Cold Model Performance Test of 50 KWe Dual Fluidized Bed Gasification Technology

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ABSTRACT
Research on the development of sustainable alternative fuels to replace fossil fuels has received serious attention because of the increasing world oil prices and environmental concerns. This study focused on the development of Dual Fluidized Bed Gasification technology, especially the cold model performance to obtain the hydrodynamic characteristics of bed material. The cold model performances are carried out at the Lab. Biomass PTSEIK BPPT Gedung 625 Puspiptek Serpong. Bed material used is silica sand which is circulated externally from the combustor to gasifier and vice versa through a loop seal. From this cold model performance test, the minimum fluidization velocity (Umf) of 391 μm silica bed material is 0.15 m/s, and the pressure difference (ΔP) between the fluidized bed and freeboard reactor is 3.5 kPa. The results of this cold model performance test will be used as a reference in the operations of hot model Dual Fluidized Bed Gasification.

Keywords: *Gasification, Cold Model, Dual Fluidized Bed, Silica Bed Material, Minimum Fluidization Velocity*

1. INTRODUCTION

More than 74% of Indonesia's energy needs are still fulfilled by fossil fuels, the main sources of greenhouse gas emissions into the atmosphere. Although dependence on fossil fuels cannot be eliminated in the future, it is importance to reduce utilization of fossil fuel by developing renewable energy technologies such as biomass gasification [1].

Based on 2016 BPS data, palm oil production is 34.5 million tons per year. Empty fruit bunch is 21.5% of the fresh fruit bunch which are by-products. It can be calculated that the empty fruit bunch (EFB) production is 33 million tons. This dry EFB can be able to generate electricity of 1.65 GWe [2]. The utilized EFB is still 10% of its potential. Therefore, in addition to electricity, the EFB waste can also be used for boiler fuel and other chemicals through biomass gasification technology [3]. Gasification is a process in which a solid material containing carbon such as biomass is converted into syngas. The biomass is heated to high temperature, producing gases which can undergo chemical reactions to form a synthesis gas (syngas). There are several different types of gasification that have been demonstrated or developed for conversion of biomass. The gasifiers are fixed bed gasifier, entrained flow gasifier, circulating fluidized bed gasifier, dual fluidized bed gasifier and plasma gasifier [put reference number for each type of gasifier]. Most of these have been developed and commercialized for the production of heat and power from the syngas. The fluidized bed gasifier is suitable for biomass feedstock. This utilization of biomass is useful due to the flexibility and reliability of gasification technology for energy conversion.

A process yielding highest energy efficiency and flexibility for further application is steam gasification of biomass in a fluidized bed. This process converts solid biomass into syngas with high heating value, suitable for the production of substitute natural gas (SNG) or biofuels. The gasification developed is an endothermic process that needs an external heat supply to operate.

But the problem encountered in bubbling or circulating fluidized bed technologies, the flue gas and syngas produced are mixed and difficult for cleaning the gas product. To separate flue gas and syngas, some researchers develop dual fluidized bed gasifier [4]. Dual fluidized bed reactors may provide efficient heat management. One of the reactor is a gasifier and the other is a combustor. The required heat for gasifier can be generated from combustion of the remaining char of the first reactor. The needed heat is transferred to the gasifier through circulation of bed material [5]. A cold model DFB was built to simulate the gasifier (DFB) hydrodynamic characteristics of hot model. The cold model is made of acrylic plastic. Fundamental hydrodynamics studies were conducted using this cold model DFB. The hydro dynamics experiments were carried out to study the solid movement behavior in the Dual Fluidized Bed Gasification (DFBG).

2. EXPERIMENT

2.1. BED MATERIAL

The Silica sand was used as the bed material for DFBG system. The mean particle size was determined by sieve analysis. Table 1 summaries the physical properties of silica sand.

Table 1. Physical properties of bed material

Bed material	Silica sand
d_p	391 μm
ε_p	0.5
ρ_p	2600 kg/m³

2.2. A COLD MODEL EQUIPMENT

The combustor reactor has an inner diameter of 930 mm, the other reactor gasifier has an inner diameter of 800 mm, the pipe connecting riser (recycle chamber) in the loop seal to combustor has an inner diameter of 6 inch (15.24 cm). Cold schematic drawing of the model is shown in figure 1.

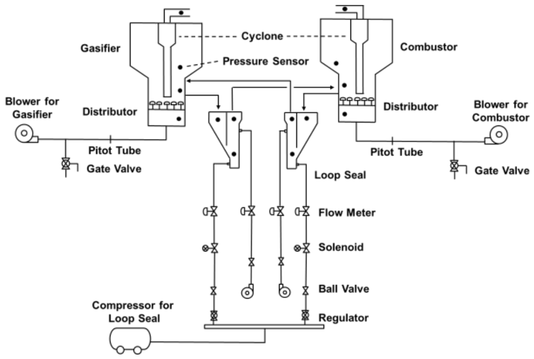

Figure 1 Cold Model DFBG.

The air fluidization was blowing by Vortex blower Hitachi VB-110-E2 capacity 8 m3/min and PUMA 7.5 HP compressor. The air flow from blower was measured using Pitot tube ALNOR AKD. The air flow from compressor via reducing valve NISCON BN-3R01-25 and solenoid valve CKD APK11-25A was measured by air flow meter Azbil capacity 1200 L/min. Solid circulation Gs was measured by ALEXA scale capacity 600 kg. Weight and pressure data variables were measured by Autonics sensor MT4W and recorded using GRAPHTEC Midi logger GL840.

In a cold model experiment to measure the amount of Gs (particle solid circulation), we measured the number of particles discharged through a loop seal from one of the fluidized reactors.

Here, the discarded particles are immediately weighed without going through another fluidized reactor. The experiment scheme is shown in Figure 2. Fluidization is done by air blowing 3 Umffrom the bottom of the reactor distributor after filling the sand in the reactor.After that, the air aeration is blown into the loopseal at the riser on top of the loop seal (VJ, RU) and the bottom riser (VJ, RD) so that bed material flows into the loop seal and flows from the loop seal then weighed.

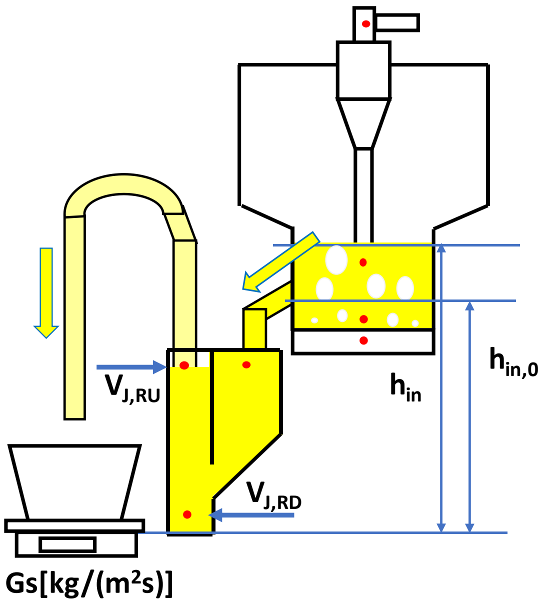

Figure 2 Cold Model Experiment

3. RESULTS AND DISCUSSION

3.1. MINIMUM FLUIDIZATION VELOCITY (Umf)

At fixed bed gasification, the gas travels only through the intra-particle gaps and no particle movement take place. Increasing gas velocity increases drag force on the particles and increase pressure drop, but at certain gas velocity, the drag force and buoyancy on the particles become equal to the weight of the particles. At this stage particles become fluidized and the bed show ability to move or expand. The pressure drop does not increase any further with flow rate. This condition is called minimum fluidization and the gas velocity at which this phenomenon occurs is called minimum fluidization velocity (Umf)[6]. The minimum fluidization velocity is measured according to the pressure drop gradient across bed material. Fig.3 and fig.4 show the experimental measurement of Umfin gasifier and combustor. The gasifier Umf is around 15 cm/s and the pressure drop **ΔP** around 3.5 kPa. The combustor Umf is around 15 cm/s and the pressure drop around **ΔP** 4 kPa. Pressure drop can be calculated using equation as follows:

$$\Delta P = \varepsilon p \cdot \rho_p \cdot g \cdot \Delta h \quad (1)$$

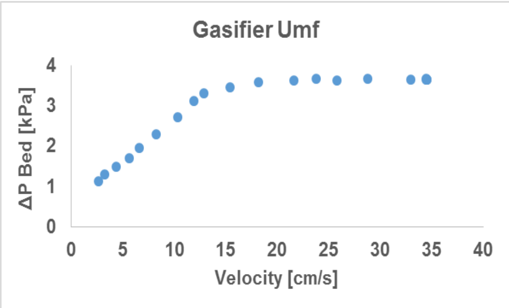

Figure 3 Umf vs Pressure drop in Gasifier

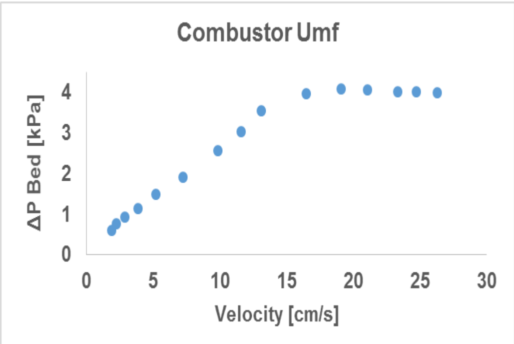

Figure 4 Umf vs Pressure drop in Combustor

3.2. AERATION RATE IN LOOP SEAL

A solid circulation is one parameter of DFBG hydrodynamic characteristics. In the fluidized bed conditions, solids are subjected to motion. At that condition, static pressure at given level is equal to the weight of the solid per unit cross section above that level. A denser object will sink into the bed and light particles will float when it is fluidized.

By using a cold model testing, a real gasification hydrodynamic system can be predicted conducted at ambient temperatures and pressures, which are easier to operate to predict the fluidization properties of the bed material. Figure 5 (with a 6-inch riser pipe connection) shows the change of particles flowing out over the time.

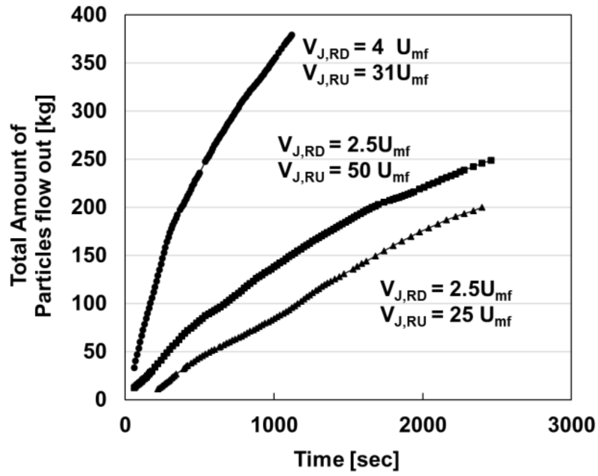

Figure 5 Total amount of particle flow out

If the experimental conditions are 2.5 Umf of $V_{J,\ RU}$ and 25 Umf of $V_{J,\ RD}$, the average number of particles released is 5 kg per minute. Whereas for 2.5 Umf of $V_{J,\ RU}$ and 50 Umf of $V_{J,\ RD}$ the average number of particles released is 6 kg per minute. This difference occurs because the rate of aeration in the riser is doubled so that the number of particles flowing out becomes larger. In addition to the information with the increasing aeration rate at the bottom of the downcomer from 2.5 to 4 Umf of $V_{J,\ RD}$,and $V_{J,\ RU}$ 31 Umf, the solid particles released increase to 20 kg per minute.

According to these results, the most influencing factor to achieve a high solid circulation rate is the aeration rate on the downcomer section. This proposes that $V_{J,\ RD}$ at the bottom is a big influence on the particles being moved because the amount of bed material falling from the downcomer increases.

3.3 SOLID CIRCULATION (Gs)

In our DFBG system, BFB-BFB type is selected. Both gasifier and combustor are operating in bubbling regime. These systems are easy to operate and suitable for small scale. The solid transfer between two beds is achieved with the help of loop seal. The condition of solid circulation is shown in Table 2.

Table 2. The condition of solid circulation

Air fluidization rate	3 Umf
Riser aeration rate	3250 L/min (gasifier) 3350 L/min (combustor)
Downcomer aeration rate	700 L/min
Height of bed material	43 cm

The results of solid circulation from gasifier to combustor (Blue line) and vice versa are shown in Figure 6.

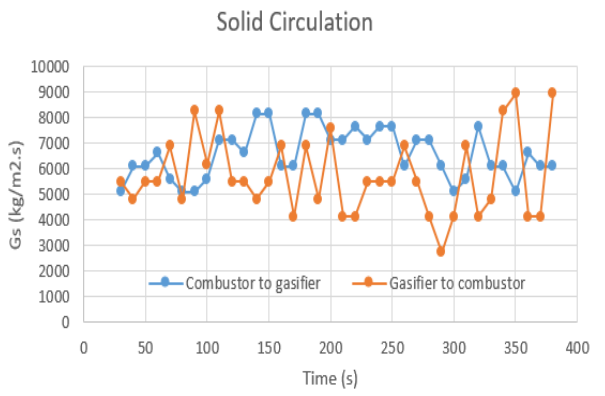

Figure 6 Solid circulation of cold model

After experiment, the height of bed material of gasifier is 47 cm, and the height of bed material combustor is 40 cm. These results need to be optimized before being used as a reference for hot model design. It was found in the experiment of cold model BFBG tests that solid flow was often disrupted in the pipe between the two main reactors (gasifier and combustor). It was observed that the solid flow was getting trouble flowing into the BFB smoothly. Solid and gas flow can be improved by changing the connection pipe 6 to 4 inch from riser loop seal to BFB gasifier.

The solids which were originally falling back to the bottom of the BFB can flow into the downcomer of the loop seal. With these channels the solids into the pipe without the disruption. The smooth flow of bed materials is beneficial for the DFBG operation.

By lowering the ID, the connection pipe, solid particles of low solid inventory will be transported from the riser to BFB gasifier easily.

The conclusions obtained from the cold flow research model are:

4. CONCLUSION

- The hydrodynamic behaviour of the combustor-loop seal-gasifier circuit and vice versa can be used as a reference in the hot model design which is the same size as the cold model.
- The prediction results for Gs after optimization are in the corresponding correlation to estimate the flow rate of solids through the loop seal on the hot model. The solids flow rate Gs depends on the balance between the total driving force of aeration and fluidization and resistance along the circuit.
- The results of the experiment also show that the aeration velocity in the loop seal downcomer greatly affect the solid circulation Gs.

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