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Prevention Study of Sand Agglomeration on Fluidised Bed Combustor with Co-Combustion Method

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Sand is the most important part in the combustion process of fluidised bed combustor (FBC). The size of the sand particle has an effect on the fluidisation phenomenon, thus having an impact on the heat transfer process that occurs in bed material. By using wood pellet as fuel, there is a possibility of fluidisation phenomenon which is unfavorable due to the formation of sand agglomeration. This is proven in an experiment where 100 % of wood pellet was used as fuel for start-up and other things. It was difficult for the bed to achieve stability in a temperature range of 500 - 700 °C even though this range of temperature is a performance criterion in FBC to generate a self-sustain condition. To counter agglomeration, the easiest method of operational measurements was by mixing wood pellet with other fuels. This method is called co-combustion or co-feeding. In this experiment, we used coconut shells as co-combustion fuel. To observe the agglomeration, the temperature was measured in three points, where two of them were located above the distributor plate at a height of 3.5 cm and 24.5 cm. The result shows that both fuel mixtures were able to reduce and eliminate the agglomeration. In a mixture of coconut shells, the best result was obtained in the mixture of 30 % coconut shells.

1. Introduction

Fluidised Bed Combustion (FBC) is a combustion technology that is based on the principle of turbulence fluidisation and solid objects. During the combustion process, the heat and mass transfer capability increases significantly due to the fluidisation effect. The efficiency of the combustion process will also increase. The phenomenon of uneven combustion is a major factor in the replacement of fuel while the fuel turnover using wood pellets capable of causing agglomeration fluidised sand that can disturb the sand. In this study, agglomeration phenomena, which occured in each experiment using fuel mixture of shell and husk at different percentage, will be reviewed. Despite its broad application, biomass combustion/gasification, fluidised bed processstill has some technical difficulties. The agglomeration of bed material is a major operational problem. Usually, a fluidised bed biomass boiler involves silica sand as bed material in the presence of ash. Inorganic alkali components from the fuel, mainly potassium (K) and sodium (Na), can be problematic as they form low-melting alkali compounds and may react with the bed material forming low-melting alkali silicates (Montes et al., 2015). Petrographic techniques have been used to examine bed materials from fluidised bed combustion experiments that utilised wood and rice straw fuel blends. The experiments were conducted using a laboratory-scale combustor with mullet sand beds at firing temperatures of 840 to 1,030 °C which lasted for 5.5 h. A narrow continuous zone border was visible across all bed particles. The highest concentrations of potassium are found in this surface zone that are enriched in appreciable amounts of other elements. Thin discontinuous films of adhesive cement formed preferentially on surfaces and contact areas between bed particles, led to bed agglomeration (Thy et al., 2010). Bartels et al. (2010) has studied on the complex phenomenon of agglomeration in fluidised beds at high temperatures, and different areas are distinguished viz. hydrodynamics, chemical reaction mechanisms, particle interaction mechanisms and molecular cramming. Special emphasis is given to the detection of agglomeration. The range of detection methods is comprised of

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fuel ash analysis methods to predict the potential agglomeration as well as analysis methods based on (on-line) process measurements, such as pressure and temperature. Finally, different methods to counteract agglomeration phenomena are presented; they are comprised of operational measures, utilisation of additives, alternative bed materials, and improved reactor design.

2. Experimental Set up and Method

2.1 Sand (bed material)

The sand, as shown in Figure 1, which was used as an overlay (bed), will affect the success of the fluidisation and combustion processes to be performed. Sand used in fluidised bed combustor (FBC) is a type of silica sand. According to current research, silica sand with a mesh size of 20 - 40 has a higher temperature working condition. Table 1 lists the properties of the silica sand used.

Table 1: Physical, thermal and mechanical silica sand

Properties	Silica sand
Particle density (kg/m^3)	2,600
Bulk density (kg/m^3)	1,300
Thermal conductivity (W/m.K)	1.3
Tensile strength (MPa)	55
Compressive strength (MPa)	2,070
Melting point (°C)	1,830
Modulus of elasticity (GPa)	70
Thermal shock resistance	Excellent

Figure 1: Silica sand used in FBC

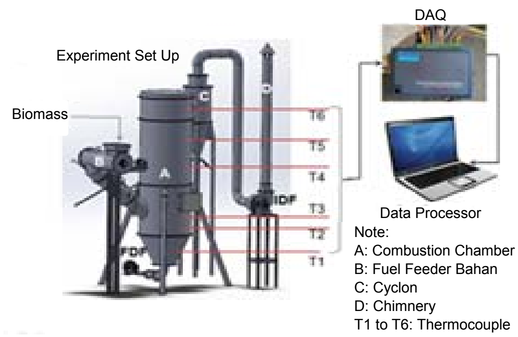

Figure 2: Schematic fluidised bed combustor

2.2 Thermocouples

There are three pieces of thermocouples mounted on the furnace, as shown in Figure 2. With reference to the distributor, the thermocouple is placed with the following configurations:

T1 = 31.5 cm below the distributor
T2 = 3.5 cm above the distributor
T3 = 24.5 cm above the distributor

2.3 Wood Pellet and Coconut shell

2.3.1 Wood Pellet

Wood pellet (raw material), as shown in Figure 3, is derived from wood or wood waste and mainly consists of sawdust powder and Kaliandra Red (Calliandra calothyrsus). Sawdust is composed of various types of wood such as Albasia, Mahogany, and Local Wood (Sonokeling, Rubber, Albasia Local, Nangka Wood). Wood pellet used in this study is 8 mm in diameter and 10 mm in length. The majority of sawdut is Albasia (P. falcataria) which has characteristics as shown in Table 2.

Figure 3: Wood pellet

Table 2: Albasia Characteristics (Acda, 2015)

Parameter	Unit	Result	Method
Total Moisture	%, ar	5.21	TG-DTA
Proximate Analysis:			
Moisture in Analysis	%, adb	5.21	TG-DTA
Ash Content	%, adb	1.45	TG-DTA
Volatile Matter	%, adb	64.13	TG-DTA
Fixed Carbon	%, adb	29.16	TG-DTA
Net Calorifiec Value	kcal/kg, adb	4,130	TG-DTA
Gross Calorific Value	kcal/kg, adb	4,158	TG-DTA

2.4 Procedural Test

After the silica sand, which is the bed material, was prepared, the inflatable blower (Forced Draft Fan) and the suction blower (induced draft fan) were turned on. Once the material was in fluidised condition, a series of documentation started during the fluidisation phenomenon. The next step was to turn on the LPG burner for preheating process. The LPG burner was turned off when the thermocouple recorded a temperature of 200 °C in the bed particles. The fuel, which is a mixture of wood pellets and coconut shells, began to be fed into the burner. The fluidisation and agglomeration phenomena appeared when the temperature in point 2 reached 700 °C. Since the LPG burner was on until the trial was completed, all the data were stored using a data acquisition Graphtec GL-70.

3. Result and Analysis

In this study, the type of system used was Bubbling Fluidised Bed Combustor, and the main fuel used was wood pellets with a fuel mixture of coconut shell. Fuel blending aims to prevent agglomeration of the sand bed. In each experiment two important phenomena were observed: the agglomeration formation and whether the burning process occurred evenly. Both of these processes were observed through temperature stability of both thermocouples, T2 and T3.

Differences between T2 and T3 were named as $|\Delta T|$. $|\Delta T|$ indicated the agglomeration phenomenon. The temperature in the FBC combustion chamber should be uniform and the temperature difference in the combustion chamber must be below 100 °C (Chirone et al., 2008). In the case of agglomeration, the temperature difference in the bed will be very significant, which is about 100 °C and if agglomeration occurrs, $|\Delta T|$ will reach above 200 °C.

Figure 4 shows the downward trend of $|\Delta T|$, which was affected by the formation of agglomeration. Too high temperatures led to agglomeration, whereastoo low temperatures decreased the efficiency of FBC. Therefore, an optimum operational temperature had to be determined while conducting the experiment.

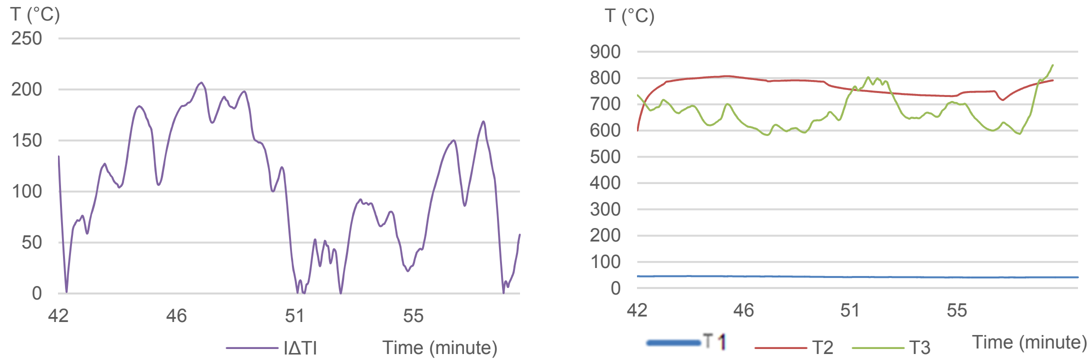

Figure 4: Results of experiment using 100 % wood pellet

3.1 Analysis result of Co-Combustion coconut shell

Co-combustion using a mixture of 10 % and 20 % of coconut shells were able to reduce agglomeration as shown in Figure 5. When 30 % of coconut shells was used for co-combustion, the agglomeration was eliminated. However, when 40 % and 50 % of the shells were used as co-fuel, there was a higher difference in temperatures and a higher fluctuation in the bed's temperature. This was due to the increased amount of shell leading to a burning of higher amount of shell, which dominated the process.

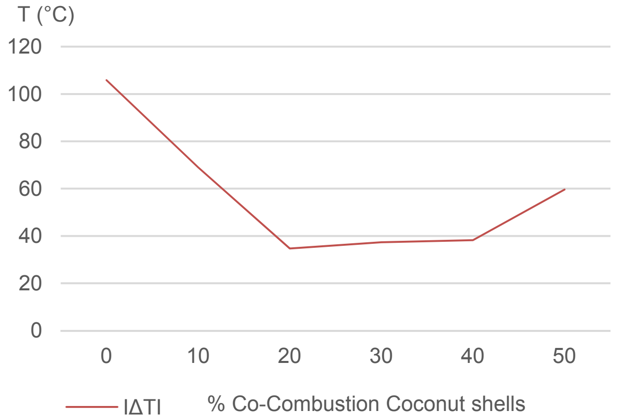

Figure 5: Average temperature difference in every experiment of co-combustion coconut shells

3.1.1 Co-Combustion Coconut shells 10 %

From the result above, the co-combustion techniques can reduce the process of agglomeration. In Figure 6, the use of 10 % shell shows difficulties in reducing the agglomeration. This can be seen from the highest temperature difference, which was about 120 °C. And also the temperature of T2 increased the combustion that used 100 % pellets. The temperature at T3 was stable as well.

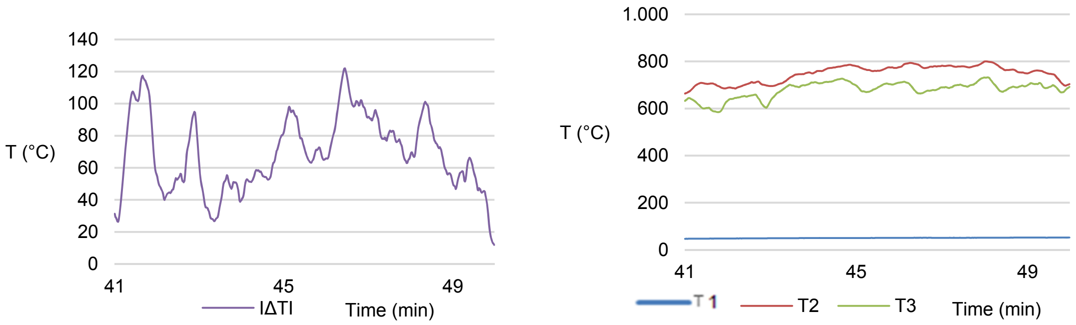

Figure 6: Experiment result of co-combustion coconut shells 10 %

3.1.2 Co-Combustion Coconut shells 20 %

The increase of shell mix to 20 % did not show much difference than that of the 10 %. However, the condition of agglomeration process could be reduced. Figure 7 shows that the temperaturedifference|ΔT| exceeded 100 °C within only avery short time, which was about 2 - 3 minutes.

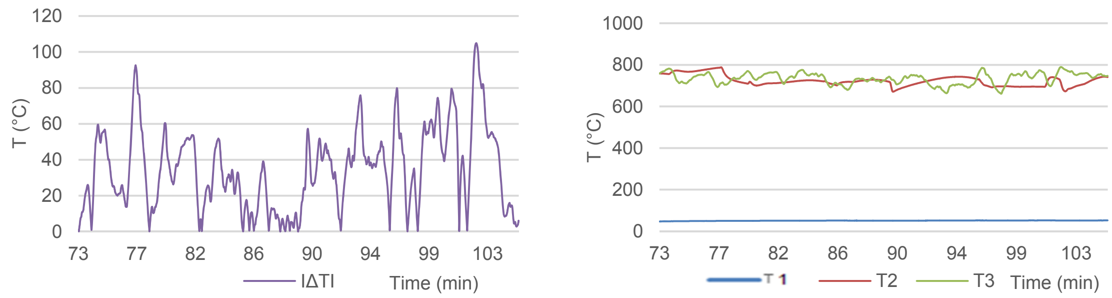

Figure 7: Experiment result of co-combustion coconut shells 20 %

3.1.3 Co-Combustion Coconut shells 30 %

Test with the shell grading at 30 % showed the best results where the bed temperature was more stable when compared with the levels of 10 % and 20 %. But in the early part of the operational conditions, the temperature difference could exceed 100 °C. Figure 8 shows that agglomeration occured when the temperature of the initial 2-point reached 850 °C. However, if the temperature was kept stable and did not exceed 800 °C, the agglomeration was not formed.

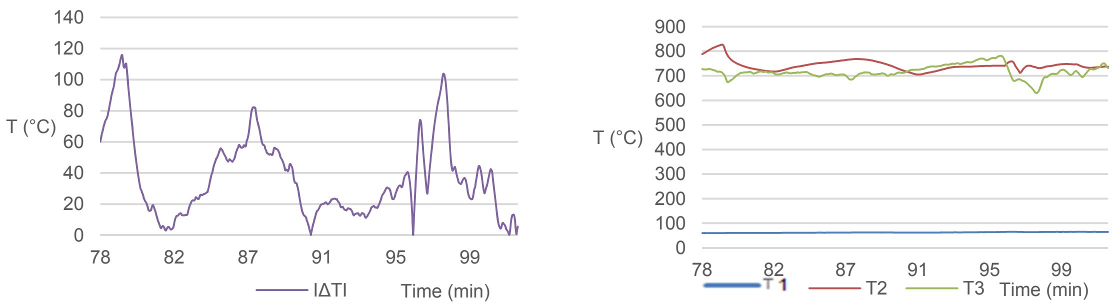

Figure 8: Experiment result of co-combustion coconut shells 30 %

3.1.4 Co-Combustion Coconut shells 40 %

According to the previous results, as indicated in Figure 8, it was clear that the agglomeration had been reduced and that agglomeration was absent when 30 % of shell mixed was used. But at the rate of 40 %, the temperature of the bed seemed very unstable. Agglomeration was not formed because the difference in the average temperature was still below 100 °C as shown in Figure 9. Instability may occur because the amount of shells was too much compared with that of wood pellets. The combustion characteristics of the shell were uneven and unstable. This was caused by an unstable bed temperature.

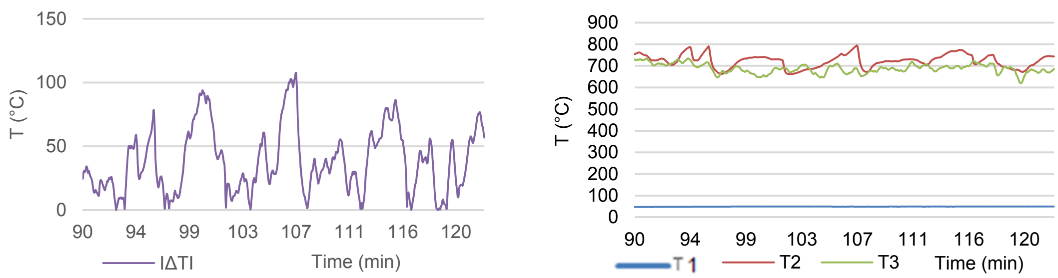

Figure 9: Experiment result of co-combustion coconut shells at 40 %

3.1.5 Co-Combustion Coconut shells 50 %

At the level of 50 %, the instability of temperature at T3 could be seen. What happened here was similat to when 40 % of shell was used as shown in Figure 10. This was because the number of shells used was greater than that of wood pellets, so it showed uneven burning characteristics as well.

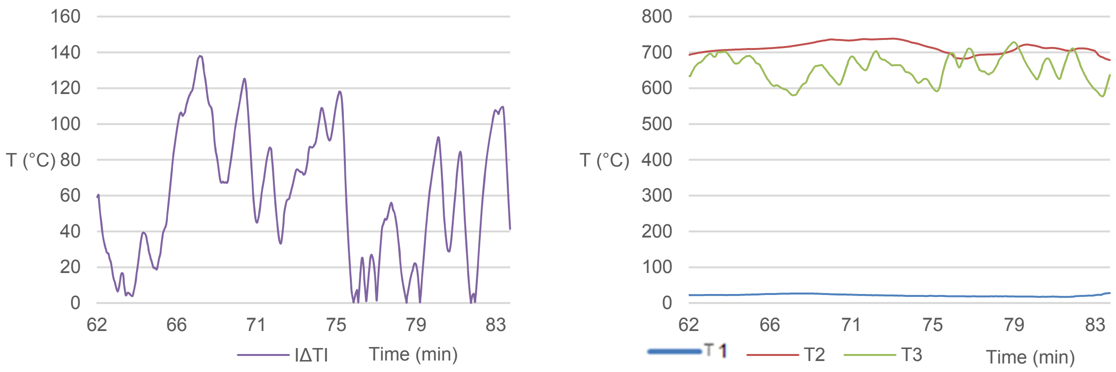

Figure 10: Experiment result of co-combustion coconut shells 50 %

4. Conclusions

The co-combustion of coconut shells could reduce and eliminate agglomeration of sand when wood pellets were used as fuel. Co-combustion with the most excellent result waswhen 30 % of coconut shells was used and when a temperature difference between T2 and T3 (|ΔT|) was at an average of 37.35 °C.

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