Experimental Analysis of a Charcoal Downdraft Gasifier and Gasoline with Motorcycle Engine

Suwimon Saneewong Na Ayuttaya\(^1\) and Wirot Jindarat\(^2\)*
\(^1\) Department of Mechanical Engineering, Chulachomklao Royal Military Academy, Nakhon-Nayok, 26001, Thailand.
\(^2\) Department of Public Works and Town & Country Planning. 224 Praram 9 road, Huay-Kwang, Bangkok and Praram 6 road, Samsennai, Phayathai, Bangkok 10400, Thailand.
*Corresponding Author: Tel: 0-2299-4729, Fax: 0-2299-4729; E-mail: wiro@chaiyo.com

Abstract

A downdraft gasifier is the one type of furnace by fuel gas is obtained from transforming hard fuel. In this study, charcoal fuel is compared with gasoline in order to study combustion and implementation with motorcycle engine. The three parts of devices are designed (gasifier bed, cyclone and butterfly valve). The experimental results show that heating value of gasoline is higher than charcoal while the three types of charcoals (parawood charcoal, coconut shell charcoal and mangrove wood charcoal) having a similar heating value. But the heating value of parawood charcoal is slighter higher than coconut shell and mangrove wood charcoal. Furthermore, mangrove wood and coconut shell charcoal hard to combustion so gasifier production of both types have less than parawood charcoal. In addition, gasifier is advantaged when the pollution of the engine is compared. The finally, the fuel consumption and pollution of gasifier are less than gasoline so the cost of gasifier cheaper than gasoline. In the future, gasifier is the alternative energy for motorcycle engine.

Keywords: Downdraft gasifier, Charcoal, Parawood charcoal, Gasoline, Fuel combustion.

1. Introduction

Gasification process offers significant potential to convert biomass materials into energy fuels and chemical. Gasifier is the kind of fuel gas obtained from transforming hard fuel such as charcoal, coal, firewood or agricultural material etc. Fuel gas is used for replacement energy of engine [1]. In order to improve efficiency of engine, many researchers seriously study in the gasifier design. For the past decade, some researcher analyses the gasifier process [2-5]. Patil [2] experimental downdraft gasifier designed with unique biomass pyrolysis and tar cracking mechanism was evolved at Oklahoma State University. This design had an internal separate combustion section where turbulent, swirling high-temperature combustion flows was generated. Maximum tar cracking temperatures were above 1100 °C. Average volumetric concentration levels of major combustible components in the product gas were 22% CO and 11% H\(_2\). Hot and cold gas efficiencies were 72% and 66%, respectively. Sharma [4] studied a fluid flow and heat transfer model. Model predictions were validated against the experiments, in this study, the temperature profile was found to be very sensitive to gas flow rate and heat generation in oxidation zone, while high bed temperature, gas flow rate and the reduction in feedstock particle size were found to cause a marked increase in pressure drop through the gasifier.

Although, gasifier is studied from many researcher but efficiency of gasifier is a little
improved. Due to the basic processes of gasifier behavior and regulation of fuel properties are not systematically investigated. In this study, experimental study was evolved from Dissertation of Srinakarinwirot University [6]. The type of gasifier fuel, heating value and fuel consumption are investigated. Furthermore, the pollution from gasifier engine is compared with gasoline engine.

2. Downdraft Gasifier design

The downdraft is the most type of gasifier design because it is a co-current reactor where air enters the gasifier at a certain height below the top. The production of gas flows through downward and it leaves through a bed of hot ash, so it is called downdraft gasifier. Since it passes through the high-temperature zone of hot ash, the tar in the production gas finds favorable conditions after than cracking is appeared. For this reason, all types of downdraft gasifier have the lowest tar production rate. From a nozzle set up, air sets around the gasifiers periphery. A fluid flow is move from top to bottom zone so it is mixed with pyrolyzed char particles. A combustion zone is developed about 1200 to 1400 °C, as showed in Fig.1. Then the gas descends further through the bed of hot char particles. The ash production leaves from the gas and it drops off at the bottom of the reactor. Downdraft gasifiers are a good operation with internal-combustion engines. Air from engine suction draws through the fuel bed and gas is produced at the end. Low tar content (0.015–3 g/nm³) in the product gas is motivated in order to use within internal-combustion engines. A downdraft gasifier requires a shorter time (20–30 minutes). From above data, downdraft gasifier is installed with motorcycle. To avoid the construction and operation problem, this gasifiers device is described from Reed et al. [7].

![Fig.1 Downdraft gasifier [6].](image)

During downdraft gasification, 10 to 20% of the biomass will remain as charcoal after pyrolysis is completed. Air is entered at the grate. The first reaction is called the Boudouard reaction. Charcoal is suddenly burned so heat and CO₂ are appeared, according to the reaction Reed et al. [7]:

$$C + O_2 \rightarrow CO_2 + \text{heat}$$

Almost immediately, the CO₂ and H₂O are appeared in the second reaction. After that CO and H₂ are reacted, according to the following reactions Reed et al. [7]:

$$C + CO_2 + \text{heat} \rightarrow 2CO_2$$

$$C + H_2O + \text{heat} \rightarrow CO + H_2$$

Equation 3 is called the water-gas reaction. The CO and H₂ are formed in the hot charcoal zone and it can react below 900°C to form methane, as shown in Equation 4, according to the reaction Reed et al. [7]:

$$C + 2H_2 + \text{heat} \rightarrow CH_4$$

3. Experimental design [6]

Fuel of gasifier is used within four strokes of motorcycle engine. Main three parts are composed. The first part is downdraft gasifier bed. The gas flow into a downdraft bed
is showed in Fig.3. For gasifier bed, this is for the downdraft bed design with round diameter: 192 mm and height: 360 mm. The gasifier bed contains 4 kg of charcoal per each time and also has to cyclone before flow to combustion chamber engine. Components of the downdraft gasifier bed are as follows.

A. Cover  B. Air Pipe  C. Nozzle
D. Barrier ashes  E. Gas Pipe  F. Sight glass
1. Air inlet  2. Combustion zone
3. Reduction zone  4. Distillation zone
5. Drying zone  6. Gas outlet
7. Charcoal feed  8. Ash bucket

The second part is cyclone, the cyclone dust trap with a diameter of 70 mm and a height of 140 mm is designed, as shown in Fig.4. It is easily installed in the system. Cyclones are not very practical for tar removal, because of the tar’s stickiness and cyclones cannot remove small (<1 micron) tar droplets. A fabric filter has been used with the help of a precoat which is removed along with the dust formed on the filter. The third part is butterfly valve, as shown in Fig.5. Throttle is absolutely opened and the air is mixed with fuel in the carburetor. The fuel ratio can adjust in order to mix air in the carburetor. Gasifier fuel from the furnace is transfer to the filter and it is transfered into the throttled.

Experimental results are compared with another fuel gasifier. Parawood charcoal, coconut shell charcoal, mangrove wood charcoal and gasoline are studied in order to analyze heating value, pollution and fuel.
consumption of fuel. For the all cases, speed test is varied from 0, 2000, 4000 and 6000 rpm.

Before starting, warm up is necessary before the experimental setup. After that downdraft gasifier engine is started. Fig.6 shows the installation of gasifier production on a motorcycle engine. When experiments set up, it is conducted by the stove, when fully packed charcoal tank. Then fire in the furnace with supply air, charcoal is quickly burned. Then turn off the stove, the air blowing through the air pipe. By opening the lid to prevent dust filter in the engine. Gas stove is sufficiently quantity to the engine. After that, we close the lid of the filter and then start the engine.

4. Results and discussions
The purpose of this study, heating value, combustion and implementation of charcoal are compared with gasoline.

4.1 Comparison analysis fuel type
Temperature and heating value of fuel are measured from bomb calorimeter.

4.2 Comparison of combustion between gasifier (parawood charcoal) and gasoline
In order to study SI engine pollution emissions (CO₂, CO, SO₂ and NO) from motorcycle engine, parawood charcoal (gasifier) is compared with gasoline. Speed tests are varied from experimental analysis. The exhaust gas analysis using IMR-3000 P, the probe of the instrument insert into the intake of the engine. The speed test of the engine set at 2000 rpm (low-speed test), 4000 rpm (medium-speed test) and 6000 rpm (high-speed test). From assumption, the engine is no-load conditions. Time of 2 minutes and read the measured value displayed on the screen and then record so combustion from fuel is measured.

Variation of SI engine CO₂ emissions with two fuels of different speed test is showed in Fig.9. Combustion from gasifier emissions CO₂ is less than gasoline due to speed test of engine.
props the gasoline engine, so weight of gasoline is increased with engine speed. By high-speed test, CO₂ from the combustion of gasoline has decreased and CO₂ from the combustion gasifier has increased. Furthermore, Fig.10 shows variation of SI engine CO emissions with two fuels of different speed test. In the all engine speed test, the emission of CO from gasifier is less than gasoline. From the beginning, the emission of CO from gasoline is significantly increased but it is a little decreased after low-speed test and CO from gasoline is nearly stabled after high-speed test. Which gasoline different from gasifier, the emission of CO from gasifier is increased from the beginning and it is a little decreased after low-speed test. After medium-speed test, the emission of CO from gasifier is increased until the end of operation.

Fig.9 Variation of SI engine CO₂ emissions with two fuels of different speed test: (gasifier and gasoline).

Fig.10 Variation of SI engine CO emissions with two fuels of different speed test: (gasifier and gasoline).

Variation of SI engine SO₂ emissions with two fuels of different speed test is showed in Fig. 11. The emission of SO₂ from the gasifier combustion is less than the gasoline. From the beginning, the emission of SO₂ from gasoline is increased but it is a suddenly decreased after low-speed test but the emission of SO₂ from gasifier is increased from the beginning and it is a gradually decreased after low-speed test. After medium-speed test, the emission of SO₂ from gasifier is again increased until the end of operation. When SI engine SO₂ emissions with two fuels are compared, it can be seen that at high-speed test (the end of operation), SI engine SO₂ emissions from gasoline is higher than gasifier. The end of operation, SI engine SO₂ emissions from gasoline is higher than gasifier.

Fig.11 Variation of SI engine SO₂ emissions with two fuels of different speed test: (gasifier and gasoline).

Fig.12 Variation of SI engine NO emissions with two fuels of different speed test: (gasifier and gasoline).
From Fig.12, variations of SI engine NO emissions with two fuels of different speed test are compared. In the low-speed test, gasoline is higher than gasifier. But after the high-speed test until the end of operation, SI engine NO emission from gasifier is higher than gasoline.

4.3 Implementation analysis on type of fuel

Comparison between the O$_2$ of two different fuels (gasifier and gasoline) with respect to speed test is showed in Fig.13. From the low-speed test, gasifier is higher than gasoline. After the medium-speed test, gasifier is continually decreased until the end of operation. While after the medium-speed test, gasoline is increased. From the end of operation, O$_2$ from two different fuels are nearly balanced combustion when the end of operation.

Variation of SI engine ash emissions with two fuels of different speed test is showed in Fig.14. After the beginning, the ash emissions from gasoline and gasifier are continually increased. It can be seen that ash from combustion is fully increased and ash combustion decreases after the low-speed test. After the medium-speed test, ashes from two fuels are again increased. Gasoline is suddenly increased and the end of operation, ash from gasoline is more increased than gasifier.

Fuel consumption in different fuels is shown in Fig.15 (Remark: Gasoline per liter in 41 baht reference rates as at 13–26 May 2012). From experimental result, parawood charcoal is the one type of gasifier, it is the lowest fuel consumption because the fuel engine from parawood charcoal can propel 4.737 km per 1 baht. Fuel consumption is obtained from the maximum speed 65 km/hr, the average speed 55 km/hr and 35 km/kg. While the fuel engine from coconut shell and mangrove wood charcoal can propel 3.181 and 3.500 km per 1 baht, respectively. Meanwhile, gasoline uses 0.789 km per 1 baht. From the result, the fuel consumption of all charcoal fuel (gasifier) is less than gasoline.
5. Conclusions

In this experimental study, the internal combustion engine of gasifier and gasoline are compared. The conclusions are obtained as follows:

1. The combustion pollution of gasifier is lower than gasoline. Thus resulting in better combustion in the confined spaces is gasifier production in larger quantities.

2. Fuel consumption of gasifier is lower than gasoline, so the cost of gasifier is cheaper than gasoline.

The idea behind this work can be used as guidance for special design of motorcycle engine system. For optimum design, it should be considered to the gasifier installation and it is used in the real condition.

6. References


