Electricity Production from Updraft Gasification in Various Types of Biomass Charcoal

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Abstract

Energy consumption in Indonesia has increased significantly from year to year. Therefore, energy reserves are gradually running out so we have to look for alternative energy sources. A renewable energy source that has great potential in Indonesia is biomass. This research method is quantitative experimental research, to determine the effectiveness of using synthetic gas from mahogany charcoal, coconut shell charcoal, or a combination of both, using an updraft gasifier to produce electricity. The research results show that variations in biomass charcoal affect the electricity produced. The highest electricity was produced from coconut shell charcoal at a temperature of 1460 °C with a current of 4.4 amperes, and the number of lights burning was 13.

***Keywords**: Biomass Charcoal, Coconut Shell, Electricity, Mahogany, Updraft Gasification*

1. Introduction

Energy resources have a significant role in national economic development. Energy is required for industrial growth, service, transportation, and household activities. The role of energy will develop further, especially in support of the industrial sector and other related activities. Although Indonesia is one of the oil and gas-producing countries, a reduction in oil reserves and the removal of subsidies caused oil prices to increase and environmental quality to decrease. Therefore, the utilization of alternative energy sources is an option.

The growing reliance on fossil fuels for power production has resulted in severe environmental pollution, such as greenhouse gas emissions and air quality degradation, highlighting the need for alternative, cleaner energy sources (Silva et al., 2021). Biomass has emerged as an appealing choice because of its renewable nature and low environmental effect (Couto et al., 2018). Biomass charcoal, made from various organic resources, has gained popularity due to its potential for sustainable energy production (Sheth & Babu, 2020). Updraft gasification, which turns biomass charcoal into syngas for power generation, effectively reduces solid waste pollution by utilizing agricultural residues, forestry byproducts, and other organic wastes (Pantangi et al., 2019). This technology not only provides a cleaner energy source, but it also solves the issue of solid waste management by converting garbage into usable energy, lowering landfill consumption, and minimizing environmental contamination (Couto et al., 2018). Recent studies have highlighted biomass gasification's environmental benefits, demonstrating its ability to reduce harmful emissions and contribute to a circular economy (Silva et al., 2021).

One of the best solutions to overcome the scarcity of fossil fuels is to get fuel from alternative energy sources. Environmentally friendly alternative energy and renewable energy by utilizing the potential of nature or waste containing biomass. Wood biomass energy is the main energy source for rural communities. 50% of Indonesia's population still uses wood biomass that is burned directly as an energy source with a consumption of around 1.2 m^3/person/year (Mufid, 2019).

Organic materials from plantation agricultural residues are elementary to obtain in Indonesia. Such as wood chips, twigs, leaves, rice husks, bagasse, hollow palm fruit bunches, sawdust, and coconut shells are some examples. Additionally, organic waste from small industries and residential areas has great potential (Cahyono, 2013). Krisnawati et al. (2011) reported that there are 54,000 hectares of mahogany plantations in Indonesia and 3,728,600 hectares of coconut plantations in Indonesia, of which 92.40% are coconut trees.

One of the technologies used to utilize biomass waste is to convert it into alternative energy using gasification technology. This technology is expected to meet electrical energy needs, especially for generator engines that use biomass fuel such as coconut shell charcoal and mahogany charcoal. The gasification process can overcome the problems of waste accumulation and grazing waste, as well as wood chip waste, and make better use of coconut shells, making it a cheap and environmentally friendly energy alternative.

Updraft gasification is a reaction where fuel is introduced to the top of the reactor and moves downwards through the drying, pyrolysis, reduction, and oxidation zones. Meanwhile, air enters at the bottom, and gas exits at the top (Ridwan et al., 2018). In gasification reactors, the combustion zone (heat source) is below the fuel and moves upwards, the hot gas produced flows upwards past the unburned fuel, and the fuel continues to fall downwards.

In this type of gasifier, fuel or biomass enters the top of the reactor and moves downwards through the drying, pyrolysis, reduction, and oxidation zones. When air comes out from the bottom and gas comes out from the top. The advantages of this type are its simplicity, high coal burning rate, internal heat exchange so that the flue gas temperature is low, and high gasification efficiency. However, the updraft gasifier's high tar production rate (5–20%) continues to be a problem, making it inappropriate for applications requiring a clean product gas (syngas) (Desrosiers R, 1982). Because of its high rate of tar production, the updraft gasifier is a good choice for the gasification of low-volatile feedstocks like charcoal (Basu, 2018).

2. Materials and Methods

The raw materials used in this research were coconut shell charcoal and mahogany charcoal, which were obtained from charcoal producers in Gunung Kidul Regency, Special Region of Yogyakarta, as seen in Figure 1.

(a) (b)

Figure 1. Coconut shell charcoal (a) and mahogany charcoal (b)

The gasification system equipment in this research is shown in Figure 2.

Figure 2. Gasification System Equipment

The tool used in this research is an updraft-type gasifier with a capacity of 3 kg of raw materials, used for the gasification process. The reactor (1) was combined with a cooler (2) to lower the syngas temperature, a filter (3) to clean the syngas, and a generator (4) as a driver of energy into electricity. The generator used is the HONDA OG 3500 LX type with a capacity of 2200 V.A. In addition, 13 light bulbs (5) with each power of 100 watts were used to identify how much electrical energy was produced, and its current and voltage was stabilized by using a voltage stabilizer (6).

Before the gasification is ignited, the first thing is to fill the cooler tube with water and weigh the raw materials: 3 Kg coconut shell charcoal, 3 Kg mahogany wood charcoal, and 3 Kg combination of coconut shell charcoal and mahogany wood charcoal. The gasification process stage starts with igniting coconut shell charcoal in a gasifier tube with the help of a suction blower to speed up and even out the combustion process in the gasifier tube. Synthetic gas (syngas) that is produced, is collected and optimally continued to the pipeline through the cooler process. The cooler itself functions to reduce the temperature of the syngas, in the process so that the syngas is condensed because to move the engine, syngas requires a low temperature of around 20-30˚C (Wijaya, 2015). The syngas that have gone through the adsorption process pass through a zeolite adsorbent whose function is to filter it so that the syngas produced are cleaner. Then the resulting syngas goes to the generator. The generator's electrical power is channeled to the voltage stabilizer so that the current and voltage are accumulated, then released and transmitted to the light bulb device with a stable and appropriate current. Next, turn on the light bulb, start the initial generator using gasoline fuel from full opening 180˚, then open the syngas tap and close the gasoline tap to obtain a syngas value of 100%. When the bulb is lit, then record the electrical output and temperature during combustion into the data collection test table sheet.

The data obtained was analyzed to determine the comparison of the lamp flame produced and the temperature of variations in coconut shell charcoal, mahogany wood charcoal and combination charcoal.

3. Results and Discussion

3.1. Research result

Data from experiments on measuring temperature and electricity production produced from syngas, each variation test uses a variety of types of materials, namely; 3 kg coconut shell charcoal, 3 Kg mahogany wood charcoal, and 3 Kg combination charcoal (coconut shell and mahogany), are presented in table 1, table 2, and table 3.

Table 1. Coconut Shell Charcoal Electricity Production Data

No	Temperature (C°)	Current (Ampere)	Number of Lights On
1	800	0	0
2	1000	0.4	1
3	1100	0.85	3
4	1125	1.05	4
5	1140	1.4	5
6	1240	1.75	6
7	1275	2.1	7
8	1295	2.4	8
9	1385	2.75	9
10	1405	3	10
11	1420	3.2	11
12	1430	3.5	12
13	1460	4.4	13

Source: Experimental Result, 2023

Table 2. Mahogany Charcoal Electricity Production Data

No	Temperature (C°)	Current (Ampere)	Number of Lights On
1	800	0	0
2	960	0.15	1
3	1100	0,3	2
4	1135	0,9	3
5	1175	0,95	4
6	1230	1,2	5
7	1320	1,7	6
8	1310	1,85	7
9	1328	1,9	8
10	1385	2,1	9
11	1410	2,4	10
12	1420	2,7	10
13	1430	2,9	11

Source: Experimental Result, 2023

Table 3. Combination of Charcoal Electricity Production Data

No	Temperature (C°)	Current (Ampere)	Number of Lights On
1	800	0	0
2	1080	0.35	1
3	1182	0.5	2
4	1185	0.9	3
5	1195	0.95	4
6	1290	1.5	5
7	1370	1.8	6
8	1390	2.1	7
9	1398	2.3	8
10	1415	2.5	9
11	1430	2.7	10
12	1440	3.2	11
13	1450	3.4	12

Source: Experimental Result, 2023

3.2. Discussion

Data is obtained from the measurements carried out to determine the influence of raw materials on reactor temperature and electric current production, which can be presented in Figure 3.

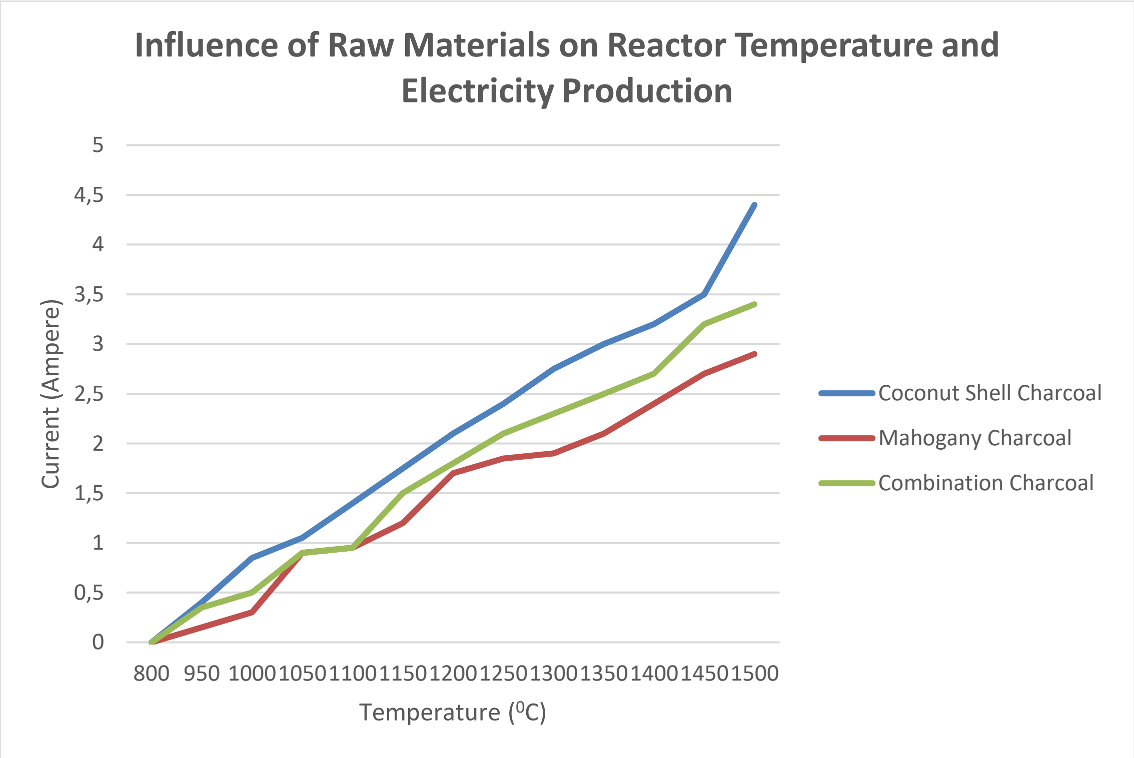

Figure 3. Influence of raw materials on reactor temperature and electricity production

Figure 3 presents the results of the gasification with 3 variations of coconut shell charcoal, mahogany charcoal, and combination charcoal. It can be seen that the highest electricity production or current strength produced from coconut shell charcoal is 4.4 amperes with a maximum gasification temperature of 1460 ˚C. The second highest electricity production, combined charcoal, produces a current strength of 3.4 amperes at a maximum temperature of 1450 ˚C. The lowest current results were in mahogany charcoal as the raw material with 1.3 amperes, with a maximum temperature of 1290 ˚C.

From the results of variations in these three materials, it can be concluded that coconut shell charcoal has good syngas yields and is an environmentally friendly alternative biomass compared to mahogany charcoal and combination charcoal. This is because coconut shell charcoal has a lower moisture level than mahogany wood charcoal, which results in a higher calorific value. This is covered under references (Aktawan et.al, 2015), which demonstrate that the value of the electricity generated by gasifying biomass increases with the raw material's calorific value.

4. Conclusion

Syngas from coconut shell charcoal, mahogany charcoal, and mixed charcoal can produce electricity. Variations in materials affect the electricity produced. The highest electricity is produced from coconut shell charcoal at a temperature of 1460˚C with current 4.4 Amperes, and the number of light bulbs on is 13, combined wood charcoal at a temperature of 1450 ˚C with a current of 3.4 amperes, with several lights on 12, and mahogany wood charcoal at a temperature of 1400 ˚C with a current of 2.3 amperes, the number of lights on is 8.

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