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Effect of Biomass Drying Temperature on The Characteristics of Gas Produced by Fluidized Gasifier Bubbling Reactors

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Abstract. Biomass is an alternative fuel that can be used and one of the technologies to utilize biomass is gasification. This study aims to determine the effect of biomass drying temperature on the characteristics of the gas produced by the Bubbling Fluidized Bed Gasifier Reactor. This research uses 3 variations of drying temperature on biomass fuel, namely 70 ˚C, 90 ˚C, and 110 ˚C. The results showed that the higher the biomass drying temperature, the higher the temperature distribution. The highest temperature distribution is found in fuel with P 110 ˚C with a temperature distribution of 592.266 ˚C and the lowest distribution occurs in fuel with P 70 ˚C with a temperature distribution of 498.64 ˚C.

1 Introduction

Until now, fossil energy is still the main energy source used by society and industry in Indonesia. This is possible because Indonesia has quite large proven oil reserves, namely 3.7 billion barrels or 0.3% of the world's proven oil reserves. Based on data from Integrated Green Business, Indonesia is one of the countries with the highest energy consumption growth in the world, namely 7% per year. Nearly 95% of energy consumption comes from fossil fuels, of which 50% use oil. Continuous use of fossil fuels will result in the availability of fossil fuels becoming increasingly depleted, which will result in fuel scarcity. Therefore, it is necessary to develop renewable energy as an alternative to petroleum as the main energy source [11].

One of the best solutions to overcome the scarcity of fossil fuels is to provide fuel from alternative energy sources. Biomass is a type of alternative energy source that is currently being developed because its quantity is very abundant. Indonesia has a large potential for biomass, especially coconut shells. Therefore, coconut shell biomass is very good as a new and renewable alternative fuel source.

The technology used to utilize biomass is gasification. Gasification is a process technology that converts solid fuel into gas, and one type of gasification technology that is being developed is a fluidized bed. Fluidization is defined as an operation in which a bed of solid substances is treated like a fluid that is in contact with a gas or liquid [2]. This phenomenon occurs in a medium called fluidized bed. A fluidized bed is a vessel containing solid particles that are flowing with fluid from below. [4].

The gasification process includes 4 stages, namely drying, pyrolysis, gasification, and oxidation. The drying process is the process of releasing the moisture content in biomass due to heat entering the biomass. This process is an endothermic process that requires heat where the heat is used for the gasification medium which is produced from the oxidation process. The level of dryness of the moisture content influences the quality of the gas from the gasification process. To obtain gas results from the gasification process, several studies have carried out treatments to obtain gas quality. Research conducted by [12] carried out gasification tests using a downdraft reactor and wood pellet fuel. This test uses variations in water content at conditions of 2%, 4%, 6%, 8%, and 10% in wood pellets and uses downdraft gasifier technology. The results of this research show that with increasing water content, tar formation products are indicated to increase as well. Therefore, this research uses different fuels and reactors, namely coconut shells as fuel and uses a bubbling fluidized bed gasifier reactor. Thus, this research aims to determine the effect of biomass fuel drying temperature on gas characteristics in a bubbling fluidized bed gasifier reactor.

2 Research methodology

2.1 Diagram flowchart

Flowchart of the process is available in Fig. 1.

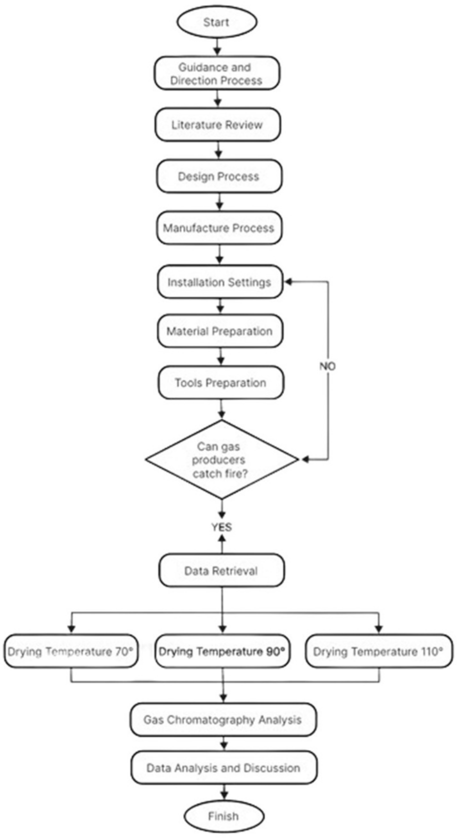


Fig. 1. The process flowchart.

The flow of this research is as follows:

1. This research began with an offer from one of the Mechanical Engineering lecturers at Muhammadiyah University of Surakarta, then the guidance and provision stage regarding reactor design, a search for literature studies, tools, and survey materials.
2. Reactor design using Auto Cad and Solid Works software, by the references provided and obtaining approval. The next stage is the reactor manufacturing process at PT. Purosani Prima in Wates, Yogyakarta.
3. The manufacturing process starts with preheating, distribution plates, fluidized bed reactor parts, screw feeders, freeboard parts, and cyclones. After the manufacturing stage was completed, the reactor was sent to the Mechanical Engineering Laboratory of the Muhammadiyah University of Surakarta.
4. The next stage is the reactor setup, preparing the tools used before the experiment begins, such as thermocouples, data loggers, orifice meters, manometers, LPG gas, silica sand, and biomass.
5. After all the tools are ready, then prepare the biomass fuel, namely by ovening the coconut shells into three variations of 70 ˚C, 90 ˚C, and 110 ˚C.
6. After the tools and materials are ready, the next step is to test the use of a bubbling fluidized bed gasifier reactor using biomass fuel with a drying temperature of 70 ˚C, 90 ˚C, and 110 ˚C.
7. After the gas sample was obtained from the gasification process using a bubbling fluidized bed gasifier reactor, the gas sample was tested using a gas chromatograph at the UGM Mechanical Engineering Energy Conversion Laboratory to determine the characteristics of the gas produced.
8. Processing data obtained from the UGM Mechanical Engineering Energy Conversion Laboratory and preparing reports.

2.2 Research Installation

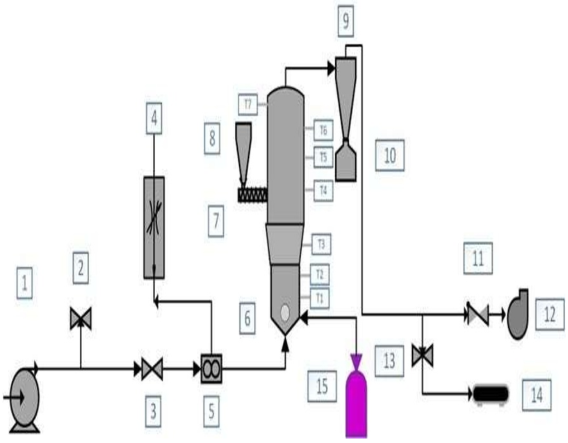


Fig. 2. Bubbling fluidized bed gasifier reactor schematic.

Fig. 2 presents a schematic of the bubbling fluidized bed gasifier reactor for the experiment. The installation consists of several parts, including:

1. Ring blower, is used to supply air to the combustion chamber.
2. Valve bypass, is used to reduce the air pressure entering the reactor.
3. Main air supply valve, used to regulate the main air entering the gasification reactor.
4. Manometer U, is used to measure pressure in a reactor using fluid. In the measurement process using the difference in water height which compares the rising air pressure and the falling air pressure, the height difference is used to calculate the flow rate in the pipe.
5. Orifice meter, is used to measure the airflow rate in the air supply pipe, measured by the pressure drop in the airflow in the pipe using a plate called an orifice plate.
6. Observation glass, is useful for knowing whether the burner is on or not.
7. Screw feeder, this is a place to enter biomass into the reactor.
8. Hooper, a reservoir for biomass that will go inside.
9. Cyclone, functions as a separator that separates ash and gas produced from the combustion process.
10. Ash container, is a place to store the ash resulting from burning.
11. Gas product bypass valve, used to flow gas products to the gas bag.
12. Blower centrifugal, functions as a sucker for gasifier gas from the reactor so that it can be channeled to

the gas-producing stove and the pipeline to the gas bag.

13. Valve gas bag, functions to close the product gas path to the gas bag so that product gas can be distributed to the suction stove more optimally.
14. LPG, is used as fuel to power the preheating stove.

2.3 Tools and Materials

This research uses tools including a bubbling fluidized bed gasifier reactor with a reactor height of 12 cm, thermocouple, data logger, orifice meter, U-manometer, sieve, digital scale, and oven. The materials for this research used 1.8 kg silica sand with a mesh size of 20 to 30 as bed material and fuel in the form of coconut shells.

3 Result and Discussion

3.1 Minimum Fluidization Velocity (U_{mf})

The minimum fluidization velocity is determined via the formula shown in Eq. (1) by Geldart, the calculations produce the Archimedes number A_r and minimum fluidization velocity (U_{mf}) as follows;

$$A_r = 3919410224.951$$

$$U_{mf} = 0{,}257 \text{ m/s}$$

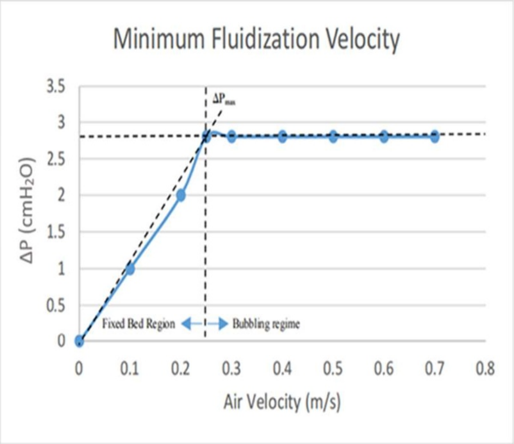


Fig. 3. Minimum fluidization speed in the Bubbling Fluidized Gasifier reactor.

Fig. 3 shows a graph of the minimum fluidization velocity, from the graph above it can be seen that at an air velocity of 0.1 m/s the pressure (ΔP) is 1 cmH2O, at an air velocity of 0.2 m/s the pressure (ΔP) has increased by 2 cmH2O, then at an air speed of 0.257 m/s the pressure (ΔP) increases by 2.8 cmH2O. Furthermore, from the graph above, after the airspeed is 0.257 m/s, the pressure (ΔP) does not increase, so the minimum fluidization velocity is 0.257 m/s.

The minimum fluidization velocity is also used as an operating parameter in determining the bubbling regime, so the fluidized bed gasifier bubbling reactor used in this research requires a minimum air velocity of 0.257 m/s to achieve the initial process of the bubbling regime. In this study, the airspeed used was 0.56 m/s so the bubbling regime occurred.

3.2 Comparison Results of Temperature Distribution Using Fuel with Drying Temperature 70 ˚C, 90 ˚C, 110˚C

Fig. 4 shows a graphical comparison of temperature distribution during fuel dryness in an oven with temperatures of 70 ˚C, 90 ˚C, and 110 ˚C obtained from the gasification process in a bubbling fluidized bed gasifier reactor. with equivalent ratio and fixed air velocity, the biomass is introduced at a temperature of 500℃ through T4 to T5.

From these three variations, it can be seen that the highest temperature at T1 was achieved in fuel with a drying temperature of 110 ˚C with an average temperature of 592.296 ˚C, and the lowest temperature at T1 was achieved in fuel with a drying temperature of 70 ˚C with an average temperature of 498.640 ˚C, this is because the drier the material, the more heat it releases. From Fig. 4, it can be seen from the three variations affecting the temperature distribution in the bubbling fluidized bed gasifier reactor that the higher the fuel drying temperature, the higher the temperature distribution in the reactor.

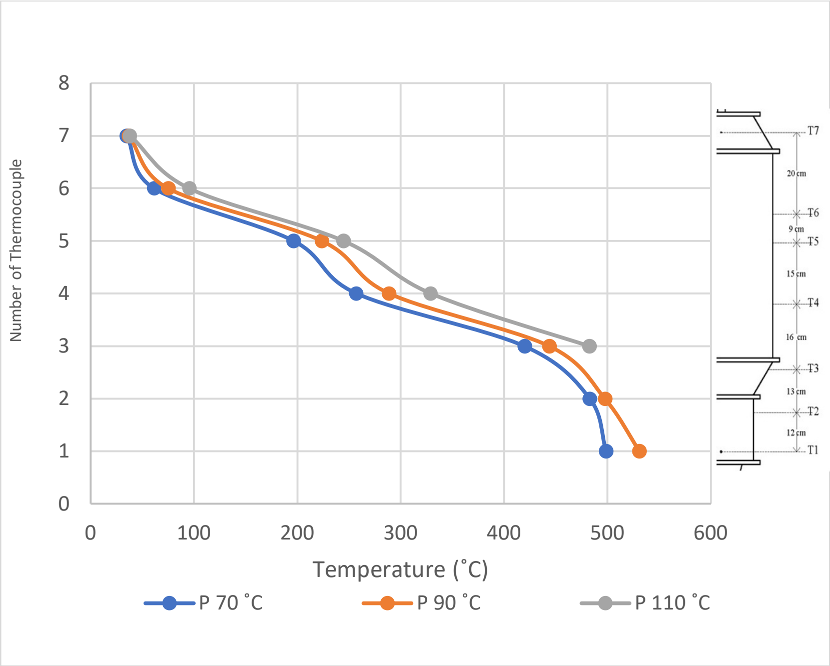
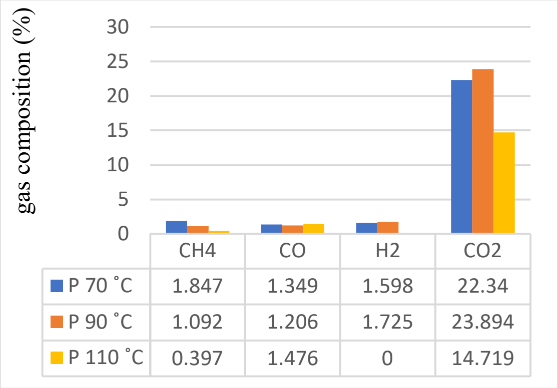


Fig. 4. Results of the temperature distribution of the bubbling fluidized bed gasifier reactor on fuel with drying temperatures of 70 ˚C, 90 ˚C, and 110˚C.

3.3 Comparison Results of Gas Composition Using Fuel with Drying Temperatures of 70 ˚C, 90 ˚C, 110 ˚C

Fig. 5 shows a graph of the gas composition resulting from burning biomass using fuel with P 70 ˚C, P 90 ˚C, and P 110 ˚C with operating condition parameters of superficial speed of 0.54 m/s and particle size of 0.707mm. The gas composition detected is CH_4, CO, H_2, and CO_2.



	CH4	CO	H2	CO2
■ P 70 ˚C	1.847	1.349	1.598	22.34
■ P 90 ˚C	1.092	1.206	1.725	23.894
■ P 110 ˚C	0.397	1.476	0	14.719

Fig. 5. Comparison results of gas composition in fuel with drying temperatures of 70 ˚C, 90 ˚C, 110 ˚C.

The fuel drying temperature values from P 70 ˚C, P 90 ˚C, and P 110 ˚C respectively produce CH_4 gas decreasing from 1.847 % to 1.092 % to 0.397 %, CH_4 itself is obtained from the methanation reaction R10 where the reaction occurs between CO_2 and H_2. At CO from P 70 to P 90, it decreased by 1.349% to 1.206% and at P 110 it increased by 1.476%. In H_2 gas at P 70 to P 90 there was an increase, namely 1.598% to 1.725%, and at P 110 the H_2 gas composition did not come out because the drying temperature was too high causing the H_2O content to evaporate during the fuel oven process and too little CH_4 acting on P 110. to 1.598%. CO and H_2 are obtained from the R12 reaction, a steam reforming reaction occurs between CH_4 and H_2O to produce CO and H_2. At CO_2 from P 70 to P 90 there was an increase, namely from 22.34% to 23.894%, and at P 110 there was a decrease with a value of 22.34%. CO_2 is produced from the oxidation reaction (Table 2.1) R6 between CO and O_2.

3.4 Low Heating Value Syngas

LHV (Low Heating Value) is the calorific value obtained from burning fuel without taking into account the heat of steam condensation (water produced from combustion in the form of gas/steam).

Fig. 6 shows a comparison of the LHV graph for fuel with P 70 ˚C, P 90 ˚C, and P 110 ˚C. From the LHV calculation formula in equation 4 in Chapter 2 [2], it was found he highest LHV value was obtained for fuel with P 70 ˚C with an LHV value of 1.032 MJ/Nm3, then for P 90 fuel the LHV decreased by 0.751 MJ/Nm3 and the lowest LHV was obtained in fuel with a drying temperature of 110 ˚C with an LHV value of 0.32 MJ/Nm3, this was because the fuel with P 110 ˚C had the lowest CH4 composition of the three variations and H2 had no composition.

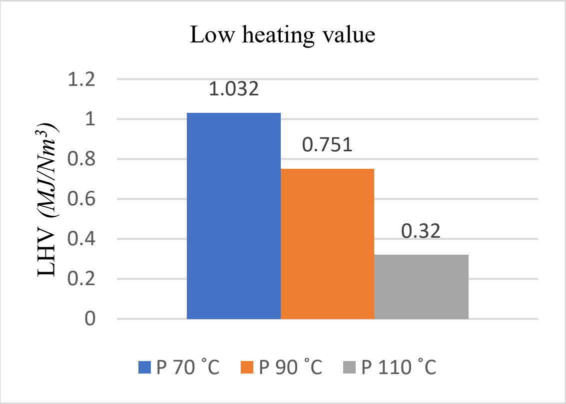


Fig. 6. LHV comparison results for fuel with drying temperatures of 70 ˚C, 90 ˚C, 110 ˚C.

3.5 Comparison Results of Flame Colors Using Fuel with Drying Temperatures of 70 ˚C, 90 ˚C, 110˚C

Fig. 7 shows the results of comparing the color of the flame resulting from burning biomass with different drying temperatures. In fuel with P 70 ˚C the dominant flame is orange because in P 70 ˚C fuel the composition of hydrogen gas (H_2) is lower than in P 90 ˚C fuel, in fuel with P 90 ˚C the flame is predominantly colored dark yellow because in fuel P 90 ˚C the composition of hydrogen gas (H_2) is the highest compared to fuel P 70 ˚C and fuel P 70 ˚C (Figure 4.9), and in fuel with P 110 ˚C the flame is dominant is red because the P 110 ˚C fuel does not contain hydrogen gas (H_2). Of the three variations, the most effective flame color result is the most effective flame color in the P 90 ˚C fuel because the Hydrogen composition (H_2) is the highest.

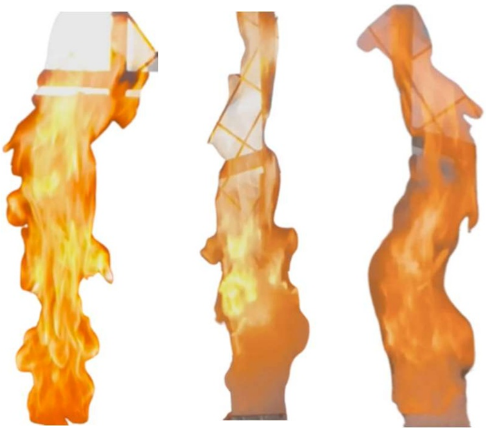


Fig. 7. Flame color from burning biomass with fuel with drying temperature (a) 70 ˚C (b) 90 ˚C (c) 110 ˚C.

4 Conclusion

Based on the analysis and results of the discussion of the test data on the effect of different drying temperatures on the working of the bubbling fluidized bed gasifier reactor, the following conclusions were obtained: First, the temperature distribution shows that the higher the drying temperature of the fuel, the resulting temperature distribution also increases. The highest temperature distribution occurs at P 110 ˚C which has a temperature at T1 which is 592.266 ˚C and the lowest distribution occurs at P 70 ˚C which has a temperature at T1 which is 592.266 ˚C. Second, the gas composition results detected are CO_2, CH_4, CO, and H_2 gas. In CO_2 the highest composition is at P 110 ˚C with a concentration value of 23.894%, in CH_4 the highest composition is at P 70 ˚C with a concentration value of 1.847%, in CO the highest composition is at P 110 ˚C with a concentration value of 1.476%, and in H_2 the highest composition obtained at P 90 ˚C with a concentration value of 1.725%. Third, the flame color results with a dominant yellow color were obtained at P 90 ˚C, the flame color results with a dominant orange color were at P 70 ˚C, and the flame color results with a dominant red color were at P 110 ˚C.

Following the results of the research, what follows are several suggestions for future works. First, to make it easier to insert biomass into the reactor, the design of the screw feeder should be improved so that it is not difficult during the process of inserting biomass. Second, before carrying out the test, you should ensure that all tools are working optimally.

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