EXPERIMENT ON SAWDUST GASIFICATION

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EXPERIMENT ON SAWDUST GASIFICATION USING OPEN TOP DOWNDRAFT GASIFIER INCORPORATED WITH INTERNAL COMBUSTION ENGINE

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ABSTRACT

An increase in world energy demand leads to a scarcity of fossil fuels. Producer gas from biomass sawdust gasification is one of the energy alternatives for the replacement of fossil fuels. The stability of producer gas from gasification is required for an application on internal combustion engine. The aim of the research is to develop and experiment on sawdust gasification system using open top downdraft gasifier incorporated with internal combustion engine to generate small-scale electricity. The gasifier feed was sawdust. The capacity of gasifier was about 2.5 kg per batch, and about 5 kg of sawdust was consumed per hour. The result of the study showed that combustible gas was produced after being in operation for 20 minutes. The application of producer gas on diesel engine could save about 50% on diesel oil.

Keywords: sawdust, gasification, open top, downdraft, diesel engine.

INTRODUCTION

The need for energy is increasing, whereas at the same time fossil energy resources are decreasing therefore, it is necessary to look for alternative energy sources that could provide sustainable energy. One of this sustainable energy is biomass. The sources of biomass, which could produce energy and one of them is waste from wood processing such as sawdust [1], are more readily available in Indonesia especially in Sumatera. Sawdust can be used to generate energy through gasification technology. Sawdust has a bulk density below 100 kg/m^3, which is low compared to wood (250 kg/m^3) [2], and it also contains a lot of fiber. These conditions pose sawdust with problems down inside of the gasifier because sawdust is light weight and bind. The size of sawdust is small which makes its high-pressure drops in air flow rate inside the gasifier and its air flow rate varies [3]. The open top downdraft gasifier could overcome these problems and results in relatively low tar [2]. Open top downdraft gasifier could produce 50 to 80 mg/Nm^3 of tar [4], whereas the value of tar content in producer gas for internal combustion engine is required to be below 100 mg/m^3 [5]. A combination of gasifier with gas cleaning system will reduce tar below the required value.

The utilization of and experiment on biomass gasification system to generate power in small scale have been done by several researchers. Jain *et al* have investigated rice husk gasification using open top downdraft gasifier to drive an electric generator with electric power of 3 to 13 kW, and the results showed that the system could operate for approximately 300 hours without problems [6]. Desmukh *et al* have developed a gasification of higan fruit shell coupled to diesel engine with a capacity of 3.7kW, and it was reported that producer gas could replace a maximum of 60% of diesel oil [7]. Rajvanshi *et al* developed wood gasification system using open top downdraft gasifier to generate engine with a capacity of 3.75kW. The energy generated is used to drive pumps for irrigation system and reported to make varied saving from 50% to 78% in diesel oil [8].Rajeev *et al* have utilized sugar cane leaves to generate electricity using gasification system with a capacity of 3.5 to 11.3kW, and the results showed that the system was technically quite feasible with diesel oil saving over 50% [2]. Shaw *et al* have utilized risk husk as fuel open top downdraft gasifier before producer gas was used to generate diesel engine, and the results showed that about 22% of diesel oil engine could be saved [9]. Singh *et al* have done wood gasification using open top downdraft gasifier where producer gas was used to generate dual fuel bio-diesel engine. The result showed the producer gas could substitute for 78% of biodiesel oil of 78% [10].

This research has developed and experimented on sawdust gasification system using open top downdraft gasifier combined with internal combustion engine to produce ± 1kW of electrical power.

OPEN TOP DOWNDRAFT GASIFIER

The construction of open top downdraft gasifier is shown in Figure-1, where the top of gasifier is opened for air and fuel to enter. Inside the gasifier are uniform (throttles). The zones of the reaction inside the gasifier are drying zone, pyrolysis zone, char reduction zone, and inert char zone [11]. In gasification process, the stability of combustible gas depends on the availability of the zone inside of the gasifier.

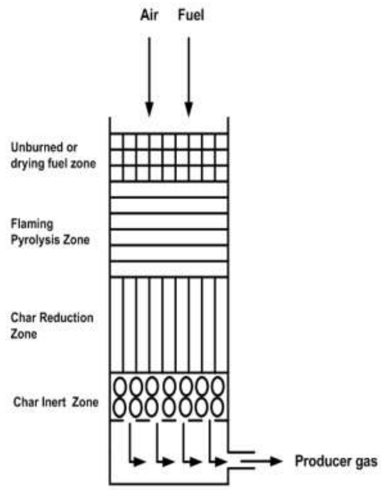

Figure-1. Open top downdraft gasifier [11].

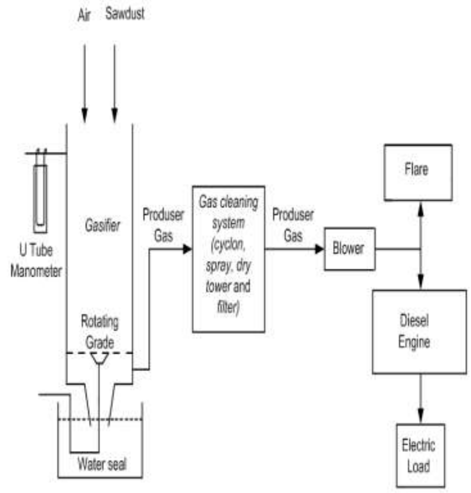

Figure-2. The skema of experimental set-up.

Figure-3. Experimental set-up.

METHODOLOGY

In this study gasification and gas cleaning systems that were integrated with internal combustion engines have been developed. The gasifier used the open top downdraft, which is 63 cm in height and 22 cm in diameter. The reactor is made of SUS 304 stainless steel [12], and it was covered by ceramic fiber wool to prevent heat loss. Air entered the gasifier from the top, where as fuel entered from the top of the gasifier in the same line as the air. The grate of the gasifier was made of stainless steel. The grate was designed in rotary condition, so it could be rotated to adjust to the flow rate of fuel in the reactor. At the bottom of the reactor was placed a water seal to prevent gas from escaping and air from entering from the bottom of the gasifier [13]. The gas cleaning system consists of cyclone, spray tower, dry tower and filter. Producer gas was passed in a gas cleaning system to reduce the tar.

The internal combustion engine system used a diesel engine with maximum of electrical load of 3 kW. Diesel engine was coupled with dynamo and electric load of 1kW. The experimental set-up used for collecting data is shown in Figure-2 and Figure-3. The producer gas entered through the air duct of the engine and mixed with air combustion. The controlling air and producer gas were mixed using a valve. At the beginning of the process, diesel engine was driven using diesel oil and then the producer gas valve opened until it reached the required limit on producer gas.

Sawdust, fuel for gasifier, which is more freely available in the surrounding area of Universitas Sriwijaya, has bulk density of 104 kg/m^3 with the proximate and ultimate analysis shown in Table-1. The ignition of gasifier was turned on by inserting approximately 0.25 kg of sawdust and then burned using air that was sucked by the blower. After all of the fuels were burned, the additional fuel was burned until the flaming pyrolysis zone was at a height of 43 cm. Furthermore, the addition of fuel must be done if the flaming pyrolysis zone appeared. The fuel feeding process has been done continuously.

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Table-1. Proximate and ultimate analysis of Sawdust.

Proximate analysis	Unit	Value
Moisture	Mass Fraction (%)	6.75
Ash	Mass Fraction (%)	0.38
Volatile	Mass Fraction (%)	80.11
Fixed Carbon	Mass Fraction (%)	12.76
Ultimate Analysis (dry basis)		
Carbon	Mass Fraction (%)	47.45
Hydrogen	Mass Fraction (%)	6.46
Oxygen	Mass Fraction (%)	45.54
Nitrogen	Mass Fraction (%)	0.05
Sulphur	Mass Fraction (%)	0.12

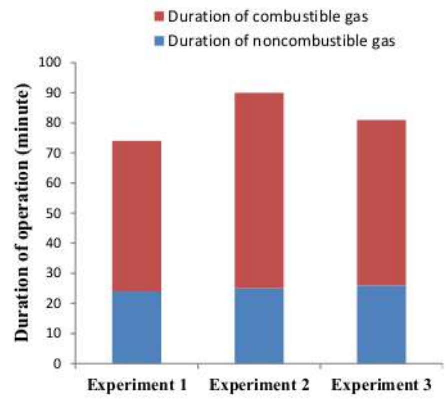

Figure-4. The contrast between noncombustible gas and combustible gas in duration.

Figure-5. Flare of producer gas.

RESULT AND DISCUSIONS

The mass flow rate of sawdust consumed was about 5 kg/h and the mass flow rate of air gasification consumed was about 8.9 kg/h. The mass flow rate of fuel has the same value as the result shown [6] by a 15 cm in diameter reactor. The mass flow rate of air gasification is in the range of 1.5 to 3.5 of air-fuel ratio (A/F) in biomass gasification [14].

Generally, combustible gas was produced after it has been in operation for about 20 minutes as shown in Figure 4. An amount of time was used to increase the temperature to release all volatile matter of fuel (80% of high volatile matter) and to create zones of gasification; the combustible gas was indicated by the flare when producer gas was ignited as shown in Figure-5.

The stability of combustible gas was controled by the existence of drying layer of fuel over the zone of flaming pyrolysis and shaking of the grade [2]. The existence of fuel on the drying layer would determine the product of combustible gases. If the drying layer is reduced, the combustible gas will be reduced too, and such reduction was caused by the availability of CO H_2, CO_2 and H_2O as products of flaming pyrolisis that have been reduced [15]. The rotation of the grade can avoid the blockage of the gas flow rate through the grade caused by the ash. The decreasing combustible gases were indicated in reduced length of flare. The sawdust must be added into the gasifier and rotate the grade if flare length continues to decrease.

The application of producer gas on diesel engine was done with dual fuel system. The maximum amount of producer gas that could be mixed with diesel oil was indicated by the increasing vibration of the engine. The results show that the application of producer gas on no-load condition can save about 50% of diesel engine as shown in Figure-6.

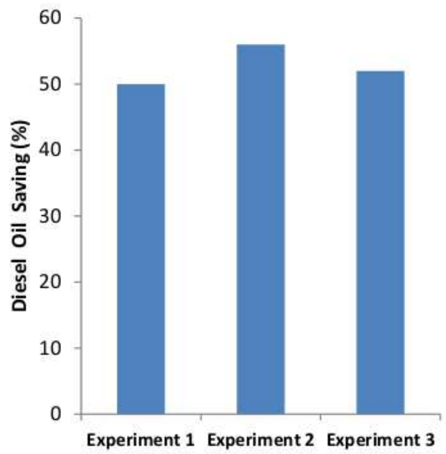

Figure-6. Diesel oil saving at a condition without electrical load.

The addition of 1kW electrical load will decrease 5 % to 10% of diesel oil saving as shown in Figure-7, because addition to electrical load will increase fuel consumption (producer gas and diesel oil). The increased fuel consumption was not followed by the addition of producer gas because of the ability of the engine to receive an amount of producer gas. These results have value in the range as reported by Rajvanshi *et al* [6] and Malik *et al* [16] for dual fuel diesel engine.

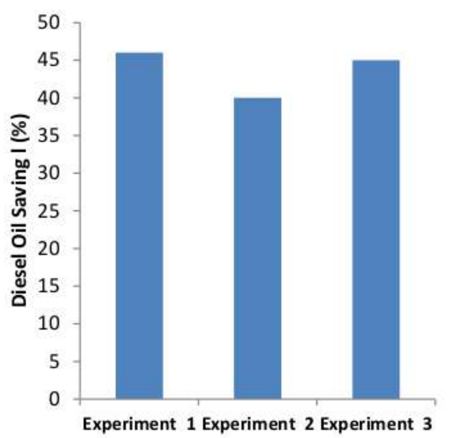

Figure-7. Diesel oil saving at condition with electrical load of 1 kWe.

CONCLUSIONS

The results of the experiment show that sawdust can be gasified to produce producer gas using an open top throttles downdraft gasifier. The mass flow rate of sawdust was about 5 kg/h. The combustible gas was produced after being in operation for 20 minutes. Producer gas was used to generate diesel engines which could save diesel oil 40 to 50%.

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