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CHARACTERIZATION OF TEMPERATURE AND ELECTRICAL POWER GENERATION IN A GASIFICATION SYSTEM USING CHARCOAL FROM TRADITIONAL MARKET WASTE

Wira Widyawidura[1*], Syamsul Ma'arif[2], Muhammad Noviansyah Aridito[1], Habib Abdillah Nurusman[1], Syaiful Mansyur[3]

[1]*Department of Environmental Engineering, Universitas Proklamasi 45, Yogyakarta - Indonesia*
[2]*Department of Industrial Engineering, Universitas Sarjanawiyata Tamansiswa, Yogyakarta - Indonesia*
[3]*Department of Industrial Engineering, Universitas Proklamasi 45, Yogyakarta - Indonesia*

Email: wirawidura@up45.ac.id

Abstract

The Giwangan traditional market in Yogyakarta City, Indonesia, produces over 4,387.95 kg of waste daily, of which 2.89% consists of wood and twig by-products. However, these wastes are not being effectively used to generate energy and are instead sent directly to the landfill. This study aims to convert waste into energy using a gasification system, focusing on data related to temperature and power generated from 3 kg of charcoal made from wood and twigs. The gasification system includes the following components: (1) a 22.5-litre gasifier reactor, (2) a water cooler, (3) gas filters, (4) a modified generator set with a 2200-watt power capacity, and (5) 100-watt light bulbs. Measurement instruments, including (1) a K-type thermocouple, (2) a voltmeter within a voltage stabilizer, and (3) a clamp meter for AC, were used to track the temperature and power generated by the system. Results indicated that the average reactor temperature during the pre-heating phase before the syngas entered the internal combustion chamber, was 1041°C over a period of 14 minutes. During the syngas operational phase, the maximum, minimum, and average reactor temperatures as a fuel generator were 1035°C, 924°C, and 951°C, respectively. The generator produced an average power of 723.2 watts over 50 minutes, with a maximum output of 1043.6 watts.

Keywords: charcoal, gasification, organic waste, electrical power generation, traditional market

1. Introduction

In Yogyakarta Province (DIY Province), traditional market waste is the primary source of organic waste generation. Although it is popularly known as the center of buying and selling basic household necessities compared to the modern market, its main problem concerns environmental aesthetics which tends to be dirty with sordid smell from waste [1]-[3]. This is because most traditional markets in Indonesia have no means of utilizing waste to produce energy.

One of the biggest markets is the Giwangan traditional market. Several kinds of fruits are sold here with its waste generation dominated by organic products with 60% moisture content. A total of 4387.95 kg of waste are transported to the central landfill daily with none utilized for energy production. 10% of the total by-products collected are processed into compost and liquid fertilizer. Fig. 1 depicts the current waste situation at Giwangan Market.

Figure 1. Waste condition of the Giwangan Market in DIY Province, Indonesia

Several studies have been conducted to convert waste into energy using methods such as thermochemical processes (gasification, co-gasification pyrolysis, hydrothermal) [4]-[7] and biochemical processes (anaerobic fermentation, landfill gas, and ethanol fermentation) [8]-[10]. The choice of the appropriate technology depends on the characteristics and quantity of the waste generated [need citation]. Consequently, this research focuses on converting traditional organic waste into electricity using gasification technology.

Gasification is a thermochemical conversion process that produces syngas, a mixture of H_2, CO, and CH_4 gases [11]. The ratios of these gases are influenced by the use of air, oxygen, or steam as an oxidizer, with heating values ranging from low (4-6 MJ), medium (12-18 MJ), to high (40 MJ) [12].

Some researchers have utilized gasification technology with municipal solid waste (MSW) to generate electrical power. Laurence and Ashenafi [13] investigated biomass-based fixed-bed gasifier technology to produce 20 kW by incorporating a heat exchanger and cyclone after the reactor. In Odanthurai Panchayat, Coimbatore District, India, residents successfully developed biomass-based gasifiers that generate 9 kW of electricity for water pumping and street lighting [14]. Garg and Sharma [15] successfully developed a 5 kW wood-based gasifier engine system, the Ankur Model: WBG-10, installed at AHEC, the Indian Institute of Technology. This system includes a gasifier reactor, water scrubber, heat exchanger, filters, gas engine, and a synchronous generator. This research aims to implement a waste-to-energy (WtE) process based on solid waste from the Giwangan market using the gasification method. The objective is to convert organic waste into electricity with an output power range of 500 to 1000 Watts. By applying this technology, it is anticipated that the amount of organic waste in landfills can be reduced and repurposed for use in kiosks and street market lighting.

2. Methods

The study was conducted at the Renewable Energy Lab of the Environmental Engineering Department, Proklamasi 45 University, Yogyakarta. The fuel in the gasification reactor uses twigs from garden and yard waste from the traditional market in Giwangan.

2.1 Experimental Set-up

This gasification system consists of (a) a gasifier reactor capacity of 22.5 Liter, (b) a water cooler, (c) gas filters, (d) a voltage stabilizer, (e) a modified generator set with maximum power capacity of 2200 Watt, and (f) light bulbs with 100 Watt (Fig. 2). Measurement equipment required to determine the temperature and electric power generated from this gasification system are K-Type thermocouple, Voltmeter contained in voltage stabilizer, and clamp meter for AC.

Figure 2. Experimental setup of gasification system based on organic waste from the traditional market

2.2 Thermal and Electrical Properties Characterization

Preheating and operational temperature measurements were performed on the reactor and cooling water system to characterize the temperature of this gasification system. To determine the electrical power generated, the current and voltage on the load were measured using clamp meters and voltmeters respectively.

3 kg of wood charcoal fuels is fed into the gasification reactor and preheated by fireworks and a suction blower with a tip installed on the filter channel for oxygen addition. When the reactor hole turns bright yellow, the conducted preheating temperature

is recorded in 1 minute along with the preheating start-up internal combustion (IC) generator using gasoline fuel. In this preheating process, the syngas input valve on the generator IC carburetor is opened. In contrast, the gasoline input valve is closed, with the land and valve settings left ajar for oxygen.

Once it is confirmed that the generator IC has fully used the syngas fuel (where the valve for gasoline input is fully closed), the preheating process is declared complete, while the gasification operation procedure continues. In this process, the temperature measured on the gasifier reactor and water cooling system utilizes 1 minute till the IC generator set machine stops spinning. Furthermore, measurements of electrical current and voltage on the load (light bulbs) are conducted.

3. Results and Discussion

3.1 Temperature Characteristics of Gasification System

The average temperature during the preheating phase (Fig. 3) was 988 °C. Initially, the combustion temperature was close to 1200 °C, but within six minutes, it dropped to approximately 574°C before rising again and stabilizing by the 14th minute. After this, the syngas begin burning while connected to the generator. The generator starts with gasoline, and once ignited, the piston suction draws syngas from the manifold. As syngas replace the gasoline completely through open caps, valves, and air inlets, the syngas valve remains closed until it is fully stable. To achieve this, a load consisting of 2-4 lamps (200 watts) is required to gradually open the syngas valve, eventually allowing around 14 lights to be powered. Table 1 presents the temperature conditions during the pre-heating phase of the gasification system.

Table 1. Pre-heating condition of the gasification system

Parameter	Unit	Value
Reactor volume	Liter	22.5
Max temperature of the reactor	°C	1,137
The average temperature of the reactor	°C	1,041
The temperature of the water cooler	°C	27

Source: Experimental result

During operation, the average temperature in the gasification reactor is 951 °C (Table 2), which aligns with the theory that the gasification oxidation-reduction reaction occurs at a temperature range between 800 -1000 °C [16]. Temperature fluctuations typically range between 900-1000 °C, but never fall below 900°C (Fig. 4). This indicates that the gasification process is efficiently converting to syngas with a load of 14 lights (100 Watts). However, the brightness of the lights fluctuates due to flickering. Table 2 provides a detailed overview of the operational temperature during the gasification process.

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Table 2. Operation condition of the gasification system

Parameter	Reactor Temp.(°C)	Water Cooler Temp. (°C)
Initial temperature	1,000	27
Final temperature	933	38
Minimum temperature	924	29
Maximum temperature	1,035	38
Average temperature	951	33

Source: Experimental result

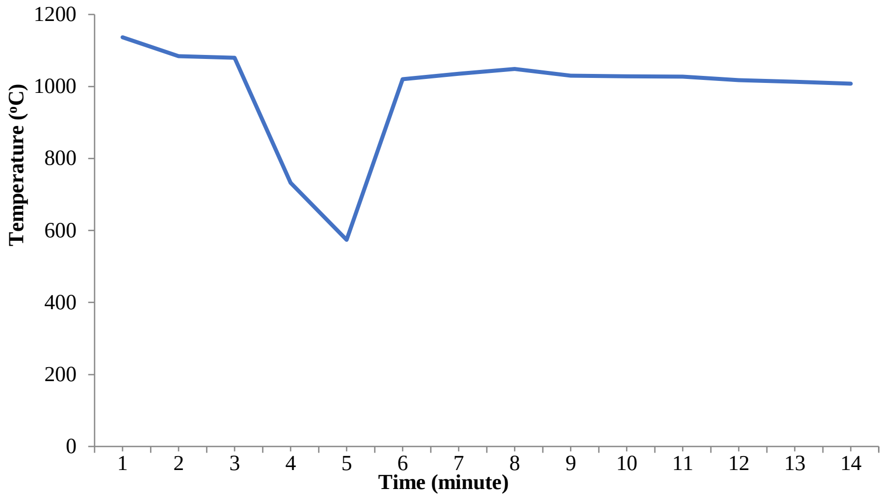

Figure 3. Gasifier temperature during the preheating process

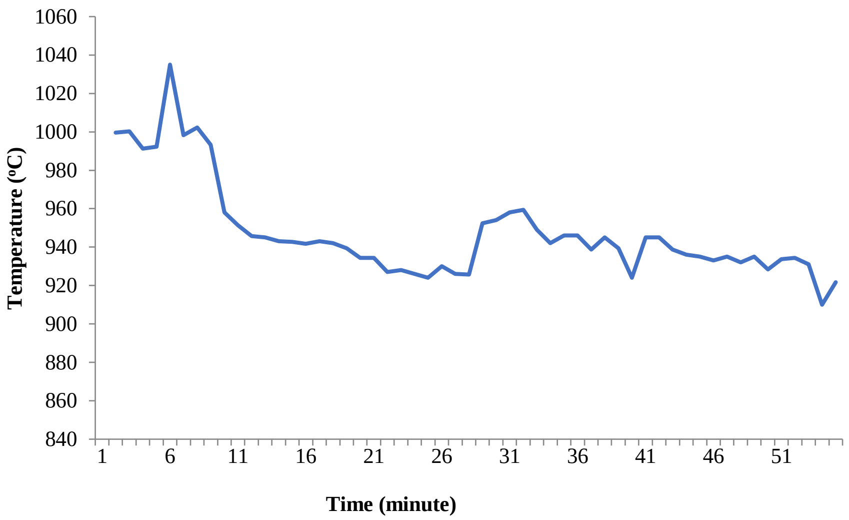

Figure 4. Gasifier temperature at the operational process

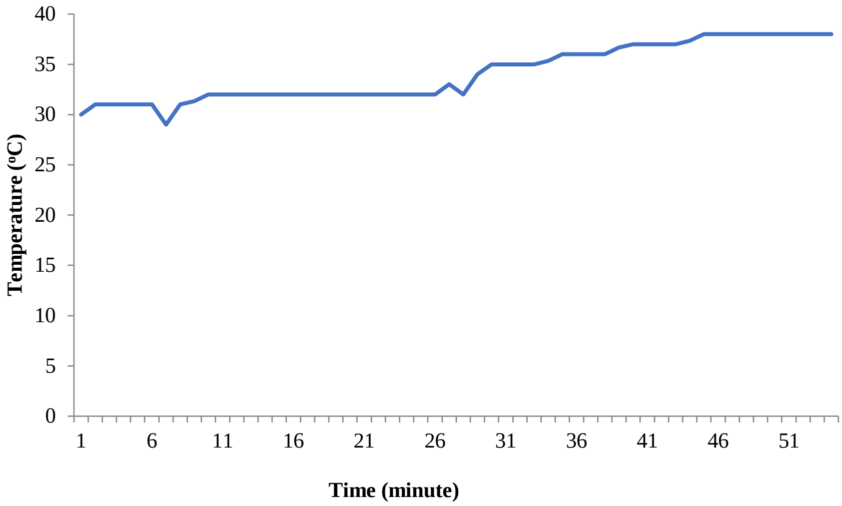

Figure 5. Cooling water temperature in the operational process

As seen in Fig. 5, the cooler temperature in the gasification system increases from 30 °C to 38 °C. This occurs because the circulation system does not pass through the water cooler. If the water fails to circulate, the temperature rises by approximately 8°C per hour, which leads to a decrease in performance when the system is loaded with lights.

3.2 Characteristics of Electrical Power Generation

Based on the current and voltage data generated from the gasification system using several lamps with a maximum power of 100 W each, the average electric power generated is 723.2 watts. From the power rating, the efficiency of generator IC with burn syngas becomes 33% of the 2200 watts total power output generator. The average, minimum, and maximum data values of voltage, current, and electrical power are shown in Table 3.

Table 3. Electrical properties on power generation of the gasification system

Parameter	Voltage (Volt)	Current (Ampere)	Electrical Power (Watt)
Maximum value	222	5.0	1043.6
Minimum value	204	1.2	270.1
Average value	211	3.5	723.2

Source: Experimental result

The resulting electric voltage fluctuates with a minimum and maximum value of 204 and 222 Volts. With this range of values, we can be sure that this gasification system is still safe to use for electronic equipment in Indonesia (220 Volt / 50 Hz).

Fig. 6 shows a relationship between water cooler temperature with electric current and load. At the beginning of the process, an electric current will be produced till it reaches a peak of 5A and loads up to 14 lamps. If the cooler temperature is stable at 10 to

31 minutes visible electric current, and a light load is also stable at its peak. At the 31st minute there was a decrease in the number of lights that can light up as well as the electric current down, the minute it looks cooler temperatures increase and tend to continue to rise till the final minutes. It also affects the electric current which then becomes down and fluctuates, as well as the number of lights that tend to fall and fluctuate.

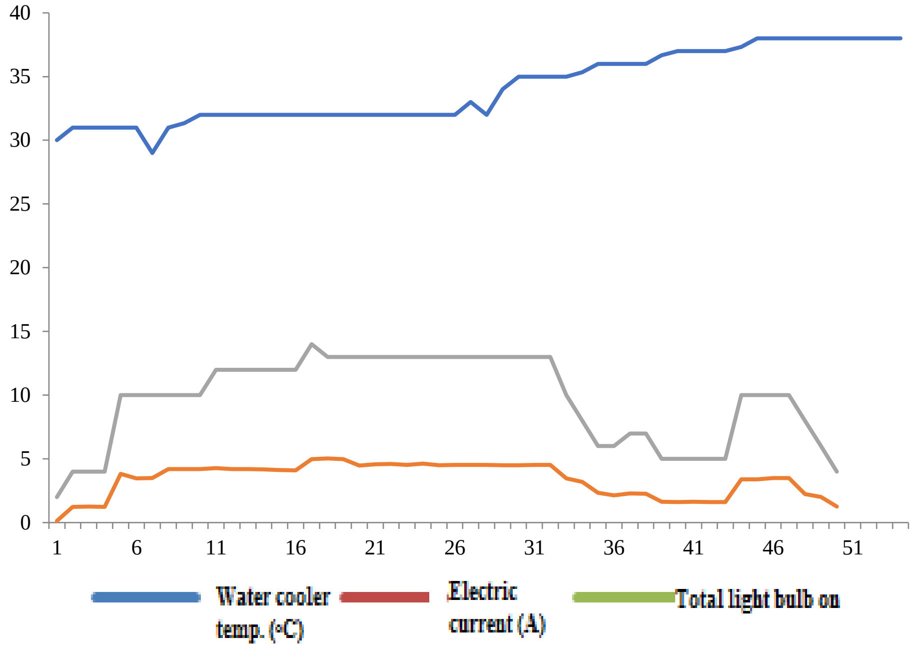

Figure 6. The relation between cooling water temperature and electric current on the gasification system

This shows there is a relationship between the water cooler temperatures and the performance of the IC Generator. Just as the water cooler temperature reaches a maximum value of 38°C, the generator's IC engine stops working, and the reactor temperature is recorded at 934°C. In addition, 1.2 kg of charcoal fuel remains which indicates that the non-working IC generator machine is not only caused by insufficient charcoal fuel and low reactor temperature but also by the water cooler temperature. The cooling system plays an important role in improving the quality of syngas. According to Setioputro et al [17], the ideal temperature of syngas entering the IC is less than 50°C. This is to protect non-metallic components in the IC device. The reduction in syngas temperature can be done using a heat exchanger and an open water jacket [17-18].

4. Conclusion

This study shows that wood and twig by-products from the Giwangan traditional market in Yogyakarta City can be effectively converted into energy using a gasification system. The reactor reached temperatures up to 1041°C during pre-heating and maintained a range of 924°C to 1035°C during syngas production. The generator produced an average power output of 723.2 watts, with a maximum of 1043.6 watts over

50 minutes. These results highlight the potential for utilizing market waste as a renewable energy source, reducing landfill waste, and supporting sustainable energy practices. Future studies could focus on optimizing the system for larger-scale waste conversion, exploring the long-term viability of such systems, and assessing the environmental and economic benefits of widespread implementation in similar markets.

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