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Experimental Biomass Gasification in Updraft Gasifier with Gas Outlet at Reduction Zone and Air Supply using Suction Blower

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ABSTRACT

Rice husk gasification is increasingly attractive, particularly with updraft gasifier type, because of its simple construction and ease of operation. However, updraft gasifier has a disadvantage of generating substantial amounts of tar. Tar will decompose into combustible gas when exposed to high temperatures. The reduction zone has a high temperature for tar decomposition to occur. Therefore, in this research, updraft gasifier was modified by positioning gas outlet at the reduction zone and inducing gasification air supply using a blower. Modifications are made by moving the gas outlet from the top to the middle or reduction area. The initial start-up of the system uses a blown air supply system, then after the syngas are produced by the operation, it is replaced with a sucked air supply. Two blowers are used, namely an exhalation or blowing blower for initial start and a suction blower for continuous operation. The fuel used was low bulk density, specifically rice husks. The aim was to characterize the modified gasifier, focusing on parameters such as operating time, duration of gas combustion, air-to-rice husks ratio, and flame color. Typically, the experiments were conducted under constant of air velocity and fuel quantity. The results showed that the average operating time, duration of flammable gas, and air-to-rice husks ratio were 74.25 minutes, 52.28 minutes, and 7.6 kg air/kg husk, respectively, and the flame produced was a bluish-yellow color that indicates a reduction tar.

1. Introduction

Biomass is a very promising energy source due to its renewability, low emissions, and CO2 neutrality [1,2]. In countries such as Indonesia, rice husks are abundant, serving as readily available sources of biomass [3]. The widely used technique for converting solid materials, such as rice husks into gas fuel is gasification [4-6]. Research has extensively explored the use of rice husks and sawdust for energy production through gasification [7-11]. Despite the potential benefits, using rice husks for gasification causes challenges due to low bulk density, necessitating specialized treatment. Among

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the various gasification reactor options, the fixed-bed configuration serves as the preferred choice for rice husks, with updraft gasifier arising as a particularly suitable type [12]. Numerous research has used updraft gasifier for rice husks, as evidenced by the works of Qi *et al.,* [13], Cerinski *et al.,* [14], and Nguyen-Thi *et al.,* [15].

Updraft gasifier type offers the advantage of simple construction and easy operation [16,17]. However, there is a disadvantage when a large amount of tar is produced [18]. Previous research investigated gas outlet methods from the reduction zone, with air gasification supply, and wood as fuel [19,20]. According to tests conducted by Surjosatyo *et al.,* [19], wood gasification produced 111 g/m^3 of tar. Meanwhile, this outcome can be reduced by modifying gas outlet system, as shown by [19]. Moving gas outlet position from the top to the reduction zone can reduce tar production to 81 g/m^3 [19]. It is because tar decomposes after passing through the reduction zone which has a higher temperature. Consequently, the research shows the effectiveness of modifying gas outlet to the reduction zone in addressing updraft gasifier issues. Previous investigations used wood fuel with high bulk density and an exhalation or blowing blower for gasification air intake system. On the other hand, the current research uses low bulk density fuel, specifically rice husks, and a suction blower air supply. The objective is to investigate the operational characteristics of an updraft gasifier with gas outlet at the reduction zone and a sucked blower of air supply, focusing on low bulk-density fuel, namely rice husks.

2. Methodology

This research was carried out experimentally using an updraft gasifier that had been modified with a gas outlet at the reduction zone as shown in Figure 1. The modification was carried out by moving the gas outlet from the top to the middle or reduction zone. Gasification air is supplied using a blower. Airspeed is measured using an anemometer. The airspeed used in this experiment is constant at 2.1 m/s. The fuel used is rice husks as presented in Figure 2. Rice husks were chosen as fuel in this study because this fuel has many problems when gasified even though it uses a gasifier without a thoroatless area such as an updraft. This is because it is very light and has a low bulk density so the fuel flow in the reactor is not smooth, which in turn results in the gasification reaction not taking place properly to ensure the stability of the producer gas produced [21]. The ultimate analysis of rice husks is shown in Table 1. The amount of rice husks used in a bed is 4 kg.

The gasifier operation process is carried out in two stages. 1st stage, namely start-up, is shown in the blue dotted line in Figure 2, and 2nd stage, namely continuous or stable operation, is shown in the red dotted line in Figure 2.

In operation 1st stage (start-up) operation, gasification air is supplied using 1st blower or blowing blower then the gasification results exit to the 2nd burner. In this operation, the 1st valve and 3rd valve are opened but the 2nd valve and 4th valve are closed and the 2nd blower (suction blower) is turned off. Operation 1st stage (start-up operation) is completed after producer gas is produced, then continued with operation 2nd stage (continuous operation).

In operation 2nd stage (continuous operation) begins by turning off the blowing blower (1st blower) closing the 1st valve and 3rd valve, then turning on the suction blower (2nd blower) and opening the 2nd valve and 4th valve. The 2nd stage operation is completed when producer gas is no longer produced or the rice husks, as shown in Figure 3, in the gasifier have been used up.

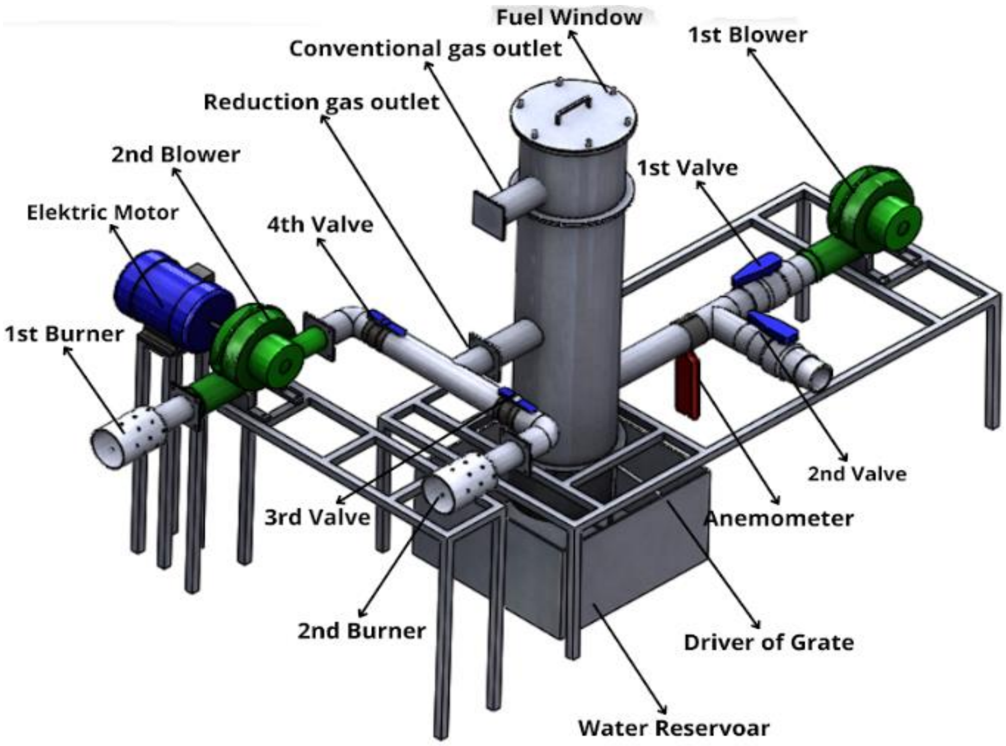

Fig. 1. Experimental set-up of modification updraft gasifier

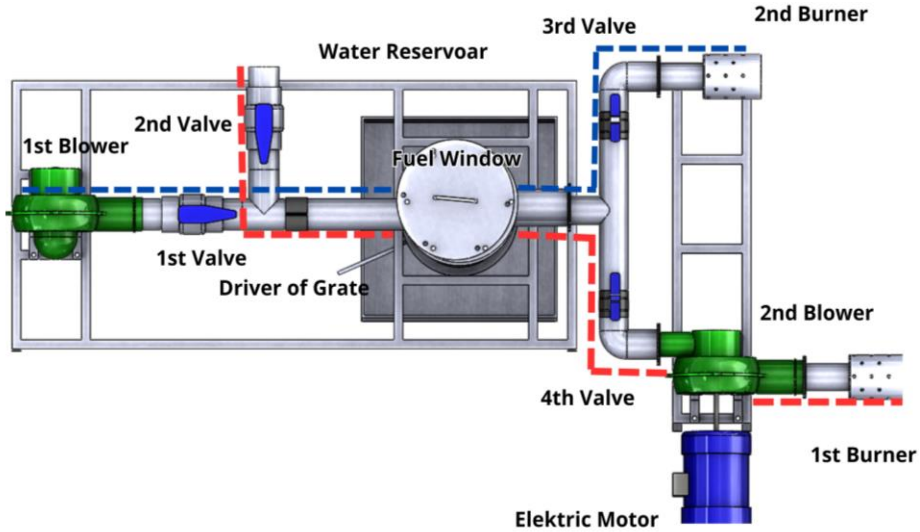

Fig. 2. Start-up and continuous operation of gas outlet at reduction zone using suction blower

Fig. 3. Rice husk

Table 1
Analysis of Rice Husk

	Unit	Value
Proximate Analysis		
Moisture	Mass Fraction (%)	10,74
Volatile Matter	Mass Fraction (%)	55,00
Fixed Carbon	Mass Fraction (%)	13,16
Ash	Mass Fraction (%)	21,10
Ultimate Analysis		
Carbon	Mass Fraction (%)	33,70
Hydrogen	Mass Fraction (%)	5,53
Nitrogen	Mass Fraction (%)	0,37
Sulfur	Mass Fraction (%)	0,06
Oxygen		39,24
Calorific Value		
Gross Calorific Value	Cal/g	3,076

3. Results and Discussion

Several operating characteristics that are important to obtain during testing of the gasification process, especially for new equipment systems, are the operating time in bed, the length of time the existing producer gas, the ratio of air to rice husks, and the color of the flame. Operation time is the time from start-up to the end of the gasification process. Of course, a long operating time is expected with a small amount of fuel. The duration of time that existing producer gas or flame is the time that producer gas is present during the operation. A good existing of producer gas time is obtained about 20 minutes after the operation begins for 1st bed until the end of the operation [22]. The air-to-rice husk ratio is an important parameter to obtain in research which will later become the baseline for supplying air or rice husk if the known parameters are the rice husk mass flow rate or air mass flow rate. The color of the flame will indicate the volatile content in the producer gas, the yellow color indicates a high volatile content and also identifies a fairly large tar content, while the bluish color indicates a smaller amount of volatiles and also identifies low tar. The overall blue flame color identifies the amount of tar below 30 mg/m^3 [23].

3.1 The Duration of Operation Time and Existing Flame (Producer Gas) Time

Figure 4 shows that the average duration of operating time and existing flame (existing producer gas) time were 74.24 and 52.28 minutes, respectively. From the three tests conducted with a constant gasification air velocity and fuel quantity, variations were observed in the obtained operating time duration and existing flame time duration. The differences were recorded because the gasification reaction was influenced by factors such as biomass size, residence time, and operating temperature [24,25]. These results were also consistent with the research conducted by Hsi *et al.,* [26], and Kukharets *et al.,* [27]. Additionally, the duration of the existing flame time was obtained at 75% of the operating time duration.

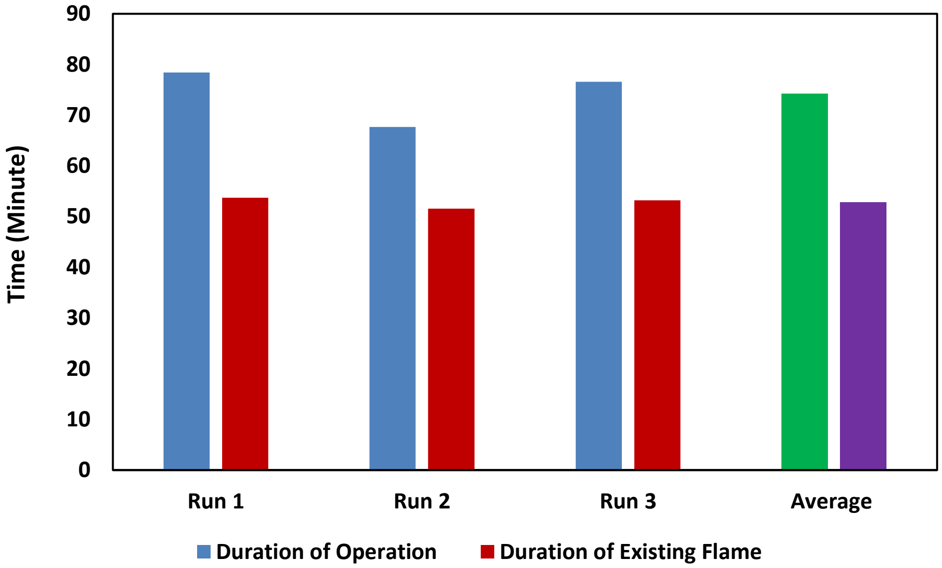

Fig. 4. Duration of operation and existing flame (existing producer gas)

3.2 The Air- Rice Husk Ratio

Figure 5 shows the ratio of air and rice husk produced for three running times. The ratio of air to rice husk produced is 7.6. From each run, there is a difference in the ratio of the amount of air and rice husks used. This is because there is a change in the duration of operation time for each running as in Figure 4. This result is in line with the research conducted by Hsi *et al.,* [26].

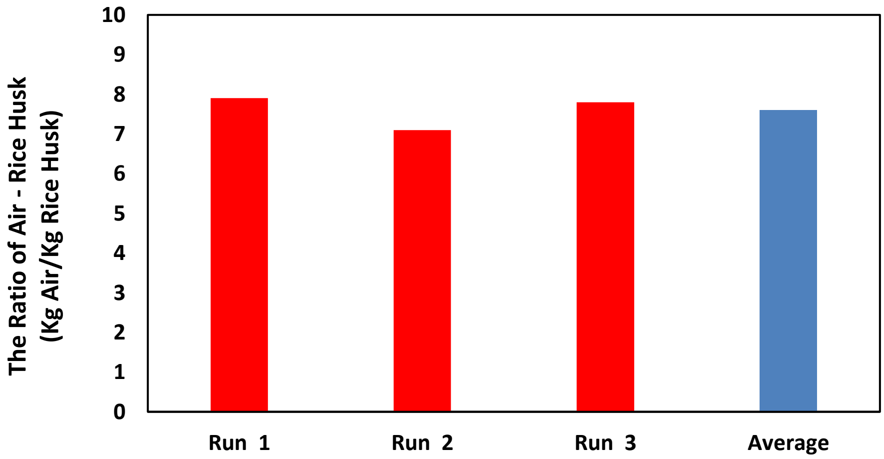

Fig. 5. Ratio of air – rice husk

3.3 Flame of Producer Gas Burning

According to Figure 6, the flame color for each test was bluish-yellow, closely resembling the results obtained by Susastriawan *et al.,* [28]. The flame color tended towards blue, indicative of reduction of tar conditions compare to full yellow. Moreover, the intensity of the flame burst was observed to be stronger during the suction operation compared to the blowing operation. In addition, the size and roughness of the fuel cause hydrophobic and fuel floating differences in the reactor which in turn affects the flame length [29-31].

Fig. 6. Flame of producer gas burning

4. Conclusions

In conclusion, the modification of the updraft gasifier with a gas outlet at the reduction zone, along with gasification air supplied by a suction blower, was successfully tested and operated stably. The test was conducted while maintaining a constant air velocity of 2.1 m/s with a fuel of 4 kg. Consequently, the results showed an average operating time duration of 74.25 minutes, an average existing flame time duration of 52.28 minutes, and an air-to-rice husk ratio of 7.6 kg air/kg rice husk. It should be acknowledged that the flame produced was a bluish-yellow color.

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