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Indonesian Coal Combustion Characteristics Using TG-DSC Analysis

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***Abstract*—Selection of coal fuel for coal-fired power plant is usually required to fulfil criteria such as calorific value, combustion characteristics, slagging fouling potential, and emissions potential. This paper describes coal combustion characteristics were studied by the thermogravimetric analyzer and differential scanning calorimetry (TG-DSC) using nine raw coal samples from Kalimantan and Sumatra. The coal samples had gross calorific value (as received) of around 3700-5200 kcal/kg. The results of TG-DSC analysis show that SS B Coal has highest reactivity with the lowest maximum rate of combustion (Tmax) which is 337.4°C, at the other hand SS A Coal has lowest reactivity with highest Tmax of 436.0°C. For ignition temperature (Tig), SS B Coal has lowest with 280.7°C while KS A Coal has highest with 357.1°C. As burnout temperature (Tbo), KS D Coal has highest with 668.4°C while KT C has lowest with 509.4°C. SS A Coal has smallest interval temperature (Tbo-Tig) with 165.6°C while KS D Coal has biggest with 371.3°C. Concerning maximum combustion rate (Rmax), KS A, KT B, and KT C Coal has higher rate than six other coals. KS A Coal and SS A Coal are hard to ignite and burn but fastest to be burn out.**

***Keywords*—Indonesia coal combustion characteristics, TG-DSC analysis, interval temperature**

I. INTRODUCTION

Coal fired power plant is still one of the important sectors of Indonesian energy. For electricity supply, fossil fuels are still widely used with 60% dominated by coal [1]. In accordance with national energy policy which implemented renewable energy, coal is still became one of the main energy sources with more than 30% for power plant by 2025 [2]. Meanwhile, coal production in 2020 is predicted to produce 550 million tons of coals dominated by low and medium rank coals [3]. The distribution of coal resources is uneven, 94% of coal resources in Indonesia are located in 7 regions, namely basins in Tarakan, Kutai, Barito, Ombilin, Bengkulu, Central Sumatra, and South Sumatra. The basins in Ombilin and Bengkulu are dominated by high calorific value coal, the basins in Tarakan, Kutai, and Barito are dominated by medium calorific value coal, and basins in Central Sumatra and South Sumatra are dominated by low calorific value [4]. Low and medium calorific value coal usually used as fuel in Indonesian coal fired power plants.

Coal for power plant fuel usually has to meet the requirements for calorific value, combustion characteristics, slagging fouling potential, and emissions potential. Coal combustion characteristics can be studied using thermogravimetric analyzer and differential scanning calorimetry (TG-DSC). With TG-DSC, the coal weight reduction rate can be monitored in dynamic conditions with a function of time or temperature so that combustion characteristics are obtained such as initial combustion temperature, final combustion temperature, maximum peak temperature, and maximum weigh loss with respect to time [5]. In this study, TG-DSC analysis was carried out on nine coals from various mines in Indonesia, especially Kalimantan and Sumatra, to determine its combustion characteristics.

II. Experimental

A. Coal Samples

The coal samples low and medium rank coal originated from the several mines in Indonesia which are 3 from East Kalimantan (KT A, KT B, and KT C Coal), 4 from South Kalimantan (KS A, KS B, KS C, and KS D Coal), and 2 from South Sumatera (SS A and SS B Coal). The raw samples were collected following ASTM coal sampling then prepared and tested with ASTM standards to obtain the characteristics coal in laboratory. For TGA-DSC sample, coals were crushed and pulverized to obtain coal which pass 200 mesh sieves (75μm) because it is the size used in coal fired power plant with pulverized coal boiler.

TABLE I. RESULT OF CHARACTERISTICS COAL ANALYSIS

Parameter		KT A	KT B	KT C	KS A	KS B	KS C	KS D	SS A	SS B
Total moisture, %	ar	21.20	27.78	22.24	27.43	36.16	43.42	36.00	26.90	33.36
Inherent moisture, %	adb	12.83	12.48	10.88	11.02	13.29	11.78	10.98	9.48	9.90
Ash content, %	adb	5.24	3.05	6.14	2.18	3.76	6.78	4.07	7.36	6.43
Volatile matter, %	adb	38.95	42.56	38.51	42.58	42.35	43.28	42.76	39.74	42.39
Fixed carbon, %	adb	42.98	41.91	44.47	44.22	40.60	38.16	42.19	43.42	41.28
Total sulfur, %	adb	0.71	0.10	0.50	0.13	0.13	0.19	0.13	0.36	0.20
GCV, kcal/kg	adb	5814	5652	5993	6036	5609	5476	5791	6054	5676
GCV, kcal/kg	ar	5256	4664	5229	4923	4130	3723	4163	4889	4198
Carbon, %	adb	60.18	59.70	62.40	63.08	61.53	59.48	62.82	62.32	60.12
Hydrogen, %	adb	4.41	4.20	4.41	4.42	3.98	4.08	4.04	4.64	4.32
Nitrogen, %	adb	1.20	0.72	1.20	0.92	0.78	0.75	0.73	0.90	0.90
Oxygen, %	adb	28.26	32.23	25.35	29.27	29.82	28.72	28.21	24.42	28.03

B. Combustion Characteristics

TG-DSC analysis has been carried out by using LINSEIS High-Pressure STA apparatus. The test was performed at atmospheric pressure, under an inert air atmosphere. The sample under test were weighted uniformly 5 mg, the temperature was increased from ambient to 800°C at heating rate of 10°C/min constantly. From TG-DSC analysis various parameter combustion characteristics can be obtained such as [5].

- Tig (°C) : Ignition temperature at which the weight loss curve of combustion and pyrolysis is deviated
- Tmax (°C): Maximum temperature at which peak temperature of maximum weigh loss rate
- Tbo (°C) : Burn out temperature at which all char has been burned and the rate of heat flow is zero
- Rmax (mg/s) : Maximum weigh loss with a time

III. Results and Discussion

Based on Table 1 and ASTM [6], KT B, KS B, KS C, KS D, and SS B Coal are categorized as low rank coal, while KT A, KT C, KS A, and SS A Coal are medium rank coal. SS A Coal has highest ash content with 7.36%. KS B, KS C, and KS D Coal has higher total moisture content with value more than 35%, as for inherent moisture KT A, KT B, and KS B has higher. Volatile matter and fixed carbon analysis results are almost the same as KT A, KT C, and SS A Coal has lower value of volatile matter than others, while KS C Coal has lowest value of fixed carbon. KT A Coal has highest total sulfur content with 0.71%.

The result of TG-DSC analysis from nine coal samples showed their combustion characteristics. Peak temperature at the maximum combustion rate (Tmax) that related to reactivity of coal showed that SS B Coal has lowest Tmax with 337.4°C while SS A Coal has highest with 436.0°C (see Figure 1). Coals with lower Tmax generally has higher reactivity and easier to ignite and burn [7]. Such coal expected to burned in the lower part of boiler furnace while coals with higher Tmax would require longer residence time in boiler furnace to obtain a low unburned carbon loss [8,9].

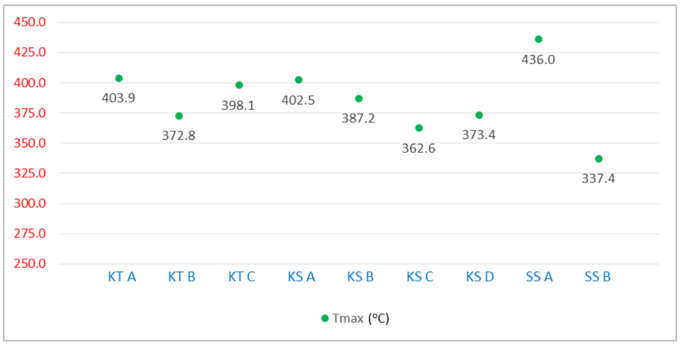

Fig. 1. Tmax from TG-DSC analysis.

The Tig value corresponds to the ignition temperature of the volatile matter. The ignition behavior of coal is considerable importance of controlling combustion process due to its influence on the formation and emission of pollutants [5]. The higher Tig, the lower volatile matter [10]. The higher volatile matter, it will be easier to burn [9]. From the TG-DSC analysis SS B has lowest Tig with 280.7°C while KS A Coal and SS A Coal has highest Tig with 357.1°C and 325.4°C respectively. Compared to the reactivity, KS A Coal and SS A Coal also has higher Tmax than other coals, generally it will be harder to ignite and burn.

The Tbo value corresponds to the temperature when the rate of heat flow is zero, it reflects the char characteristics [5,10]. From analysis KS B, KS C, and KS D Coal has highest Tbo with value more than 600°C while KT C, SS A, and SS B Coal has lowest Tbo. Based on Tig and Tbo, interval temperature (Tbo-Tig) which reflects the length of time coal to burn out can be obtained [5]. Interval temperature from smallest is SS A Coal with 165.6°C, KS A Coal with 189.0°C, KT C Coal with 199.3°C, KT B Coal with 217.9°C, SS B Coal with 235.5°C, KT A Coal with 252.8°C, KS C Coal with 328.8°C, KS B Coal with 358.0°C, and KS D Coal with 371.3°C. It showed that its necessities longer combustible time to burn up more amounts of carbonaceous matter on KS B, KS C, and KS D Coal. Tig and Tbo from TG-DSC analysis can be seen in Figure 2.

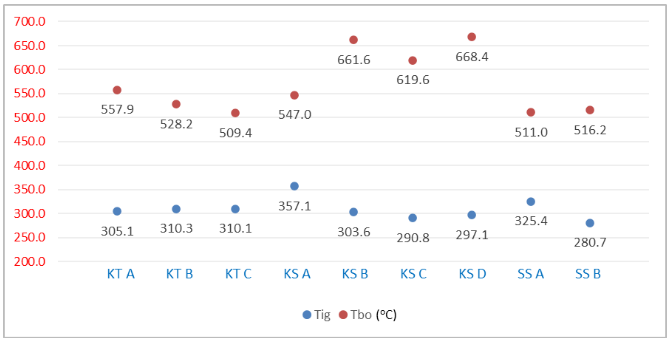

Fig. 2. Tig and Tbo from TG-DSC analysis.

The Rmax indicates the maximum combustion rate, the higher Rmax value it easier to coal to burn due to its high calorific value and less moisture content [11]. KS A Coal has highest Rmax while KS B Coal has lowest Rmax. KS A Coal with Rmax 0.0172 mg/s, KT B Coal with 0.0154 mg/s, and KT C Coal with 0.0147 mg/s has significant gap higher Rmax than six other coals. Coal with high Rmax, high Tig, and high Tmax value usually has high calorific value. From table 1, coal with highest calorific value is SS A Coal, from TG-DSC analysis it has sixth at Rmax, second highest at Tig, and highest Tmax. KS A Coal has second highest calorific value, from TG-DSC analysis it has highest Rmax, highest Tig, and second highest at Tmax. Rmax from TG-DSC analysis can be seen in Figure 3.

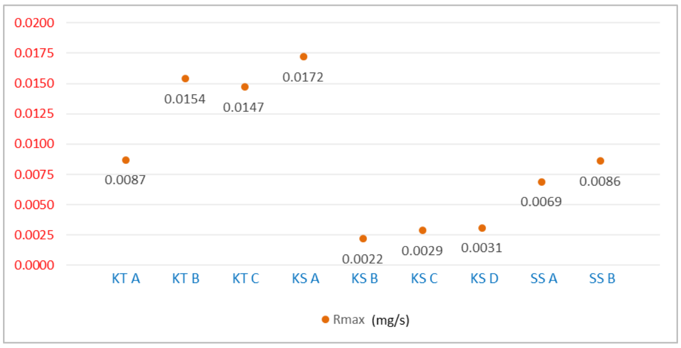

Fig. 3. Rmax from TG-DSC analysis.

IV. Conclusion

The result of TG-DSC analysis show that SS B Coal has highest reactivity with lowest Tmax value of 337.4°C while SS A Coal has lowest reactivity with highest Tmax value of 436.0°C. For Tig SS B Coal has lowest value of 280.7°C while KS A Coal has highest value of 357.1°C. As for Tbo, KS D Coal has highest value of 668.4°C while KT C Coal has lowest value of 509.4°C. SS A Coal has smallest interval temperature with 165.6°C while KS D Coal has biggest with 371.3°C. Concerning Rmax, KS A, KT B, and KT C Coal has higher rate than six other coals. SS A Coal which has highest Tmax and KS A Coal which has highest Rmax and Tig are two coals with highest calorific value. Based on Tmax and Tig value, KS A and SS A Coal are harder to ignite and burn, but from Rmax value and interval temperature both are fastest to be burn out, only need higher temperature to start to burn.

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