Advances in Engineering Research, volume 208
Proceedings of the International Conference on Innovation in Science and Technology (ICIST 2020)

SEM Observation of Slagging Fouling on Ash Deposit from Co-Firing Lignite Ash Coal and 10% Biomass Using Drop Tube Furnace

Hariana*, Hanafi Prida Putra, Fairuz Milkiy Kuswa
The Laboratory of Fuel and Engineering Design (BTBRD-BPPT)
Indonesia
*hariana@bppt.go.id

Minako Kawai
Environmental Management Bureau, Ministry of Environment, Government of Japan
Japan

Clause Nielsen
Eqtec UG and Eqtec SOA GmbH
Germany

***Abstract*—Co-firing technology is an essential part of reaching 23% EBT in 2025, where Coal-fired power plant still dominates Indonesian power plant situation. On the other hand, the use of biomass co-firing increases the risk of slagging fouling. An effort to reduce the risk is a test with DTF on a temperature probe according to the Coal-fired power plant conditions. The results of these tests were observed using SEM technology, especially in terms of morphology. SEM test results of ash deposit observation from lignite ash coal blend for probe temperature 550°C (fouling) and probe temperature 600°C and 700°C (slagging) is considered safe. It showed on SEM image and EDS analysis which alkali and iron content still at safe limits while for SEM observation of ash deposit from blending of lignite ash coal blend and 10% sawdust showed that SEM image and EDS analysis for probe temperature 550°C and 600°C is considered safe. However, at probe temperature 700°C even from EDS analysis is safe, but from SEM image it showed sintering began to form.**

Keywords—SEM observation, drop tube furnace, EDS analysis

I. INTRODUCTION

Currently, Indonesia is making every effort to achieve EBT 23% in 2025 [1]. On the other hand, coal power plants are still dominant in Indonesia [2]. With such conditions, biomass co-firing is the right technology choice because its implementation does not have to make large investments to build new power plants compared to other methods. The fact that Indonesian coal availability is in the low range and medium-range coal, generally Coal-fired power plant uses blending coal according to the initial design of the Coal-fired power plant.

Generally, the study of co-firing with the addition of biomass into coal will affect the characterization of slagging and fouling, mainly from various things in it, especially alkali [3]. The tendency of high slagging and fouling can interfere with the power plant's performance and efficiency [4]. Slagging and fouling are generally caused by the ash composition of the fuel used. According to Hare et al. [5], one of the leading causes of slagging fouling is fuel. By co-firing biomass, the alkaline ash, especially potassium (K_2O) will show a high number where the safe limit for evaluating alkaline content is below 0.3% of the total ash [6]. Potassium content in the ash could melt and react with other elements at 500-600°C [7]. The need for supercritical generator technology requires a higher steam temperature of up to 700°C.

The potential for slagging and fouling must be succeeded early by presenting predictions, one of which is doing a combustion test with a Drop Tube Furnace (DTF) because DTF can be considered the same as Coal-fired power plant to predict the risk of slagging and fouling, the result of slagging material was observed using SEM. This research was carried out by conducting observations with SEM of lignite coal blending product's combustion with 10% sawdust biomass in a DTF with a surrounding temperature about 1200℃, and probe temperatures are 550℃, 600℃ and 700℃ with 5% excess oxygen. These results were observed based on the type of ash [8–11].

II. EXPERIMENTAL

A. Equipment

The equipment used in this study was a Jeol JSM 6510-LA Scanning Electron Microscope with a Moxtrex 550i thin film on an IXRF spectrometer. Besides that, it also uses FEI Quanta 650 with Oxford EDS for certain parts.

B. Coal and Biomass Samples

The sample used in this research is coal blending adjusted to the biomass characteristics to be used. The biomass that will be used in this research is sawdust. The coal blended with sawdust biomass with a composition of 90% coal and 10% sawdust, which will then be called C10 in this study. The following are ash fusion temperature and ash analysis test results from coal and C10.

TABLE I. AFT AND AAS ANALYSIS OF COAL AND COAL+10% BIOMASS

Parameter			Coal	C10
Total Sulfur	%	db	0.63	0.57
Ash Content	%	db	6.78	6.60
AFT Reducing				
Deformation	◦C	atm	1140	1110
Spherical	◦C	atm	1200	1180
Hemisphere	◦C	atm	1220	1220
Flow	◦C	atm	1260	1260
AFT Oxidizing				
Deformation	◦C	atm	1220	1150
Spherical	◦C	atm	1250	1220
Hemisphere	◦C	atm	1260	1260
Flow	◦C	atm	1280	1300
Ash Analysis				
SiO_2	%	in ash	51.20	50.54
Al_2O_3	%	in ash	14.34	15.63
Fe_2O_3	%	in ash	7.83	8.54
CaO	%	in ash	8.72	8.43
MgO	%	in ash	2.82	2.69
TiO_2	%	in ash	0.48	0.58
Na_2O	%	in ash	3.63	3.31
K_2O	%	in ash	0.83	0.79
Mn_3O_4	%	in ash	0.09	0.10
P_2O_5	%	in ash	0.20	0.30
SO_3	%	in ash	9.62	8.68
			db :	dry basis

III. RESULTS AND DISCUSSION

From the test results shown in Table 1, there is not much difference between the results shown by the coal test and the blend of coal and 10% biomass (C10). The decrease occurred in the total sulfur and total ash content, while the AFT results was a slight change that was not too significant, this indicated an increase in the risk of slagging fouling. For ash composition, generally SiO_2, Al_2O_3 are medium, Fe_2O_3 and CaO are low, and Na_2O and SO_3 are relatively high indicates fouling.

Coal and C10 are burned at DTF with specifications according to reference [11-13], the temperature probe is also similar. SEM observed the ash results from the DTF burn test shown in Figure 1. In principle, SEM observations can be categorized as a classification of deposit material into Metallic, Amorphous, Vescular, Sintered [8]. Meanwhile, Laursen et al. [9] classified SEM observations into Porous Deposits, Powder Deposits, Iron Rice Deposits, Semi Fused Slags and Fused Slags. Furthermore, Wang et al. [11] detailed the SEM results surface and the elements that make up the slagging particles. It is described based on grain size, color, texture, and explained the elements of nature concerning the EDS results of each element's properties and effects [13]. Following are the results of SEM imaging carried out on each probe tested on the DTF.

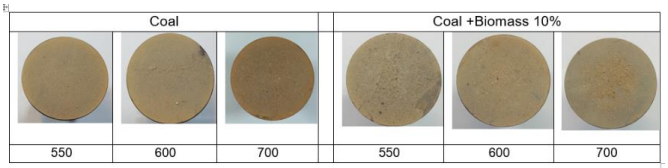
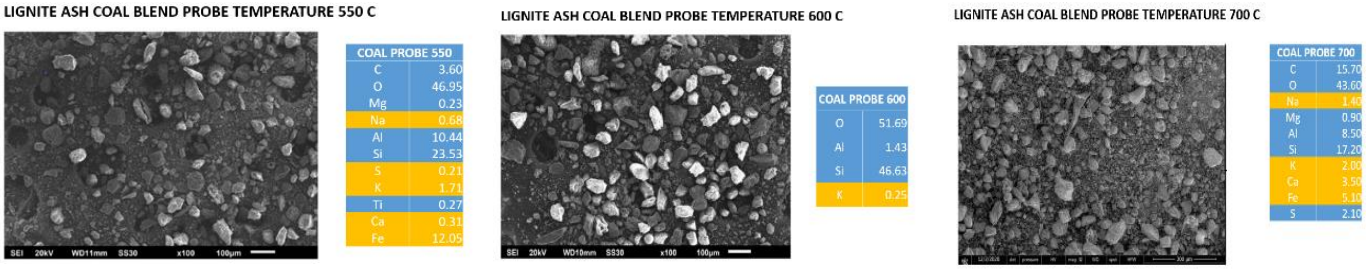


Fig. 1. Probe sample various temperature from combustion coal and C10 in DTF.

Figure 2 (a) depicts morphologically of 550°C probe is dominated by flakes with about 100 microns in size or smaller. The dominant dust color is bright, which indicates that the elements have more atomic weight than other elements. There are also spheres about 20 microns in size, and this usually represents an element with a Fe content. At 100x magnification, an area provides information that the bright color is an element with the dominance of Si, Al, and O, even though there is a small Fe. While there is a reasonably large Fe element in other areas, around 33%, this point is very high compared to other elements. From the observations that have been made, it shows that the K element is in moderate amounts and Na is low.



(a) (b) (c)

Fig. 2. SEM results of coal (a) Probe 550; (b) Probe 600; (c) Probe 700.

Same as with the previous probes, Figure 2 (b) depict morphologically of 600°C probe is dominated by ash in the form of flakes. The average size is about 100 microns, although some are slightly larger. Although it is not much, there is also a relatively small amount of melt due to alkali. An element that should be suspected is Fe, even though its size is small and relatively minimal. The predominance of bright white indicates Si. In general, the elements at 100x magnification were dominated by Si with bit of Al and K (average less than 1%). Other elements were not detected. Some balls show melting even though they are not dominant.

Based on observations of the coal probe at temperature 700°C, Figure 2 (c) depicts morphologically there were still many grains and flakes with sizes that were dominated by sizes below 100 microns, even though there were sintering material and balls but not much compared to flake material. By the element side, it can be stated that this probe is still within reasonable limits when looking at the element. Compared with Figure 2 (b), the risk of sintering from this probe is more significant even though it still looks safe.

Furthermore, Figure 3 (a) of 550°C C10 probe shows no significant difference in morphology comparing probe with the probe in Figure 2 (a). Minerals that appear are also dominated by 100 microns size or below. Several materials look like balls or balls with holes. The shape of these spheres is more numerous than the 550°C coal probe (Figure 2 (a)). There is also a small cylindrical material that usually represents high amounts of Al. The colour does not differ much compared to the coal probe.

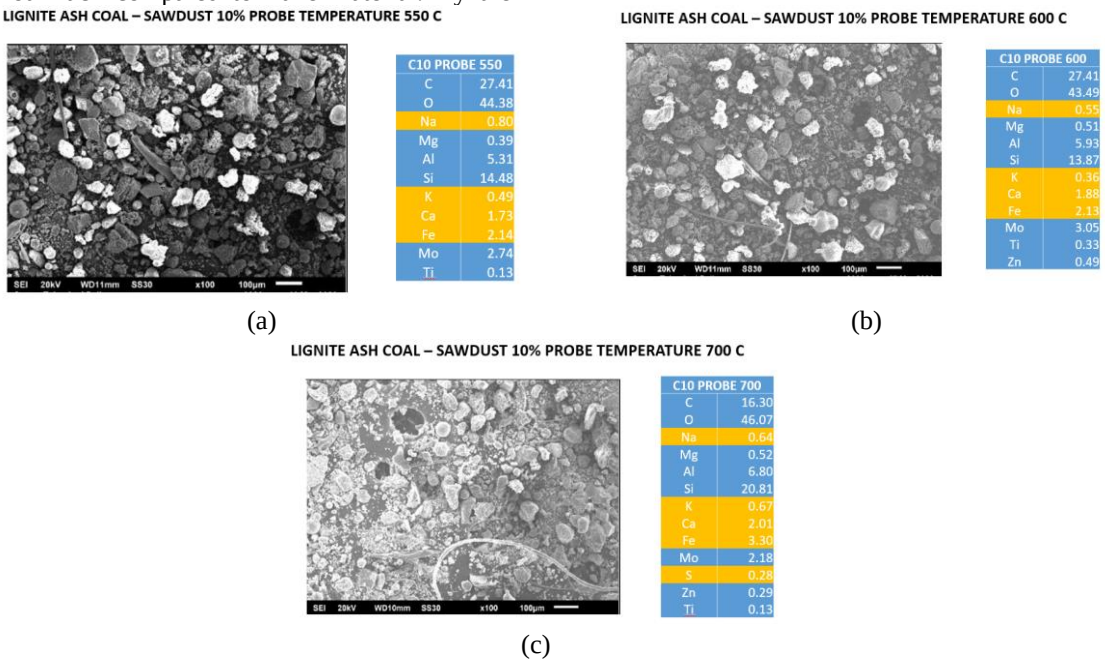


Fig. 3. SEM results of coal and 10% biomass blend (C10) (a) Probe 550; (b) Probe 600; (c) Probe 700.

Figure 3 (b) of 600°C C10 probe compared to Figure 2 (b), this probe has more material with 100 microns in size. Likewise, when compared with the 550°C C10 probe (Figure 3 (a)). In terms of colour, there is no significant difference when compared with the 600°C coal probe (Figure 2 (b)) or the 550°C C10 probe (Figure 3 (a)). The material in the form of long cylindrical is also visible on this probe. Co-firing carried out using this biomass is still considered reasonable and safe.

Figure 3 (c) shows morphologically of 700°C C10 probe, there are more melts and spheres than the 700°C coal probe (Figure 2 (c)) and 600°C C10 probe (Figure 3 (b)), as well as the material in the form of a long cylindrical which is usually considered Al. However, melted material found no larger than 200 microns. Considering a large amount of sintering material in cylindrical shape and melts compared to 700°C coal probe and 600°C C10 probe, further tests can be considered.

IV. Conclusions

The research shows the results of the combustion and the results of the SEM imagine observation. Furthermore, it can be concluded that SEM observation of ash deposit from lignite ash coal blend for probe temperature 550°C (fouling) and probe temperature 600°C and 700°C (slagging) is considered safe, it showed on SEM image and EDS analysis which alkali and iron content still at safe limits. SEM observation of ash deposit from blending of lignite ash coal blend and 10% sawdust showed that SEM image and EDS analysis for probe temperature 550°C and 600°C is considered safe, but at probe temperature 700°C even from EDS analysis is safe, but from SEM image it showed sintering begin to form, it needs to be watched out.

REFERENCES

[1] P. Agung, Terapkan Metode Co-Firing di PLTU, Ini Potensi Biomassa Untuk Subtitusi Batubara. Jakarta: Kementerian Energi Dan Sumber Daya Mineral Republik Indonesia, 2020.

[2] D. Arinaldo and J. C. Adiatma, Dinamika Batu Bara Indonesia: Menuju Transisi Energi yang Adil. Jakarta: Institute for Essential Services Reform (IESR), 2019.

[3] Y. Niu and H. Tan, "Ash-related issues during biomass combustion: Alkali-induced slagging, silicate melt-induced slagging (ash fusion), agglomeration, corrosion, ash utilization, and related countermeasures," Prog. Energy Combust. Sci., vol. 52, pp. 1–61, 2016.

[4] T. F. Wall, S. P. Bhattacharya, D. K. Zhang, R. P. Gupta, and X. He, "The properties and thermal effects of ash deposits in coal-fired furnaces," Prog. Energy Combust. Sci., vol. 19, no. 6, pp. 487–504, 1993.

[5] N. Hare, M. G. Rasul, and S. Moazzem, "A review on boiler deposition/foulage prevention and removal techniques for power plant," in Recent Advances in Energy and Environment. Proceedings of the 5th IASME/WSEAS International Conference on Energy & Enviroment (EE'10), 2010, vol. 23, p. 25.

[6] ASME Research Committee on Corrosion and Deposits from Combustion Gases andd E.C. Winegartner, Coal fouling and slagging parameters. New York: ASME, 1974.

[7] R. W. Bryers, "Fireside slagging, fouling, and high-temperature corrosion of heat-transfer surface due to impurities in steam-raising fuels," Prog. energy Combust. Sci., vol. 22, no. 1, pp. 29–120, 1996.

[8] R. M. Hatt, "Fireside deposits in coal-fired utility boilers," Prog. Energy Combust. Sci., vol. 16, no. 4, pp. 235–241, 1990.

[9] K. Laursen, F. Frandsen, and O. H. Larsen, "Ash deposition trials at three power stations in Denmark," Energy & fuels, vol. 12, no. 2, pp. 429–442, 1998.

[10] S. V. Vassilev, C. G. Vassileva, Y.-C. Song, W.-Y. Li, and J. Feng, "Ash contents and ash-forming elements of biomass and their significance for solid biofuel combustion," Fuel, vol. 208, pp. 377–409, 2017.

[11] X. Wang, Z. Xu, B. Wei, L. Zhang, H. Tan, T. Yang, H. Mikulčić and N. Duić, "The ash deposition mechanism in boilers burning Zhundong coal with high contents of sodium and calcium: a study from ash evaporating to condensing," Appl. Therm. Eng., vol. 80, pp. 150–159, 2015.

[12] H. Hariana, H. P. Putra, and F. M. Kuswa, "Pemilihan batubara kalimantan untuk PLTU dengan PC boiler menggunakan tinjauan potensi slagging dan fouling," in Prosiding Seminar Nasional NCIET, 2020, vol. 1, no. 1, pp. 48–58.

[13] J. Li, M. Zhu, Z. Zhang, K. Zhang, G. Shen, and D. Zhang, "Characterisation of ash deposits on a probe at different temperatures during combustion of a Zhundong lignite in a drop tube furnace," Fuel Process. Technol., vol. 144, pp. 155–163, 2016.