Thermal Analysis for Improving Fuel Characteristics of Empty Fruit Bunch (EFB) Fibers

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Abstract- Agriculture waste is well known with low melting ashes. This is due to the large quantities of alkali metals are required as nutrients. Potassium is the one of the alkali metal that contributes to the low melting ash of empty fruit bunch biomass fuel. Thermal analysis was conducted in order to determine the increasing of ash fusion temperature of EFB fiber. Ash fusion temperature has four type of shape which is initial deformation, softening temperature, hemispherical temperature and fluidization temperature. EFB fiber has melting temperature 1061°C in average. To solve low melting ashes, Ca(OH)₂ was added with EFB fiber in order to increase the ash melting point. 2%, 4%, 6% and 8% by dry weight was added to EFB fiber. From the experiment by adding 2%, 4%, 6% and 8% of Ca(OH)₂, the melting temperature was increase to 1114°C, 1239°C, 1277 °C and 1315 °C respectively. As conclusion this lab scale thermal analysis test was conducted in order to allow the determination of additive percentage for larger scale in order to adapt with biomass gasifiers.

1.0 Introduction

In living plants, large quantities of alkali metals are required as nutrients and counter ions. Potassium is especially abundant in annual and short-life crops like palm oil with sodium substituting in minor amounts. In the fast growing parts of trees (small branches, twigs and leaves), the alkali content is higher compared to the trunk and larger branches. The usefulness of biomass fuels in energy production is often limited by maintenance problems such as sintering, fouling and hot corrosion. These processes, which are largely due to the presence of potassium and chlorine, reduce the capacity, efficiency and availability of thermal conversion plants using biomass. Around 90% of the alkali in biomass is present in water-soluble or ion exchangeable form and is susceptible to vaporization during heating [1].
1.3 Effect of Additive with Increasing of EFB Softening Point

Slag formation slightly form of hard foam mineral layer on gasifier will occur if the temperature exceeds the softening temperature of ash [2] with a low heat transfer coefficient. Slag formation is mainly influenced by the gasification feedstock. Feedstock with high ash content and low softening point such as palm oil EFB, will more likely to form a slag. Elements such as Ca and Mg increase the ash melting point while K and Na decrease the melting point. Chlorides and low melting alkali and alumino silicates may decrease the softening point as well [3].

According to Sorensen et al, addition of calcium compound to the biomass before or during gasification process is recommended in order to change the composition of ash leading to in compound having higher fusion point temperature. According to the inventive patent [4], it is considered reasonable to obtain CaKPO4, having a melting temperature of 1560°C. Hence a goal can be to generate this compound as the major product. This means that one mol of K requires one mol of Ca.

Slaging and sintering can be avoiding by reducing the operating temperature in gasifier but lower temperature may affect the quality of flue gases. Apart from adjusting the operational temperature, another solution identified is by adding additive such as CaO to increase the melting point of the feedstock by compensating the lowering abilities of the K [5].

2.0 Methodology

The amount of additive supplemented in EFB is 2, 4, 6, and 8% mass by dry weight of EFB. The fibers and additive were mixed in a small plastic container and manually shake by hand until fibers and additive have been in a homogenously mix. Usually EFB fibers have average 12% of moisture content in natural environment. Additional water spray is not required in order to attach the additive surface to the EFB fiber surface. Sample EFB fiber with additive will be ashes in the furnace at 550 °C for 2 hours. Then the ash sample will be mould into cylindrical shape for ash fusion temperature analysis. The cylindrical shape will be observed into 4 kind of shape which is initial deformation, softening point, hemisphere temperature and fluidize temperature. The picture is taken for each 10 °C temperature increase. [6]
3.0 Result of Ash fusion temperature of EFB with addition of Ca(OH)$_2$ as additive

In this chapter, all the ash fusion result is shown by each additive percentage with amount of test. Four trials are made in order to confirm with previous test and get the average of fusion temperature for each percentage of additives.

| Characteristic                  | EFB + 0% of Ca(OH)$_2$ | EFB + 2% of Ca(OH)$_2$ | EFB + 4% of Ca(OH)$_2$ | EFB + 6% of Ca(OH)$_2$ | EFB + 8% of Ca(OH)$_2$ |
|--------------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Initial Deformation (°C)      | 934                    | 1046                   | 1166                   | 1237                   | 1274                   |
| Softening Temperature (°C)    | 1061                   | 1114                   | 1239                   | 1277                   | 1315                   |
| Hemispherical Temperature (°C)| 1170                   | 1146                   | 1280                   | 1320                   | 1320                   |
| Fluid Temperature (°C)        | 1185                   | 1220                   | 1295                   | 1320                   | 1320                   |

From table 3.1, mean value of EFB ash fusion temperature is increase by addition of additive. From the initial hypothesis, by increasing ash fusion temperature of EFB, the slag and sintering occur in gasify chamber can be reduce.

![Figure 3.1](image)

**Figure 3.1** Bar column for each addition of additive (%) and ash fusion temperature (°C)

4.0 The correlation of EFB ash fusion temperature with addition of additive

In this chapter, the ash fusion temperature of EFB will be discussed. In natural form, EFB have a low ash fusion temperature. This is causes by high alkali element in EFB such as Potassium (K) and Sodium (Na). Both elements cause low softening temperature in all biomasses, especially in agricultural plants. These mineral is supply three times per year as palm oil plant growth factor or as known as inorganic fertilizer [7]. Plant will absorb all the nutrient and mineral and accumulated in straw, fruit, leave and trunk. Figure 3.1 shows the addition of additive affecting ash fusion temperature of the EFB fiber.
EFB fibers with 0% of additive have low ash fusion temperature. The mean of initial deformation is 934 °C with standard deviation ±16.15. Raw EFB have inhomogeneous composition that resulting high standard deviation when it reach softening temperature phase. The mean of softening temperature from four trials is 1061 °C with standard deviation ±91.07. This is why from previous works; slagging problem occur inside the combustion chamber even though the operating temperature is below 1000 °C [8]. The inhomogeneous element of EFB fiber is cause by rainy season, material handling and contamination with soil. On the other hand, ash content is increasing in biomass during growth and is affected by biomass species, origin, soil and other factor [8]. At average temperature 1170°C ±102.8, the cylindrical shape is turn to hemisphere shape or it is called hemisphere temperature point. By continuously raising the temperature, the flow temperature is form which is half of the hemisphere shape. 1185°C±91.15 is the flow temperature of the raw EFB which is the ashes is in fluid state.

Once again from figure 3.1, it can be seen directly from the bar column that the ash fusion temperature is increasing with addition of additive. The additive use in this study is Ca(OH)₂ where calcium (Ca) is the main element in increasing as fusion temperature. By addition 2% of Ca(OH)₂ with EFB, the initial deformation is increase with mean 1046±25°C and softening temperature is 1114°C±20°C. While by addition 4% of Ca(OH)₂; the initial deformation is increase with mean 1166±15°C and softening temperature is 1239±47°C. Then by addition 6% and 8% of additive also increase the initial deformation and softening temperature compare to 2% and 4% with initial deformation and softening temperature at 1237±25°C and 1277±34°C for 6% of additive while 1274±30°C and 1315±10°C for 8% of additive.

5.0 Conclusion

As shown above, thermal analyses experiment lab scale allow the determination of additive percentage necessary for successfully running European solid biomass gasifier with Malaysian biomasses such as EFB fibers by adapting them. The lab scale test is much faster and less cost intensive than test with the original big plant.
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7.0 References

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