	1130	1150	1120
Moisture content (wb) %	8.75	9.12	8.9
Volatile matter (%)	76.96	77.07	79.14
Fixed carbon (%)	16.46	15.88	13.52
Ash content (%)	6.58	7.05	7.34
Ashfusion temperature (°C)	1147	1210	1183
Calorific value (kcal/kg)	4520	4107	4180

Biomass consumption (kg/h)

Biomass consumption is the amount of mass of a material that goes through combustion over an amount of time for the biomass combustion is complete. With known amount of total burnt briquette and burning time, average combustion rate can be calculated by using following formula.

Biomass consumption kg/h

$$= \frac{\text{Mass of briquette burn}}{\text{Burning time}}$$

Specific rate of combustion (kg/h-m^2)

Specific rate of combustion ($\text{kg}/\text{h}-\text{m}^2$) is the amount of mass of a material that goes through combustion over an amount of time per unit cross-sectional area of reactor.

$$\text{SRC}\ (\text{kg}/\text{h}-\text{m}^2) = \frac{\text{Biomass consumption (kg/h)}}{\text{Grate area}\ (\text{m}^2)}$$

Temperature of combustion chamber

Temperature of combustion chamber depends on the moisture content and fuel composition will vary continuously as a function of burnout. This, together with a much lower fuel consumption rate, may decrease the temperature in the combustion chamber below the level needed for complete combustion. Combustion temperature measured by using type K-thermocouple with digital temperature indicator.

Temperature of flame

Temperature of a flame is dependent on the type of fuel involved in the combustion, the combustion temperature of a flame measured by type K-thermocouple with digital temperature indicator.

Air flow rate

Anemometer have traditionally been employed for measuring the air velocity at numerous points, calculating the mean velocity, and then multiplying the mean velocity by the cross sectional area of the pipe. Air for combustion was supplied from air compressor through three perforated pipes with four holes in each pipe. The mass flow rate of air was calculated as ma = velocity of air x cross-sectional area of holes x no. of holes (Hussain *et al.,* 1). The air flow rate (m^3/h) through the circular pipe is determined by using following formula.

$$\text{Air flow rate} = \frac{\pi}{4} \times d^2 \times V$$

Where, d = diameter of pipe, (m) and v = velocity of air, (m/s)

Air fuel ratio

Air fuel ratio defines as the mass of air added relative to the mass of feedstock. It is used for quantify the amounts of fuel and air in a particular combustion process. The air fuel ratio is the amount of air in a reaction to the amount of fuel. The air fuel ratio can be expressed on a wet basis or dry basis. The standard measure of the amount of air used in a combustion process is the Air-Fuel Ratio (AFR), defined as follows. Mass of air = ρvA .Where, ρ = Density of air, (1.25 kg/m^3), v = Air velocity, (m/s) A = Area of pipe, (m^2)

Air fuel ratio calculates by following formula.

$$\text{AFR} = \frac{M_{air}}{M_{fuel}}$$

Where, M_{air} = mass of air, (kg/hr), M_{fuel} = mass of fuel, (kg/hr).

It is the ratio between the mass of air and the mass of fuel in the fuel–air mix at any given moment.

RESULTS AND DISCUSSION

Combustion characteristics

The combustion characteristics of different crop residues briquette was studied in combustion chamber. In this experiment air was supplied for combustion by using electric blower with positive air supply through five air nozzles are fitted at equally distributed on combustion chamber above the grate. These air nozzles were connected with circular pipe for uniform flow of air. The velocity of air is measured by a thermal anemometer. The flow rate of air is controlled by a valve, provided at the inlet of air supply. Blower was start at the time of ignition. Ignite at the bottom of the chamber with ignition torch, duration of ignition 6 - 9 minute required for flame formation.

Fig. 1 Photograph of biomass combustion chamber with blower.

Effect of briquette on specific Rate of combustion

The biomass consumption of soybean briquette varied 14.3 to 16.2 16.9 kg/h, pigeon pea briquette 14.9 to 17.1 kg/h, and mix biomass briquette 14.3 to

17.6 kg/h at the air flow rate 25.4, 38.2, 50.8, 63.6 m^3/h. In this experiment higher biomass consumption was observed in mix briquette 17.6 kg/h with airflow rate 63.6 m^3/h. show in (fig. 2).Combustion rate are increase with increasing airflow rates. in experiments were specific rate of combustion observed that

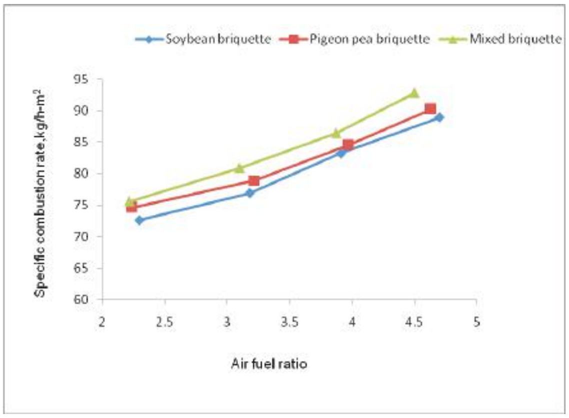

Fig. 2 : Specific rate of combustion of briquette of different biomass.

soybean briquette 72.5, 78.9, 85.4, 88.9 kg/h-m^2, in pigeon pea briquette 74.6, 77.9, 84.2, 90.2 kg/h-m^2 and mix briquette 75.2, 80.9, 86.5, 92.8 kg/h-m^2 with air flow rate 25.4 ,38.2, 50.8, 63.6 m^3/h respectively. Were found that Combustion rate are increasing with increasing airflow rates and decreasing time of reaction of the combustion process as shown in Fig 3. The combustion rates are higher in the temperature increasing stage; they may reflect that the combustion behaviours of densified briquettes are changes during the course of the combustion processes at different air flow rate.

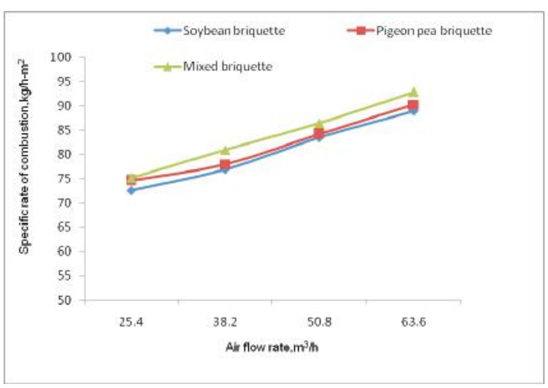

Fig. 3 : Rate of combustion w.r. to air flow rate of crop residues briquette.

Effect of briquette on oxidation Temperature and Flame temperature

Oxidation temperature and Flame temperature play important roles in combustion control and variations in gases. Temperature of combustion chamber was measured by using K-type thermocouple. Thermocouple positioned at oxidation zone, had the highest temperature reading which was found that in soybean briquette 1129 °C, in pigeon pea briquette 1139 °C and mix briquette 1135 °C at the air flow rate 63.6 m^3/h respectively. It also found that achieved higher oxidation temperature in the combustion chamber result that clinker formation at near the air nozzle. Generally, flame temperature rises with increasing primary airflow rate. At a small air flow rate, a wet fuel can produce a higher peak flame temperature in the bed than a drier fuel, but the maximum flame front temperature achievable in the whole air flow range decreases with increasing moisture in the fuel. Flame temperature in the combustion chamber as depend on a function of airflow rate. Flame temperature responds to a further increase in the airflow. In experiment observed that the flame temperature of the different briquette was found that the higher temperature achieved in soybean briquette 1027 °C, pigeon pea briquette 1037 °C and mix briquette 1018 °C with higher air flow rates 63.6 m^3/h, respectively.

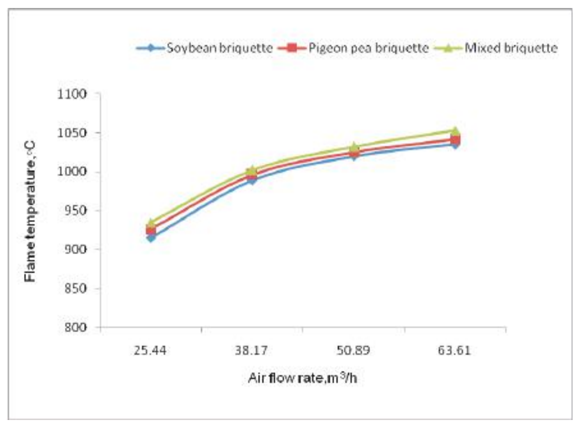

Fig. 4 : Oxidation temperature of briquette at different air flow rate.

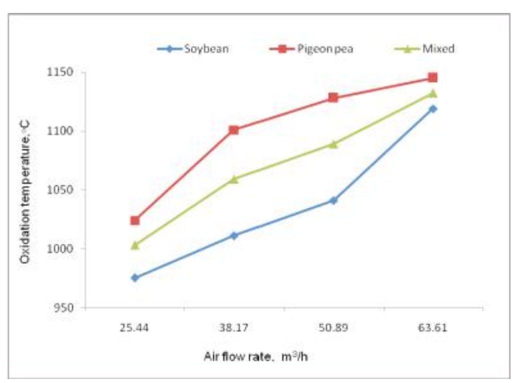

Fig. 5 : Flame temperature with briquette at different air flow rate.

Effect of Air Flow Rates on combustion of briquette

The effect of airflow rate on the ignition behaviour of the combustion chamber was experimentally investigated. It can be seen that the increasing air flow rate (Fig.4 &,5) increasing the temperature, flame temperature, and higher rate of combustion in the combustion chamber It could be also observed that the increasing of the air flow rates decreased reaction of time. Combustion time for a single densified biomass fuel such as pellet or briquette mostly depended on the raw material composition and on the density the combustion time is the sum of pyrolysis time and char combustion time (Rhen *et al.,* 7). Air fuel ratio was calculated that for soybean briquette 2.30, 3.18, 3.91, 4.70, pigeon pea briquette 2.24, 3.22, 3.97, 4.63, and mix briquette 2.22, 3.10, 3.87, 4.50 at different air flow rate 25.4, 38.2, 50.8, 63.6m^3/h, respectively.

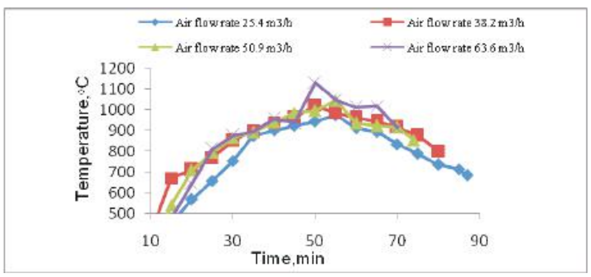

Fig. 6 : Temperature profile of oxidation zone with soybean briquette.

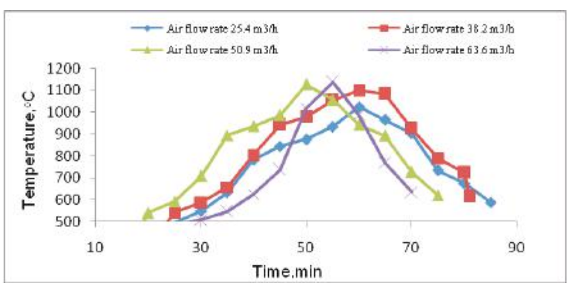

Fig. 7 : Temperature profile of oxidation zone with pigeon pea briquette.

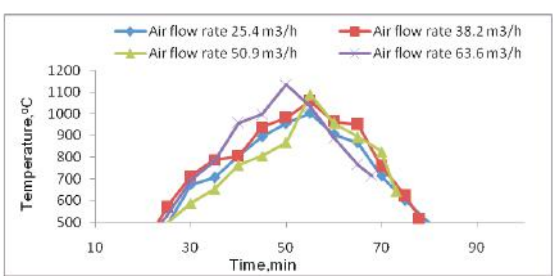

Fig. 8 : Temperature profile of oxidation zone with mix biomass briquette.

CONCLUSION

This work was carried out to examine the Combustion behaviours of densified briquettes produced from different crop residues using specially design combustion chamber. There combustion character changes during the course of the combustion processes at different air flow rate. The result indicates that as the airflow rate increase, the specific rate combustion and temperature of combustion both increase simultaneously. The maximum specific rate of combustion achieved 92.8 kg/h-m^2 and higher biomass consumption was observed that mix briquette 17.7 kg/h. with air flow rate 63.6 m^3/h respectively. Increasing the air flow rates decreased reaction of time, the residence time needed for complete combustion is directly affected by the combustion temperature and air flow rate.

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