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Combustion Characteristic of Low Rank Coal Blend with EFB and Plastic Waste[#]

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ABSTRACT

Plastic waste and organic waste in the form of biomass are possible to produce alternative energy to drive turbines in power plants by turning them on with coal in the co-firing process. This study has purpose analyzing the behavior of coal combustion with a mixture of EFB and plastic compared to the pure coal using the TGA-DSC method. Test were carried out under atmospheric conditions. Addition of biomass in mixture lower the ignition temperature (T_{ig}) of coal. The sample with lowest T_{ig} is C1 (Coal + EFB) with value of 257.8°C. Mixture with biomass decreasing the reactivity of coal with value T_{max} is increase, C2 (Coal + EFB + PET bottle) has highest T_{max} with value of 423.1°C. C2 also has highest T_{bo} with value of 622.5°C. From T_{max} and T_{bo}, it showed that addition of biomass decreases the self-burning tendency and prolong the combustion.

Keywords: plastic, empty fruit bunch, co-firing, TGA-DSC

NONMENCLATURE

Abbreviations	
EFB	Empty Fruit Bunch
DTG	Differential Thermo Gravimetry
ar	As Received
adb	Air Dried Basis

1. INTRODUCTION

Indonesian waste production is expanding in line with the country's economic development and population growth. Plastic garbage is one sort of waste that be a source of concern. Plastic garbage accounts for 15% of total national waste production, with an average annual growth rate of 14.7%, making it the second greatest contributor after organic waste [1]. The use of plastic in society is very high because of its wide function, hygiene, low cost production, and easy to find [2]. In one year, 10.95 million pieces of plastic waste were produced by 100 member stores of the Indonesian Retail Entrepreneurs Association (APRINDO) [3]. Plastic waste and organic waste in the form of biomass can be utilized as a material for coal mixtures in the co-firing process. Joint combustion, often known as co-firing, is a method of waste utilization into fuel. Co-firing is the use of two fuels in one boiler furnace at the same time [4]. Alternative energy will be generated by combining waste with selected coal and biomass to power turbines in power plants. Because it does not necessitate the construction of new power plants, co-firing biomass is a less expensive option to utilize biomass for energy production [5]. The empty fruit bunch (EFB) is a form of biomass that can used as material for co-firing mixtures, the waste obtained from the production of crude palm oil, at least 42 million tons of waste are generated annually in Indonesia [6]. The use of biomass as a mixture fuel at power plant combustion is one option to meet the Indonesian government's 23% target for new and renewable energy mix objective by 2025 [7].

This study has purpose analyzing the behavior of coal combustion with a mixture of EFB and plastic waste compared to the pure coal using the TGA-DSC method. Simultaneous mass and thermal changes during combustion can be analyzed and imaged using TGA-DSC analysis [8]. The TGA-DSC instrument can be used to investigate changes in mass and temperature from initial ignition to combustion. The results of the TGA-DSC analysis can also be utilized to create boiler designs [6], determine the feed point of mixed fuel to the boiler that produce stable combustion [9], and to compare the combustion characteristics of mixed fuel with design coal, to find the feasibility of mixed fuel compared to design coal through the combustion characteristics. TGA-DSC thermal analysis can also indicate reactivity, such as pyrolysis rate (weight loss per unit time) and as well as fuel content [10] [11] [12]. The TGA and DSC curves utilized to determine the thermal behavior of fuel samples tested in a fixed environment during the heating process [13] .

2. MATERIAL DAN METHOD

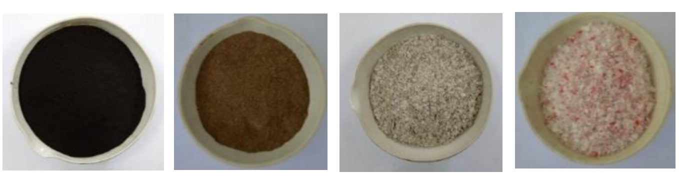
2.1 Materials

Low-rank coal (coal) sample was sourced from mines in central kalimantan while biomass EFB obtained from Puspiptek, Serpong. Plastic waste used are plastic bottle (polyethene terephthalate) and plastic bag of various kinds that gathered from domestic waste in the South Tangerang, Banten. For coal preparation, sieving was carried out pass 200 mesh sieve. EFB prepared to pass size of 60 mesh sieve and plastic with a pass size of 20 mesh sieve. Then blended with a ratio of 75% coal + 25% biomass to three different blends which biomass in mixture consist of 100% EFB for C1, 75% EFB and 25% plastic bottles for C2, and 75% EFB and 25% plastic bag for C3.

Table 1. Characteristics sample analysis

Parameter	Coal	EFB	C1	C2	C3
Total Moisture (ar), %	43.42	4.94	33.80	35.35	35.20
Moisture in Sample (adb), %	11.78	4.81	10.04	10.31	10.70
Ash Content (adb), %	6.78	3.20	5.52	6.22	6.25
Volatile Matter (adb), %	43.28	74.57	53.59	53.41	52.76
Fixed Carbon (adb), %	38.16	17.42	30.85	30.06	30.30
Total Sulphur (adb), %	0.19	0.08	0.15	0.17	0.17
Gross Calorific Value (adb), %	5476	4174	4996	5044	5039
Total Chlorine (adb), %	0.0054	0.0700	0.0216	0.0216	0.0203
Ultimate Analysis					
Carbon (adb), %	59.48	45.36	54.27	54.22	54.16
Hydrogen (adb), %	4.08	5.59	4.56	4.57	4.54
Nitrogen (adb), %	0.75	0.62	0.70	0.73	0.73
Oxygen (adb), %	28.72	40.34	32.46	31.64	31.26

Figure 1 shows the materials used for testing which are low-rank coal, EFB, PET bottle waste, and plastic bag waste.



(a) (b) (c) (d)

Fig. 1 Materials used are (a) low-rank coal (b) EFB (c) PET bottle waste (d) plastic bag waste

2.2 TGA-DSC Analysis

The HP STA LINSEIS thermal analysis apparatus was used to analyzed the combustion characteristics. Tests are carried out in a controlled environment. The sample weight is 5-10 mg, and the temperature is raised to 900°C with heating rate of 10°C per minute.

3. RESULTS AND DISCUSSION

3.1 Ultimate – proximate analysis

The chemical properties of the sample can be evaluated by analyzing the basic parameters of the main organic elements. Table 1. It shows the comparison between flammable and non-flammable elements. The flammable elements are carbon, hydrogen, and sulfur. At the same time, nitrogen, oxygen, and chlorine are non-flammable elements [14]. Carbon content of Coal is higher (59,48%) more than EFB (45,36%). While carbon of polyethylene terephthalate (PET) base on previous report is about 60% [15]. The incineration process produces both harmful and harmless gas emissions. The sulfur content of SOx and the nitrogen content of NOx which resulted in a slight emission of gas produced, was not as harmful as in the EFB, which was less than 1%. The oxygen element of EFB is the highest (40,34%), followed by Coal C1 with 32.46%. The oxygen content contributes to the sample's full combustion. Oxygen content has a crucial role in the combustion process as a good combustion element and to limit combustion efficiency if the oxygen content is low. Atoms in oxygen escape into free forms and into little molecules of oxides that are free during combustion [16].

The Table 1 shows proximate analysis. The Coal sample have higher moisture content than EFB. The volatile content of PET is highest (88,61%) [15], respectively followed by EFB with 74,57%. The Coal have higher ash content than EFB and sample blending with plastic waste has value in between. Calorific value is related to mainly elemental composition and also moisture content. Calorific value of Coal and EFB were higher than calorific value of PET. Base on the previous report, calorific value of PET is about 10-13 MJ/kg or 2.388-3.104 kcal/kg [17]. While calorific value of Coal and EFB were 5476 kcal/kg and 4174 kcal/kg.

Table 2. Summary of combustion characteristics of TGA-DTG/DSC

No	**Code sample**	**T_{ig} °C**	**T_{bo} °C**	**Mass loss at 105°C %**	**Mass loss at T_{bo} °C %**	**R_{max} mg/s**	**T_{max} °C**	**Onset point**		**Offset point**	
								°C	**minutes**	**°C**	**minutes**
1	Coal	282.8	490.1	20.0	80.0	0.0190	334.0	311.9	26	347.3	30
2	C1	257.8	579.7	12.0	80.0	0.0180	378.1	250.3	21	501.5	47
3	C2	276.2	622.5	10.0	77.0	0.0085	423.1	263.6	23	501.9	48
4	C3	267.4	575.3	11.0	91.0	0.0155	349.3	316.6	28	387.3	35

3.2 Combustion characteristics

Figure 2 is an illustration of the TG-DTG curve of the sample being tested. While Table 2 contains data on the combustion characteristics of the TG-DTG curve.

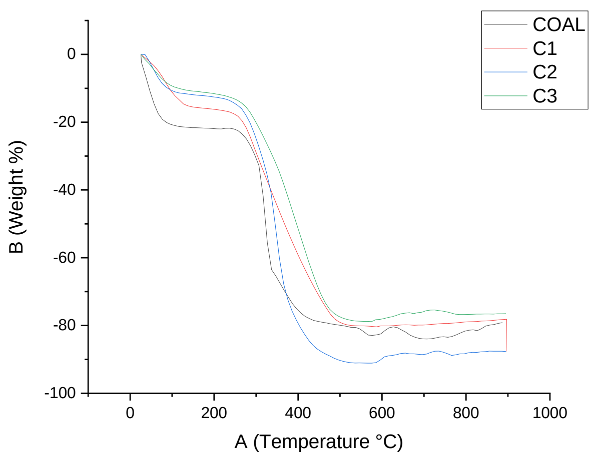


Fig. 2 Sample curve of TG-DTG

Figure 2 shows the behavior of heat and mass changes using differential thermogravimetry (DTG) devices. The first curve at about of 105°C correspondent to weight loss of moisture that called drying stage. The TGA curve of coal sample indicates a sharp declining, which is analogous to the high-water content with weight loss is about 20%. This is in accordance to the proximate results which is the coal water content is highest. The C1 sample has lower water content with the curve is slightly declining than Coal sample. While the C2 and C3 samples have almost of the similar water content are about 10-11%.

After the drying stage, the curve is relatively stable and not subjected to significant decomposition up to at the temperature about of <290°C. In this condition, the samples are starting to experience initial combustion at the ignition temperature (T_{ig}). Ignition temperature (T_{ig}) is condition required to produce stable combustion in the boiler with the lowest temperature, this is also related to the potential for volatile matter devolatilization. To keep the furnace temperature stable, the temperature must be at the Ti_g value when the coal is feed for combustion to occur. It is relatively safe to feed coal at higher temperature than T_{ig}, but it takes more time and initial fuel [9]. The T_{ig} value relates to the temperature, which the volatile compounds start off to ignite. The ignition behavior of coal is critical for arrange the process of combustion because it influences pollutant production and emission [17]. T_{ig} shows sample volatility content, samples with the low volatility is generally have high T_{ig} [18] [19]. The Coal sample has ignition temperature (T_{ig}) of 282.8°C with weight loss is 23.78%, while C1, C2, and C3 sample are 257.8°C, 276.2°C, and 267.4°C respectively, with weight loss 18.25%, 15.56%, and 16.33%.

The degradation of four samples begins at around 300°C, and the largest weight loss is found between 300°C and 500°C, with the maximum temperature (T_{max}) indicated in Table 3. T_{max} is related to the fuel reactivity to oxidizing at low temperature, lead to self-combustion. Fuel sample with lower T_{max} value has higher reactivity to self-burn. The tendency to self-burn will increase with a lower T_{max} value because usually with a lower T_{max} value, the reactivity is higher [20]. The curve between T_{ig} and T_{max} is indicates that the presence a mixture of plastic bottles makes it more difficult to burn compared to other mixtures, thus affecting a high degree of self-burning tendency. The C2 sample has highest T_{max} of 423.1°C and C2 has the lowest tendency of self-burning.

The mass release increases with the increasing temperature, which causes the decomposition of hydrocarbon bonds. Decomposition and pyrolysis process, continue until the maximum combustion rate

(R_{max}) is reached. The highest R_{max} was reached by Coal sample at 0.0190 mg/s and these is assumed to have a high combustion efficiency. Regarding to the R_{max} , If the calorific value and fixed carbon are high while moisture content is low, the R_{max} will be high [20]. Onset and offset point represent the start and ends of oxidation reaction carbon and oxygen in samples. The longest time of the oxidation reaction among of oxygen and carbon is occurred of C1 sample for 26th minutes.

Charcoal formation and aggression became the final phase of weight loss, the weight decreased to the lowest level reaching 900 °C at the end of the pyrolysis process. [21]. The burnout temperature (T_{bo}) shows the characteristics of char in the fuel and the point at which combustion has ended [20]. Coal has the lowest T_{bo} of 490.1°C, whereas C2 sample has the highest T_{bo} of 622.5°C. Interval temperatures that reflect the length of sample burnt can be calculated using T_{ig} and T_{bo} [18] [23]. The relation between T_{ig}-T_{bo} values for during combustion process was showed in Figure 3.

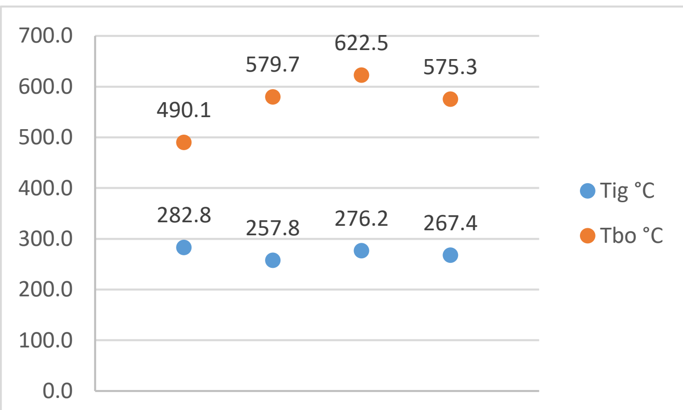


Fig. 3 The relation between T_{ig} and T_{bo} values

4. CONCLUSION

Biomass addition in co-firing fuel lower the ignition temperature (T_{ig}) of coal. T_{ig} of Coal is 282.8°C while the lowest C1 (Coal + EFB) with value of 257.8°C. Mixture with biomass decreasing the reactivity of coal with value T_{max} is increase. Coal has T_{max} of 334.0°C while the highest T_{max} is C2 (Coal + EFB + PET bottle) value of 423.1°C. T_{bo} of Coal is 490.1°C, C2 has highest T_{bo} with value of 622.5°C. From the value of T_{max}, T_{bo}, and T_{bo}-T_{ig} showed that addition of biomass decreases the self-burning tendency and prolong the combustion of the low-rank coal.

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