# An experimental two-stage of air supply in downdraft gasification

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***Abstract:***
*This work studies an experiment on two-stages of air supply in a downdraft gasifier. The two stages of air supply had three nozzles location of each stage. Palm shell was used as solid fuel in this experiment. This experiment was operated in difference air flow rates which fed into two-stage of gasifier and distribution by nozzles. The quality of gas compositions were investigated when operating in difference condition. The percentage of gas compositions were highest when increase the maximum air flow rate around 415 l/min and also reduced the concentration of tar when increase the air flow rate. In addition, the maximum air flow rate was also increase temperatures in the combustion zone.*

***Keywords:*** *Downdraft gasification; Two-stage of air supply; Palm shells*

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## 1. Introduction

Currenly, the main energy sources in the world produces from fossil fuels for instance petroleum, coal etc., As the near future, these energy resources will be exhausted. Therefore, the renewable energy sources are alternative for developing country (Abbasi et al., 2010). Thailand is also one of developing country where has been rapidly increasing an energy demand and electricity generation. These demands will be solved by alternative energy which Thailand can produced renewable energy from agricultural waste such as rice husk, rice straw, bagasse leaves, and grasses as biomass. These biomasses can be transformed into bioenergy via thermochemical technology, for instance, combustion, gasification, pyrolysis and torrefaction (Balat, 2009). For gasification is well known as technology to convert solid fuel into gaseous. The product gases mainly consist of CO, $H_2$, $CH_4$ which take place from partial oxidation. Moreover, the sufficient quantity of syngas can be used as fuel for internal combustion engine and in boiler (Jaojarueka, 2011). When biomass is used to be fuel in this technology it calls biomass gasification. However, the main problem of biomass gasification is tar formation which is a large problem in process because it causes blocking in the tube and operating system (Lopamudra, 2003). Therefore, this work studies the effect of air flow rate and different stages of air supply which result in quality of product gases.

## 2. Material and methods

### 2.1 Biomass characterization

Palm oil shell was used as the solid fuel in this experiment. Its size was 1-1.5 cm. The palm oil shell was controlled the moisture below than 15%.The ultimate analysis followed ASTM D3176, Proximate analysis followed ASTM D3172 and the heating value followed ASTM standard D-2015 are presented in Table 1. LHV and HHV of gas can be determined by using the equations:

$$\mathrm{HHVgas} = \frac{(12.75*\mathrm{H2} + 12.63*\mathrm{CO} + 39.82*\mathrm{CH4})}{100} \quad (1)$$

$$\mathrm{LHVgas} = \frac{(107.98*\mathrm{H2} + 126.36*\mathrm{CO} + 358.18*\mathrm{CH4})}{1000} \quad (2)$$

where the gas species in the equations denoted volumetric percentages that can be obtained from the gas analyzer.

**Table 1** Proximate, Ultimate and heating value analysis of palm shell.

| Proximate analysis (wt. %) | Palm shell |
|---|---|
| Moisture | 6.7 |
| Volatile matter | 74.8 |
| Fixed carbon | 13.5 |
| Ash | 5.0 |
| Ultimate analysis (wt. %) | |
| Carbon | 49.2 |
| Hydrogen | 5.4 |
| Nitrogen | 0.4 |
| Oxygen | 45 |
| LHV (MJ/kg) | 17.31 |

## 2.2 Gasification system

The downdraft gasifier with two-stage of air supply was designed and manufactured by the Thai steam service & supply. Co. Ltd (Bangkok, Thai land). The gasifier is built with an internal coating of refractory material. It had cylindrical shape with diameter of 15 centimeters and a total height of 210 centimeters (from the hopper of the reactor to the grate). There are three locations of air supply located at along the gasifier and three nozzles of air injection for each stage. Seven K-type of thermocouples were installed along gasifier for monitor the temperature at difference height. Other thermocouple was installed above cyclone to measure the temperature of product gas. The air was supplied by ring blower (2.103 kPa). Product gas was flowed down via the bottom of the gasifer passed cyclone for separated the dust in product gas by suction blower. For measurement of gas composition, a gas sampling position was installed before suction blower and using vacuum pump to collect product gas in a gas bag. All of the system was showed in Fig. 1.

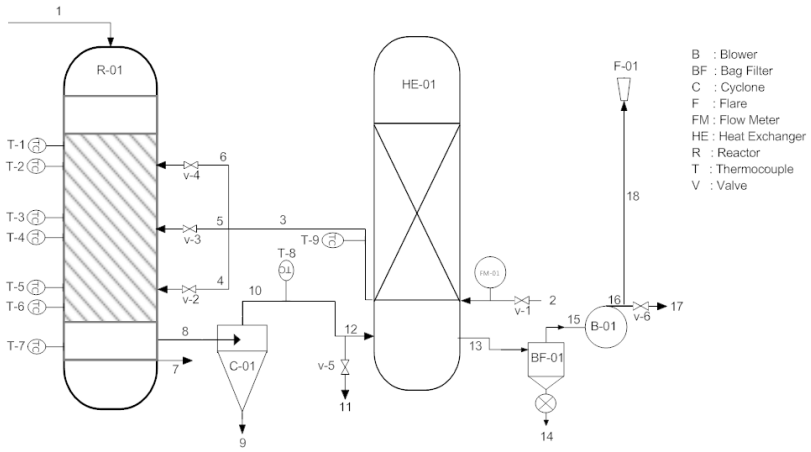


**Fig. 1** Schematic downdraft gasifier.

## 2.3 Gasification procedures

The experiment was started by feeding 22 kg of palm shell from the top of gasifier. There was an igniter located above the grate for ignition. LPG burner was used to ignite the palm shell. When the temperature reached up to 200°C, the LPG burner was turn off. Afterward, the air was introduced into the gasifier from the blower. For each stage of air supply, the amount of air was controlled by air flow meter. At steady state, the temperature at combustion zone and reduction zone were more constant. Then, the product gas was collected in a gas bag and analyzed by gas analyzer.

## 3. Results and discussion

### 3.1 Temperature profile in the gasifier

In the experiment, temperature profile along the gasifier height for two-stage of air supply was presented in Fig. 2(a) which showed the temperature profile distribution inside the gasifier above the grate. At the drying zone and pyrolysis zone, the temperature was slightly moved up from ambient temperature to be around 62.9°C and 509°C, respectively. The temperature of combustion zone increased a maximum of around 900°C. After combustion zone, temperature decreased because it was reduction zone. Furthermore, Fig.2(b) showed the temperature profile in the gasifier with time. 200 L/min of air was supplied through the first stages and the other 188 L/min of air was supplied through second stage which was a maximum total air flow rate. For this case, the maximum air flow rate was able to reach the temperature up to 900°C.

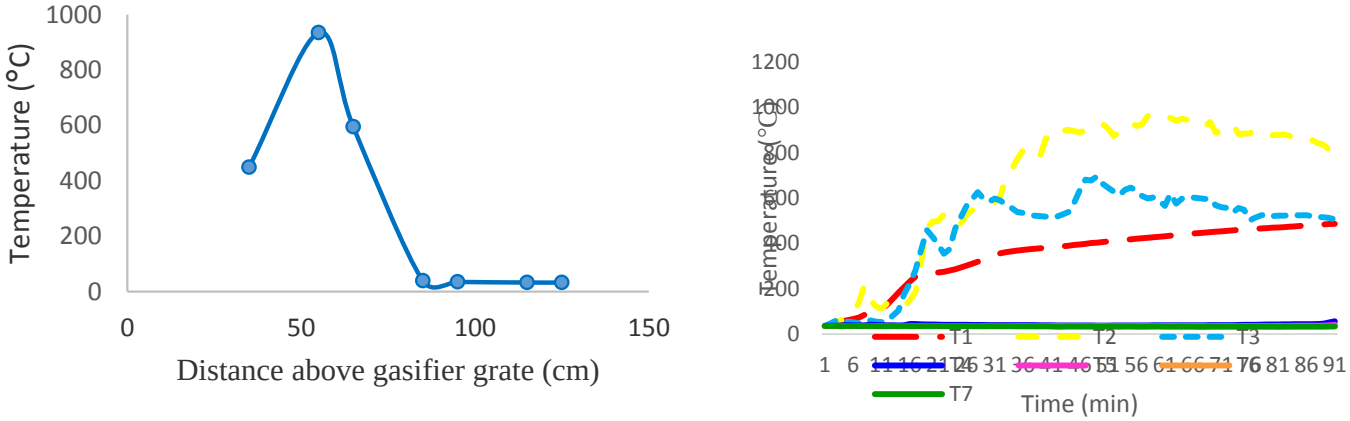


**Fig.2** (a) Temperature profile inside the gasifier; (b) Temperature profile as function of time.

### 3.2 Gas composition

The percentage of gas composition was different when vary the air flow rate. Fig. 3 showed the experiment results of gas composition by variation of the air flow rate. It found that the largest percentage of CO around 15.4 % volume when increase the maximum air flow rate and resulted in the increase $H_2$ around 10.08 % volume. A higher air flow rate represented the more $CH_4$ burned with $O_2$ and formation of CO at higher temperature (Martíneza et al., 2011). Thus, the percent volume of $CH_4$ reduced with increase of air flow rate.

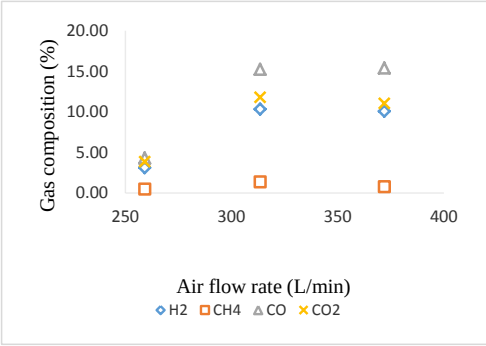


**Fig. 3** Effect of air flow rate on gas composition

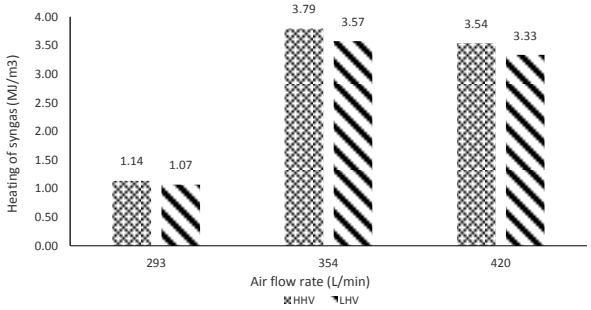


**Fig. 4** Effect of air flow rate on gas heating value

In Fig. 4 presented the air flow rate with High heating value and Low heating value of gas. From experiment, 315 L/min of air flow rate had a highest quality in term HHV and LHV were 3.79 $MJ/m^3$ and 3.57 $MJ/m^3$, respectively. In addition, Tar content in product gas showed in Table 2. The highest amount of tar can be appeared in the lowest air flow rate of 295 L/min

**Table 2** Concentration of tar in different air flow rate

| Air flow rate (L/min) | Concentration of tar ($g/m^3$) |
|---|---|
| 295 | 18.02 |
| 354 | 12.59 |
| 420 | 7.73 |

## 4. Conclusion

The experiment of two-stage in downdraft gaifier. There are three air flow rates were variation. The highest temperature were observed when adjusted the maximum air flow rate around 415 L/min and can reach the temperature up to 900°C in combustion zone. In this air flow rate can obtained the highest CO concentration around 15.4% volume and $H_2$ concentration around 10.8% volume. However, the HHV and LHV of gas were highest at air flow rate around 354 L/min. The concentration of tar in producer gas can be reduced by increase the air supply.

## 5. Acknowledgement

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