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Increased Coal Slagging Index by Using Zeolite Synthetic

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Abstract. The use of coal as fuel has experienced several obstacles, one of which is the formation of *Slagging* (crust). *Slagging* is formed by the melting point of coal ash or low ash *fusion temperature*, caused by low levels of Al_2O_3 in coal ash. The addition of synthetic zeolite to coal before use is intended to increase the level of Al_2O_3, so that it will increase the ash *fusion temperature* of coal ash. The increase in *ash fusion temperature* also causes an increase in *the slagging index* of coal. With the high increase in the *slagging index* obtained, the lower the potential for the formation of *slagging*. The smaller the potential of *Slagging* formed, the use of coal also decreases. This study aims to determine the effect of adding waste-based synthetic zeolite to coal ash on increasing coal *slagging index*. Research uses a type of experimental research. Itis collected by conducting laboratory tests, namely making observations and direct testing of samples with variations in the addition of synthetic zeolite to coal by 5%, 10%, and 15%. The results showed that synthetic zeolite added to coal was able to reduce the potential for *slagging formation. Slagging index* from the results of research for oxidation conditions is a standard sample of 1,246ºC, SBZ5 by 1,242ºC, SBZ10 by 1,250ºC, and SBZ15 by 1,274ºC. Reduction conditions i.e. standard sample of 1,130ºC, SBZ5 by 1,116ºC, SBZ10 by 1,136ºC, and SBZ15 by 1,168ºC. SBZ15 sample is a variation that has a good *slagging index*, which is for oxidation conditions which is 1,274ºC, and for reduction conditions that is 1,168ºC.

Keywords: Coal, Slagging Index, Synthetic Zeolite.

1 Introduction

Coal is one of the energy resources that humans continue to use and develop. Besides being very abundant, coal is also one of the natural resources that is very economical when compared to other natural resources, sothat it continues to be developed in supporting various sectors of human life, one of which is as a source of electrical energy through Steam Power Plants (PLTU).

An obstacle that is often found in the use of coal as fuel at coal-fired power plants and greatly affects the working process of the tool is the attachment of coal ash particles in the form of deposited solids, then melts and forms a crust in the high-temperature dispersing zone due to the coal combustion process. This phenomenon is called *slagging* [1]. According to [2], s*lagging* occurs due to the low *Ash Fusion Temperature* of coal ash. This can occur due to low levels of Al_2O_3 contained in coal ash.

Zeolite is a compound that has a high enough Al_2O_3 content which can be obtained by synthesizing coal ash waste so that Synthesis Zeolite is obtained [3]. The addition of synthetic zeolite to coal before the coal is used, will affect the Al_2O_3 levels in coal ash after coal goes through the combustion process. Increasing levels of Al_2O_3, will increase the value of ash *fusion temperature* owned from coal ash.

Ash Fusion Temperature is a value that shows the melting point or temperature of coal ash. So, to suppress the emergence of *slagging* potential, it can be done by adding synthetic zeolite to increase the levels of Al_2O_3 found in coal ash, so that there is an increase in the value of *ash fusion temperature* [4]. With the increase in *ash fusion temperature*, so does the slagging index, which is a representation of the potential for *slagging* to form.

With the smaller the potential for *slagging* formed, the smaller the maintenance and use of coal needed in the production process due to the energy efficiency that can be obtained. Based on the background of these problems, it is important to carry out research aimed at adding synthetic zeolite to coal before combustion, so that there is an increase in the value of *ash fusion temperature* on the potential or tendency of slagging formation calculated through the *slagging index* equation.

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2 Method

2.1 Ashing Procedure

a. Standard Sample (SS), 5% Zeolite Coal Sample (SBZ5), 10% Zeolite Coal Sample (SBZ10), and 15% Zeolite Coal Sample (SBZ15) coal samples were flattened on each *Crucible Ashing* in the amount of ± 50 grams.
b. The sample is heated in the *furnace* to a temperature of 500ºC for 1 hour, after which it is raised to a temperature of 750ºC for 2 hours.
c. Cooled on a *plate.*
d. After cooling, the sample is then crushed using mortar and pestle until it passes the sieve using a 75 µm *sieve*.
e. The ash sample escapes the sieve, heated in a *furnace* for 1 hour.
f. Removed and then cooled, after that it is put into the sample plastic that will be used for further analysis, namely Ash *Analysis* and *Ash Fusion Temperature*.

2.2 Ash Analysis Testing

a. Sample Preparation
   1) 0.1 grams of coal ash sample was weighed in a *platinum dish.*
   2) 0.5 grams of Lithium Tetraborate is added, then stirred until evenly distributed between the sample and *Lithium Tetraborate*.
   3) The surface of the mixture is covered with 0.5 grams of *Lithium Tetraborate*.
   4) The cup is masked into a *furnace* of 1,000ºC and melted in 15 minutes.
   5) The saucer is removed and cooled to room temperature.
   6) The bottom and outside of the saucer are carefully rinsed to eliminate possible contamination.
   7) The cup is placed into a clean beaker with a capacity of 500mL, then placed a *magnetic stirrer* in a saucer.
   8) 200mL *of Solvent Acid* is added to the dish and beaker and place it immediately on the *hot plate.*
   9) The solution is heated to a temperature of 90ºC with constant coding for 30 minutes.
   10) *The hot plate* is turned off and cooled to room temperature.
   11) Quantitatively the solution was transferred to a 200mL measuring flask, *platinum* dishes and beakers were rinsed with a certain amount of Solvent Acid and diluted with *Solvent Acid* to the limit mark. This solution will be the mother liquor (A-Test Solution).
   12) Test-A solution is pipettes as 20mL into a 50 mL measuring flask and diluted using *Solvent* Acid to the limit mark. This solution will then become a Test-B solution.
   13) Mother Solution (A) is pipettes of 10mL into a 50mL measuring flask and diluted using *Solvent Acid* to the limit mark. This solution will then become a Test-C solution.
   14) The Mother Solution (A) is pipetted as much as 10mL into a 100mL measuring flask and treated with *Solvent Acid* to the limit mark. This solution will then become a D-Test solution.
b. Sample Reading
   1) A sample solution is prepared, a standard solution, and blanks to be read using the tool.
   2) The AAS tool is adjusted to the metal analysis read on the tool.
   3) Set *Slit*, Wavelength, and *Burner* used
   4) Optimized tool to the maximum *absorbance* limit to be read on the metal.
   5) A blank sample is read, then a standard sample and look at the linerity curve of the standard.
   6) The *result* button is pressed, and a sample reading is carried out using the AAS tool, if there is *an over read* from the Test-A solution, it is transferred to the Test-B solution and its opponents until the desired value is obtained.
   7) After the reading is over, the fire is turned off. Then, *the Load Method* is pressed, then returned to *the user* then pressed *clear* and *enter*. Then press the *optimize* button and press the off button to turn off the tool.

2.3 Ash Fusion Temperature Testing

a. *Cones are made from SS, SBZ5,* SBZ10, and SBZ15 coal ash that has been mixed with dextrin solution and molded using *molds*.
b. The molded cone is placed on the *Tile* and then put into a special kiln for *Ash Fusion Temperature* testing.
c. The camera is set up directly in front of the furnace lens, and adjusted to the *cone* position.

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d. Hydrogen and CO_2 gas are flowed into the furnace for Reduction conditions, for Oxidation conditions it is enough to flow CO_2 gas.
e. The *RUN* button is pressed.
f. Every 20ºC shooting is carried out, which starts shooting at a temperature of 1,000ºC until the *cone* melts completely
g. When finished, the flow of Hydrogen and Carbon Dioxide gas is closed, and the furnace temperature is lowered and the appliance is turned off.

3 Results and Discussion

Table 1 shows the results of *Ash Analysis* of samples using *Atomic Absorption Spectophotometer (AAS).*

Table 1. *Ash Analysis*

Number	Sample	Compounds Al_2O_3 (%)
1	SS	18,5
2	SBZ5	17,7
3	SBZ10	21,2
4	SBZ15	21,7

Information:
SS: Standard Sample
SBZ5: 5% Zeolite Coal Sample
SBZ10: 10% Zeolite Coal Sample
SBZ15: 15% Zeolite Coal Sample

Figure 1 shows the levels of Al_2O_3 in SS samples at 18.5%, SBZ5 at 17.7%, SBZ10 at 21.2% and SBZ15 at 21.7%. The high levels of Al_2O_3 in SBZ10 and SBZ15 samples when compared to SS samples, caused by the addition of synthetic zeolite which has high levels of Al_2O_3. Synthetic zeolite has the ability to raise Al_2O_3 levels because synthetic zeolite is one of the compounds that has high Al_2O_3 levels [5].

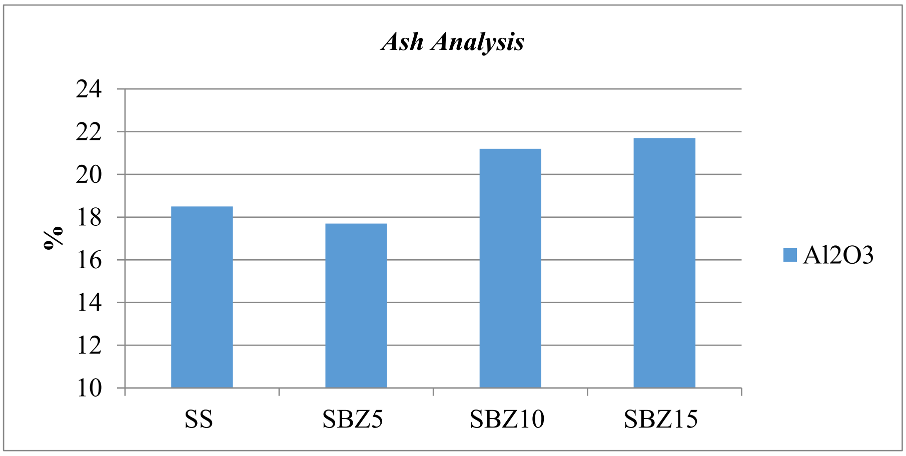

Figure 1. Ash Analysis Chart

Furthermore, *Ash Fusion Temperature* testing was carried out to test the melting point of the sample coal ash. *Ash Fusion* Temperature testing in this study, using test parameters, namely determining conditions when coal ash undergoes *Deformation Temperature (DT)* and *Flow Temperature (FT)* conditions because the values obtained from these conditions will be used in determining the *Slagging Index* value.

According to [6]*Ash Fusion Temperature* testing is held under two conditions or atmospheres, namely Oxidation and Reduction atmospheres. The purpose of using these two atmospheres or conditions is to adjust to combustion conditions on an industrial scale when coal is used as fuel faced with a temperature height of about 1,650ºC in Zone *Burner.*

Table 2 and Figure 2 which are graphs of *Ash Fusion* Temperature values in Oxidation atmospheres, show that Standard Sample (SS) has a *Deformation Temperature (DT)* value of 1,225ºC. However, the SBZ5 sample has a *lower Deformation Temperature* (DT) value when compared to the Standard Sample (SS) which is

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1,220ºC, as well as SBZ10 which is 1,205ºC. Sample SBZ15 has a higher *Deformation Temperature* (DT) value when compared to Standard Sample (SS) which is 1,245ºC.

Table 2. Ash Fusion Temperature

Number	Sample	Oxidation (ºC)		Reduction (ºC)	
		DT	*FT*	*DT*	*FT*
1	SS	1,225	1,330	1,090	1,290
2	SBZ5	1,220	1,330	1,090	1,220
3	SBZ10	1,205	1,430	1,100	1,280
4	SBZ15	1,245	1,390	1,145	1,260

Information:
SS: Standard Sample
SBZ5: 5% Zeolite Coal Sample
SBZ10: 10% Zeolite Coal Sample
SBZ15: 15% Zeolite Coal Sample
DT: Deformation Temperature
FT: Flow Temperature

Furthermore, at *Flow Temperature* (FT), the Standard Sample has a value of 1,330ºC. When compared with the SBZ5 sample which has a value of 1,330ºC indicates no increase in value. However, SBZ10 and SBZ15 experienced an increase in *the value of Flow Temperature (FT),* namely SBZ10 by 1,430ºC and SBZ15 by 1,390ºC.

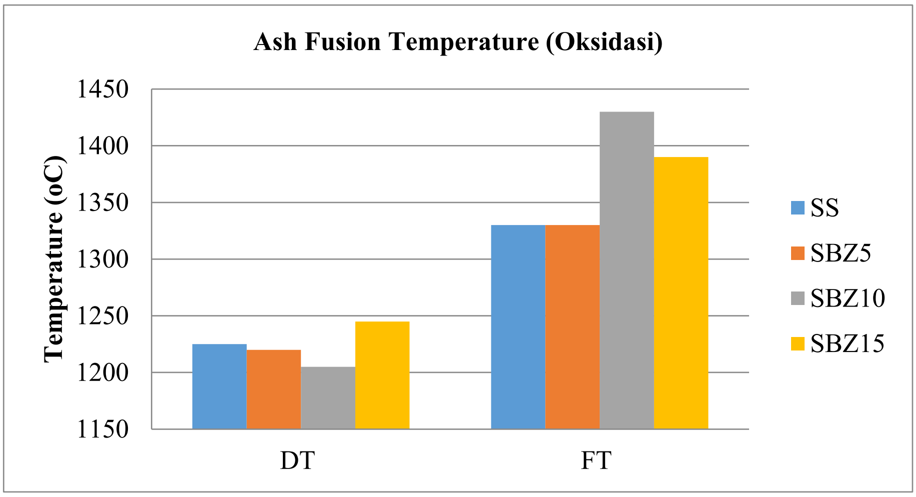

Figure 2. Oxidation AFT graph

Table 3 and Figure 3, graphing the *Ash Fusion* Temperature values under reduction conditions, show the main increase in *Deformation Temperature (DT)* and *Flow Temperature (FT).* In *Deformation Temperature (DT),* SBZ5 has the same value or does not increase with the standard sample, which is 1,090ºC, but increased in SBZ10 which is 1,100ºC and SBZ15ºC by 1,145ºC. Furthermore, at Flow Temperature (FT), the SS has a *Flow Temperature (FT)* value of 1,290ºC, which is higher than SBZ5 of 1,220ºC, SBZ10 by 1,280ºC, and SBZ15 by 1,260ºC.

Table 3. Batting Index

Number	Sample	*Slag Index* (ºC)	
		Oxidation	Reduction
1	SS	1,246	1,130
2	SBZ5	1,242	1,116
3	SBZ10	1,250	1,136
4	SBZ15	1,274	1,168

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Information:
SS: Standard Sample
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SBZ10: 10% Zeolite Coal Sample
SBZ15: 15% Zeolite Coal Sample

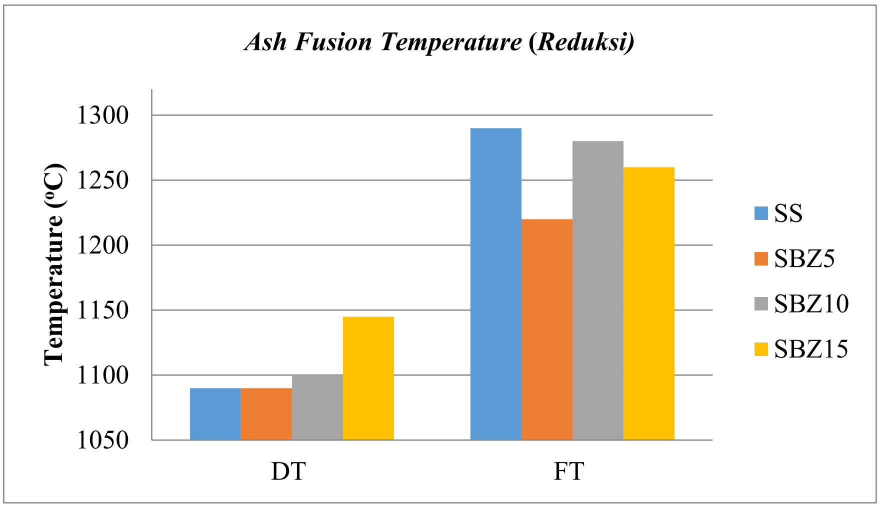

Figure 3. AFT Reduction Graph

The two graphs above, namely the Oxidation AFT and Reduction AFT graphs, show that there is an increase in the *Ash Fusion Temperature* Value under both conditions. This is due to an increase in Al_2O_3 levels from coal ash to which synthesis zeolite has been added. According to [7], the concept of ion potential plays a major role in increasing AFT in coal. The highest ionic potential is found in acidic components and tends to attract anions easily, such as O^{2-}.

The acidic components (SiO_2, Al_2O_3, TiO_2) can increase the melting point and contribute to increasing viscosity when melting is formed [8]. Al_2O_3 has the greatest effect on increasing AFT, because Al_2O_3 keeps stronger molecular bonds of oxygen than molecular bonds of other components so as to affect the viscosity behavior of the slag [9].

Coal added with additives containing Al_2O_3 will undergo a change in mechanism from a physical process to a chemical process. When there is an addition of Al_2O_3 then Al_2O_3 will react with SiO_2 to form mullite ($3Al_2O_3.2SiO_2$). Mullite is formed at temperatures of 850°C-1,000°C and has a melting point of 2,083 K or 1. 890°C. Coal accompanied by the addition of zeolite has a greater AFT value [10].

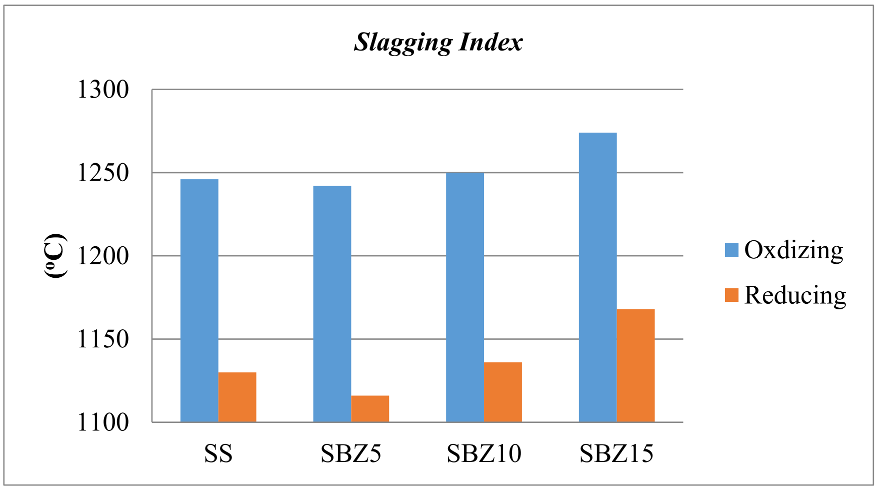

Figure 4. Slagging Index Chart

Figure 4 shows that there is an increase in *Slagging Index* in both Oxidation and Reduction conditions. Standard samples have a *Slagging Index* under oxidation conditions of 1,246°C and Reduction by 1,130°C.

However, SBZ5 has a *lower Slagging Index* value compared to standard samples in both conditions, namely Oxidation of 1,242^{o}C and Reduction 1,116^{o}C. This is due to the low AFT value in the SBZ5 sample due to the low level of Al_2O_3 in the sample when compared to the SS sample [11].

Furthermore, SBZ10 and SBZ15 have higher *Slagging Index* prices compared to standard samples under both conditions of Oxidation and Reduction. Under oxidation conditions, SBZ10 has a *Slagging Index* price of 1,250^{o}C and SBZ15 of 1,274^{o}C. Reduction Conditions, SBZ10 has a *Slagging Index* of 1,136^{o}C and SBZ15 by 1,168^{o}C.

The increase in the value of *Ash Fusion* Temperature will certainly affect the *Slagging Index* Price owned by coal, especially for *Deformation Temperature (DT)* and *Flow Temperature (FT)* [12]. Along with the increase in the value of *Ash Fusion Temperature*, the value of the Slagging Index obtained increases [13], and the higher the value of the *Slagging Index* obtained, the less likely the coal ash will experience *Slagging* [14].

Based on the description above, it can be seen that the mixing of synthetic zeolite against coal has a fairly good influence. This can be seen from the increased levels of Al_2O_3 owned by each sample mainly in SBZ10 and SBZ15. Then, ash melting point testing was carried out with the ash fusion temperature method to prove the effect of high levels of Al_2O_3 has a strong enough influence on increasing the value of *ash fusion temperature*.

The results showed that with the increase in Al_2O_3 levels, the melting point of coal ash or ash *fusion temperature* value also increased. With the increase in the value of *ash fusion temperature*, the *slagging index* obtained also increases. With a high *slagging index*, the smaller the probability or tendency of *slagging* formation. Thus, the addition of synthetic zeolite to coal can reduce the tendency of coal to undergo *slagging.*

The tendency of Slagging based on the calculation of *the Slagging Index* is [15] as shown in Table 4 below:

Table 4. Index slagging

>1,615	Low
1,505-1,615	Keep
1,325-1,505	Tall
<1,325	Very High

Based on the sample owned, the SBZ15 sample is the sample with the best *percentage of Slagging Index* among several samples owned, but is still classified as a Very High indication in the formation of *slagging* based on the standard. With the *Slagging Index* value of SBZ15 in the Oxidation atmosphere of 1,274^{o}C and Reduction by 1,168^{o}C.

Based on the data mentioned above, it can be seen that with the addition of synthetic zeolite to coal, it can reduce the potential for *slagging* formation. Similarly, with the small potential for the formation of *slagging*, energy efficiency occurs in the production process due to the effective heat transfer produced from coal, thus making coal consumption smaller.

4 Conclusion

The results showed that the addition of synthetic zeolite to coal had an influence on increasing *the slagging index*. This is due to an increase in Al_2O_3 levels in the sample which causes the *ash fusion temperature* value to increase, so that *the slagging index* also increases. The higher the slagging index obtained, the lower the potential for *slagging* formation . The *slagging index* obtained from oxidation conditions for SS, SBZ5, SBZ10, and SBZ15 samples is respectively 1,246^{o}C, 1,242^{o}C, 1,205^{o}C, &; 1,270^{o}C, and for successive reduction conditions that are 1,130^{o}C, 1,116^{o}C, 1,136^{o}C, &; 1,168^{o}C. SBZ15 sample is a variation that has a good *slagging index*, which is for oxidation conditions, namely 1,274^{o}C, and for reduction conditions it is 1,168^{o}C.

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