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GASIFICATION BURNER PERFORMANCE TEST USING BIO-COAL FUEL

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ABSTRACT

Fuel for high-energy solid fuel combustion systems must meet abundant availability, affordability, and environmental friendliness criteria, particularly having low greenhouse gas emissions. One type of fuel that meets these criteria is bio-coal. Gasification burners employ staged combustion techniques that enhance combustion efficiency and reduce the formation of harmful substances, making them more environmentally friendly. This article discusses the performance testing of gasification burners using bio-coal as fuel, with variable primary air flow rates of 25, 30, 35, 40, and 50 m3/hour and biomass percentages in the bio-coal of 25%, 50%, and 75% by weight. The parameters observed are burner capacity, temperature, and CO2 gas emission factor. The experimental results show that increasing the air flow rate from 25 to 35 m3/hour significantly increases burner capacity and temperature, while further increasing the primary air flow rate to 50 m3/hour results in a gradual increase in burner capacity. The experiments also indicate that increasing the biomass percentage in the bio-coal slightly increases burner capacity and temperature due to the similar calorific values of palm pellet and coal used. The gasification burner technology developed by BBP Tekmira has proven to operate effectively within a capacity range of 8 to 20 kg/hour for bio-coal fuel with biomass percentages ranging from 25% to 75% by weight, producing burner temperatures between 805 and 933 degrees Celsius. Using bio-coal for gasification burners has also been shown to reduce greenhouse gas emissions when the biomass percentage in bio-coal exceeds 64%.

Introduction

The dependence of energy-intensive industries on LPG gas fuel in Indonesia is very high, so the growth of SMEs also contributes to the increasing consumption of this fuel. Energy-intensive industries use fuel for boilers, drying ovens, and other continuous production processes for at least 5 hours daily (Suseno & Suherman, 2020).

As an illustration, every day, around 104 3 kg LPG cylinders are distributed in the Special Region of Yogyakarta (DIY); even at certain moments, there is a facultative supply to supply the energy needs of energy-intensive small and medium industries (IKM) in the Prov. DIY as shown in Table 1.

With restrictions on the supply of subsidised LPG and strict requirements to obtain LPG, many SMEs find it challenging to obtain, so they have to buy non-subsidized LPG at a higher price. This has an impact on increasing the cost of production.

Currently, many SMIs use fuel oil that is easy to obtain. Used oil is included in the hazardous and toxic waste (B3), as seen in the Annex to Government Regulation No. 18 of 1999. The consequences they face, if they use used oil without permission are prison sanctions or fines of tremendous value.

Table 1
The potential market of SMIs using gasification burners according to the type of industry in DI Yogyakarta

Types of SMIs	Potential Market *of* Burner Gasification					
	Sleman	Bantul	Kulon Progo	Gunung Kidul	Yogya	Sum
Food and drink	107	54	27	27		215
Batik	59	42	10	28		139
Gerabah		56				56
Blacksmith		32	2			34
Bata/getting			8			8
Lime burning				5		5
Aluminium smelting					60	60
Total	166	184	47	60	60	517

Source: (Suseno &; Suherman, 2020)

The high level of dependence of SMEs on fuel makes them look for and try various alternative fuels to reduce the cost of using fuel. One type of fuel that is cheap and abundantly available is coal and biomass. The biomass fuel and coal mixture is known as bio-coal (Samudro, Asmara, & Kuncoro, 2023).

Increased combustion efficiency can save fuel consumption. One way to improve combustion efficiency is to use burner gasification technology (Vidian, 2009). Figure 1 shows the process concept in conventional burners and gasification burners. In conventional burners, bio-coal is directly burned with the need for excess combustion air (excess air), forming exhaust gases and releasing combustion heat (Qcomb). Direct combustion of bio-coal often leaves unburned carbon, forming carbon monoxide gas that has not been completely converted into carbon dioxide (Susastriawan et al., 2021).

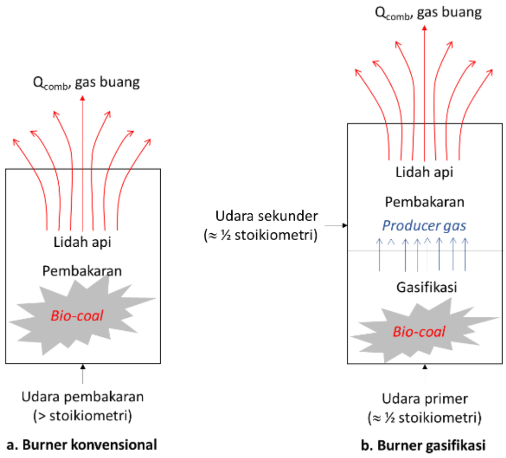

Figure 1. The concept of conventional burner and gasification burner (Susastriawan et al., 2021)

Gasification is the thermal conversion of solid fuel into flammable gas producers using air or oxygen reagents (oxidation media) (Victorio & Siregar, 2022). A gasification burner is a burner that separates the combustion stages into processes:

1. Bio-coal gasification reacts with primary air to become a gas producer. Primary air needs are half that of complete combustion air (stoichiometry) (Setiawan, Pangala, Swastika, & Tambunan, 2020).
2. The resulting producer gas is then burned using secondary air to obtain combustion heat energy (Qcomb). The need for secondary air is half the need for complete combustion air (stoichiometry) so that combustion occurs more completely. Complete combustion will increase combustion efficiency and not cause harmful substances. Therefore, gasification burners have the advantages of saving energy and being more environmentally friendly.

This gasification burner can use bio-coal fuel, which costs less than LPG. The use of bio-coal can also reduce greenhouse gas (GHG) emissions. Greenhouse gases hold sunlight in the atmosphere, so they are trapped on the earth's surface, making it hotter.

Greenhouse gases consist of carbon dioxide (CO2), sulphur dioxide (SO2), nitrous oxide (N2O), methane gas (CH4), and chlorofluorocarbons (CFCs) (Koehuan, Milo, & Riwu, n.d.). CO2 gas is the leading polluter of GHG (KLHK, 2012). CO2 gas is produced from the combustion of fuel oil, coal, and other organic fuels containing carbon (C) (Wiloso, Heijungs, Huppes, & Fang, 2016).

The Center for Mineral and Coal Testing (BBP Tekmira) will utilise this market opportunity to socialise and market alternative products, namely Burner Gasification, that can use bio-coal.

This paper discusses the performance testing of gasification burners developed by BBP Tekmira, which will be applied to energy-intensive SMIs in the form of combustion temperature, burner capacity, and comparison of GHG emission factors on the percentage of biomass use in the fuel mixture.

Research Methods

This research is an experimental study, which is research by looking for a causal relationship between several factors that influence each other. The experiment was conducted at the Workshop, Coal Laboratory, Center for Mineral and Coal Testing, Bandung. A flowchart of the entire study can be seen in Figure 2.

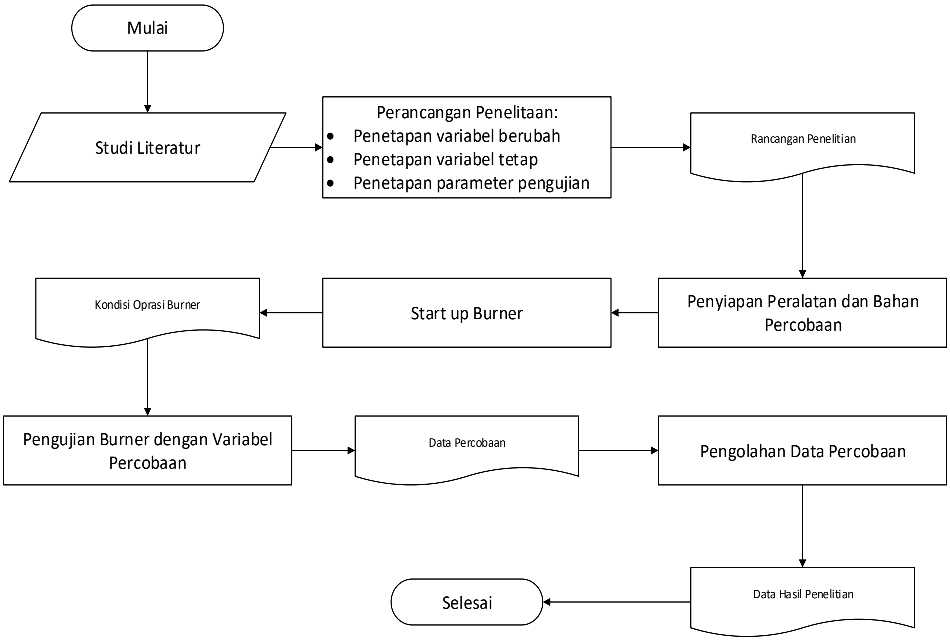

Figure 2. Flowchart of trial procedure

Experimental Equipment and Materials

The experimental equipment is shown in Figure 3. The leading equipment is a gasification burner for combustion testing. Gasification burner capacity 10-20 kg/hour fuel, fuel feed size 0 – 15 mm, bio-coal fuel type. Supporting equipment consists of a digital scale with a capacity of 15 kg to weigh fuel use, a type K thermocouple with a measurement range of 400 – 1200 OC to measure combustion temperature, and a rotameter with a capacity of 0 – 100 m3 /hour of air to measure the flow rate of combustion air.

Experimental Material

The fuel used in this research is bio-coal, a mixture of biomass and coal. The biomass used is pellets derived from palm oil fibres, referred to as palm pellets from now on, obtained from PT Arka Energi Rekacipta. At the same time, the coal used is a low-calorie type originating from South Kalimantan.

Experiment Variables

The changing variables in this study were the primary air flow rate and the percentage of biomass in the bio-coal. The primary air flow rate ranges are 25, 30, 35, 40, 45 and 50 m3/h respectively. At the same time, the percentage of biomass in bio-coal is 25, 50, and 75.

The fixed variable in this study was the fuel volume in the burner of 48,000 cm3 or the height level of the fuel bed of 50 cm. The secondary air rate was equal to the primary air flow rate. The fuel volume in the burner is kept constant by regulating the rotation of the rotary valve in the fuel feeder system, which will be observed during the experimental process. Another observation is the combustion temperature of the gas producer in the burner (Sidiq, 2022).

Trial Procedure

The schematic of the experimental equipment can be seen in Figure 5. 3 kg of wood charcoal is burned outside the burner until embers form. The wood charcoal embers are fed into the burner through the upper burner hole. Next, the primary air flowed into the burner by operating the blower and adjusting the primary air flowmeter according to the experimental variables.

Results and Discussion

The experimental results of burner gasification testing using bio-coal are shown in the variable matrix of primary air rate and biomass ratio in bio-coal, shown in Table 1.

Table 1
Experimental results

Persentase biomass (%w)	Primary air rate (m3/h)	Suhu *burner* (C)			Fuel Requirement (kg/hour)		
		1	2	Average	1	2	Average
25	25	805	845	825	7,5	7,6	7,6
	30	857	872	865	10,1	12,5	11,3
	35	886	891	889	13,3	14,4	13,9
	40	901	909	905	15,9	15,2	15,6
	45	914	916	915	16,5	16,4	16,5
	50	923	927	925	17,9	16,3	17,1
50	25	835	847	841	7,5	8,6	8,1
	30	869	866	868	11,1	12,6	11,9
	35	904	901	903	15,6	14,4	15,0
	40	911	909	910	15,9	16,2	16,1
	45	919	918	919	17,6	17,4	17,5
	50	924	928	926	17,9	19,3	18,6
75	25	855	845	850	7,5	9,6	8,6
	30	889	879	884	12,1	12,6	12,4
	35	908	907	908	15,8	15,4	15,6
	40	918	912	915	17,9	16,8	17,4
	45	919	926	923	19,2	18,7	19,0
	50	928	933	931	18,9	21,3	20,1

Effect of Primary Air Flow Rate

The effect of the primary air flow rate on burner capacity is presented in Figure 6. An increase in the primary air flow rate leads to an increase in gasification reagents. The addition of reagent media causes an increase in the amount of bio-coal gasified into producer gas at the bottom of the burner. Adding the amount of gasified bio-coal causes an increase in burner capacity (Imaduddin, 2013).

In addition to the excess air rate, there will be a shift in the gasification reaction closer to the type of combustion reaction, resulting in a decrease in carbon monoxide and hydrogen gas levels in the gas producer. The combustion reaction requires a more significant amount of air and causes the increase in burner capacitance to slope at a primary air flow rate of 35 m3 / hour. In addition to causing a decrease in the rate of increase in burner capacity, there is also a decrease in the calorific value of gas producers due to a decrease in carbon monoxide and hydrogen gas levels.

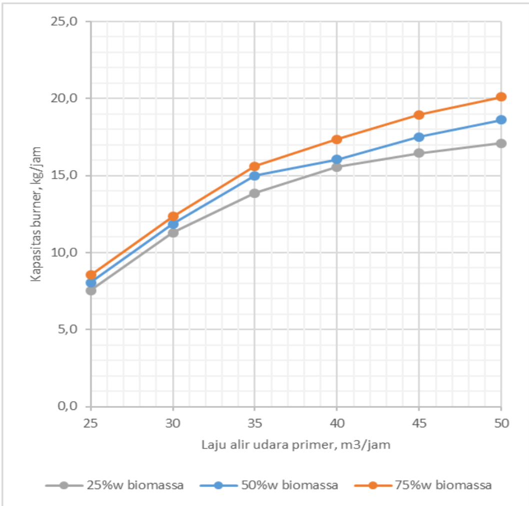

Figure 6
Effect of primary air flow rate on burner capacity

The gasified gas producer is then burned with a secondary air reagent. The combustion temperature of the gas producer is measured as the burner temperature. The effect of the primary air flow rate on burner temperature is presented in Figure 7. The greater the primary air rate, the more giant gas producers will be obtained, so more incredible combustion energy will be obtained (Wardhana, Hanafi, Finali, & Umar, 2021) the resulting combustion energy. The greater the combustion energy obtained, the higher the burner's temperature. The shift of the gasification reaction is close to the type of combustion reaction in the use of a primary air flow rate of 35 m3 / hour, so it will decrease the calorific value of the gas producer, which causes an increase in the temperature of the burner from the combustion of the gas producer to be sloping.

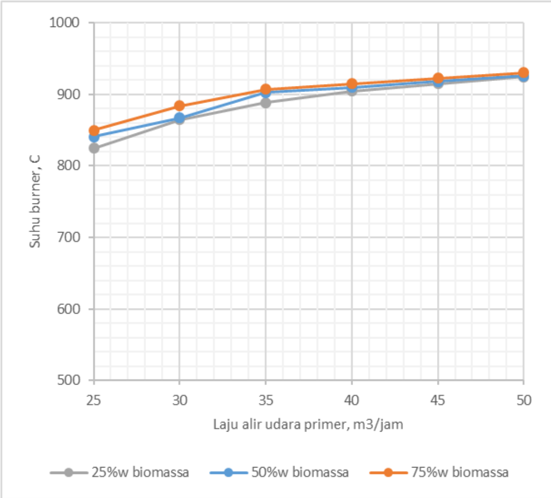

Figure 7
Effect of primary air flow rate on burner temperature

Effect of Biomass Percentage in Bio-coal

The effect of the percentage of biomass in bio-coal on burner capacity is presented in Figure 8. The addition of the percentage of biomass in the bio-coal mixture has little effect on increasing burner capacity. This shows that the palm and coal pellets biomass used has almost the same gasification reaction speed value. This condition proves that the burner developed by BBP Tekmira can use bio-coal fuel for various percentages of biomass.

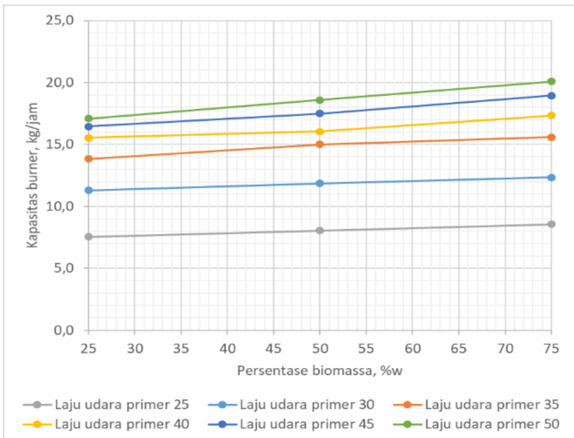

Figure 8
The effect of biomass percentage on burner capacity

The effect of the percentage of biomass in bio-coal on burner temperature is conveyed in Figure 9. The increase in the percentage of biomass also has a slight effect on the burner temperature. This is because the calorific value of palm pellet biomass is close to the calorific value of the coal used (Hidayat et al., 2020). The calorific value of palm and coal pellets used in the experiment was 4,100 and 4,046 kcal/kg, respectively.

The parameters of the calorific value and speed of the gasification reaction are almost the same between palm pellet biomass and coal, causing the combustion heat produced to be close to the same value so that the resulting burner temperature only increases slightly at an increase in the percentage of biomass that is relatively high.

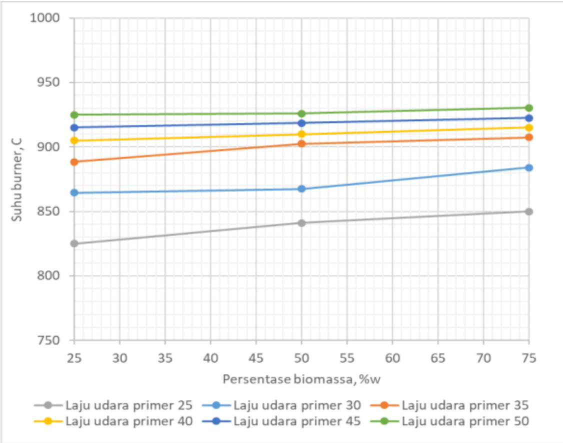

Figure 9
The effect of biomass percentage on burner temperature

Carbon Dioxide Gas Emission Calculation

CO2 gas is one type of greenhouse gas. An increase in greenhouse gases will increase global temperatures and cause climate change. The effect of the percentage of biomass in bio-coal on carbon dioxide (CO2) gas emissions is presented in Figure 8. According to the concept of carbon neutrality, burning biomass is considered not to produce CO2 gas emissions. This is because the CO2 gas produced will be re-absorbed by plants in photosynthesis. Figure 10 shows that increasing the percentage of biomass in bio-coal will result in a linear decrease in CO2 emissions. The amount of CO2 gas emissions in bio-coal combustion will be lower than the CO2 emissions produced by LPG combustion in bio-coal combustion, with a percentage of biomass above 64%.

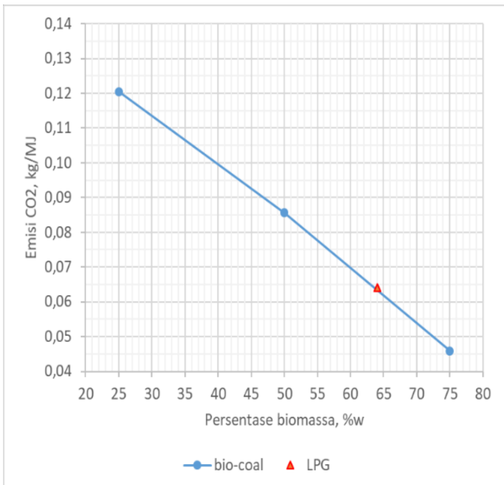

Figure 10
Bio-coal and LPG emission factors

Conclusion

The gasification burner technology developed by BBP Tekmira is proven to operate well with a capacity range of 8 – 20 kg/hour of bio-coal fuel with a biomass percentage of 25 – 75 %w and can produce burner temperatures of 805 – 933 OC. The use of bio-coal for gasification burners is also proven to reduce greenhouse gas emissions if the percentage of biomass in bio-coal is above 64%. This technology needs to be followed up with combustion efficiency testing and reliability testing through testing in small and medium industrial facilities (IKM). Using cheap bio-coal and abundant availability will help SMEs reduce fuel costs.

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