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Research Article

PRODUCER GAS PRODUCTION FROM AN UPDRAFT GASIFIER STOVE USING GOLDEN SHOWER TREE WOODY AND CHARCOAL BIOMASS AS FUEL

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ABSTRACT

This paper presents producer gas production from an updraft gasifier stove with the size of 33.5cm width×83.5 cm height and the chamber volume of 0.052 m^3 using Golden shower tree woody and charcoal biomass as fuel. The Golden shower tree biomass (4×2×2 cm size) were burdened at the top of the stove and the generated fuel gas flows through the pipe and passed through the filter and go into the cyclone due to remove of dust and tar. Producer gas consisting of CO, H_2, CO_2, CH_4. The results of the test indicated that fuel gas-producing from burning 7 kg of Golden shower chips at the air flow rate of 9.52×10-3 m^3/s the water absorbed 753.159 kJ heat and the temperature in the combustion zone was 824.6 °C. By using 7 kg charcoal as a fuel, at the same air flow rate, the water absorbed 672.115 kJ heat, the temperature in the combustion zone was 761.51 °C within 14 minutes.

Keywords: biomass; gasifier; Golden Shower chips; charcoal; thermal performance.

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1. INTRODUCTION

1.1. Rationale

At present time various countries as well as Thailand have faced with the power crisis due to the decrease of fossil fuel from now to the future. Particularly mankind needs to find out the alternative sources of energy. The use of renewable energy, biomass energy is one of renewable energy because this energy came from plants such as charcoal, rice husk or in the form of scrap. This is a locally available resource to simply find out in various regions of Thailand. After burning biomass, the gasifier is composed of carbon monoxide (CO), hydrogen (H_2) and methane (CH_4), which is the fuel gas. It can be used as fuel in its place of fossil fuel in internal combustion engine such as small gasoline engines. The performance test of a gas fired sifter used for this small engine can be used as a mechanical device in place to produce electricity, pumping water, etc., motivating the machineries in the agronomic sector. Thailand is an agriculture country, after harvesting there will be a large volume of farming waste, left which could be used as biomass energy. Biomass is the productions of industrial-agricultural waste such as rice husk, bagasse fiber and palm shell. Usually, industrial sectors use fossil fuels, including fuel, crude oil, diesel, liquefied petroleum gas (LPG), coal because of its high heating value, it's been suitable to use and to transport, and fuel costs are not high. Modern farming waste generates biomass, for example, rice husk, bagasse fiber and palm shell. Ten years ago, petroleum price has increased accordingly to the fuel price appliance in the global market. As a result, industrial sectors, instead of using petroleum fuel, used biomass fuel to substitute petroleum fuels to decrease the cost of production and to moderate waste in the plant. At present-day, industrial plants and power plants have increased their demand for biomass and as a result, prices increased affectedly and biomass and fuel shortages have been experienced in many areas. Consequently, plants and power plants using biomass have to stop process due to lack of adequate biomass fuel. Literatures of the Updraft Gasifier advantages in the past were selected. Biomass energy is likely to remain a substantial energy feedstock (Kucuk and Demirbas, 1997 and Pathak, 2005, Sims 2003). Biomass has high but in constant moisture content and is made up of carbon, hydrogen, oxygen, nitrogen, sulfur and inorganic elements. In comparison to fossil fuels, biomass contains much less carbon, more oxygen and a lower heating value in the range of 12-16 MJ/kg (Mukunda, et al., 1994; Jain, 1997 and Pathak, 2005). The chemical energy of biomass can be transformed into useful forms through biochemical, chemical and thermo-chemical conversion methods (Sokhansanj et al, 2003, Zhou et al, 2003). Gasification is a partial oxidation process at elevated temperatures (500-1400 ºC) that results in producer gas consisting of CO, H_2, CO_2, CH_4, traces of higher hydrocarbons such as ethane and ethene, water vapor, nitrogen (if air is the oxidizing agent) and various contaminants such as small char particles, ash, tar and oil. Gasification of biomass is primarily done in fixed and fluidized beds. The fixed bed gasifiers are suitable for small-scale applications (not over 10 MWth) and the fluidized bed configurations are cost effective in large-scale applications that generate over 15 MWe (Barker, 1996; Carlos, 2005; VTT, 2002 and Rajvanshi, 1986, Sims, 2003). Yang, et al., (2006) investigated high temperature agent gasification (HiTAG) of wood pellets in a batch type updraft fixed bed gasifier. The gasifier was a vertical cylindrical reactor consisting of wind box and gasifier bed. The feedstock bed was supported by a bed of ceramic balls placed on perforated disk inside the reactor. The gasification process converted faster with increase in temperature of feed gas (650 to 830 ºC). The higher feed gas temperature increases in concentration of CO (20.1 to 26.8 %) and H_2 (6.6 to 12.7 %) in the producer gas. The critical feed gas temperature (at which the yield of gaseous products was the maximum) was between the ignition temperature of biomass and the melting temperature of the ash in the biomass.

1.2 Gasification

This zone lies at the lowest of the updraft gasifier. The apparatus of the reaction between char and the surrounding gases can be designated as follows. The surrounding gases such as carbon dioxide and water vapor primarily react with the char elements on their outer surface. Then the zone of reaction changes into solid. This is known as dispersion of gas down the pore in the direction of the center of the particle. Then absorption of these gases and the surface reaction takes place. Finally desorption of product gases such as carbon monoxide and hydrogen takes place on the pore wall. These product gases are also known as synthesis gas. A portion of the hydrogen combines with carbon to form methane. These reactions are endothermic and they cause the temperature to decline from 1500° to 600°C in the gasification zone.

1.3. Biomass Thermal Conversion Processes

Thermal conversion processes for biomass comprise some or all of the following processes:

Pyrolysis: Biomass + Heat -7 Charcoal, oil, gas

Gasification: Biomass + Limited oxygen -7 Fuel gas

Combustion: Biomass + Stoichiometric' oxygen -7 Hot combustion products

Thermal processes normally have high amounts and can operate in any biomass form. Biological processes only operate on some of the components of biomass, usually the cellulose. Thermal conversion processes move the chemical composition of biomass to liquid or solid fuel regions, either by biological or thermal means.

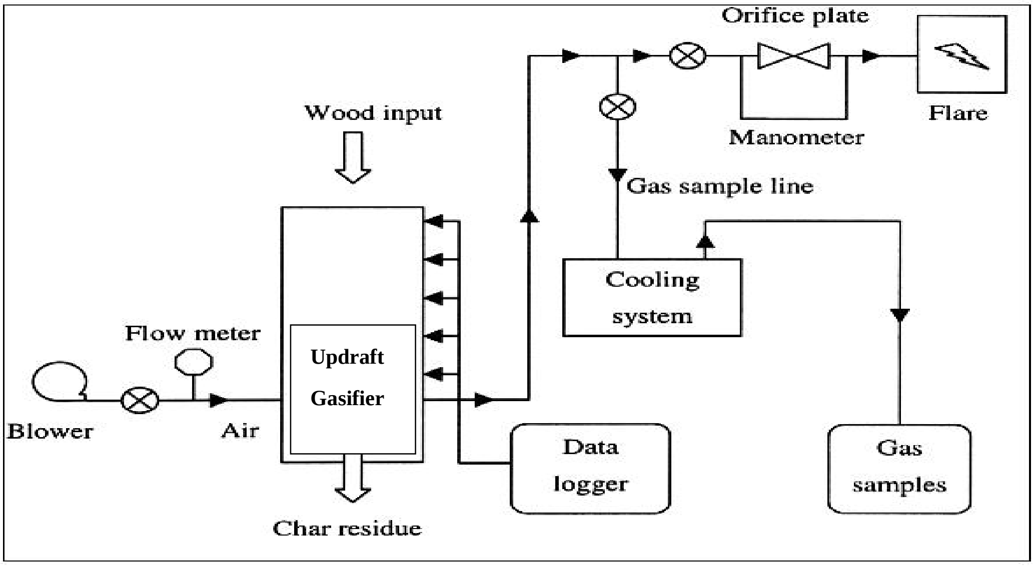

Fig.1. Biomass Thermal Conversion Processes

In this research the choice of gasifier was indicated by the fuel, its size, moisture content and ash content. The advantages of the updraft gasifier are: small pressure drop, better thermal efficiency and little tendency towards slag formation. But there are some disadvantages of this type such as: high sensitivity to tar and moisture content of fuel, poor reaction capability with heavy gas load.

2. MATERIAL AND METHOD

Thermal conversion processes for biomass comprise some or all of the following processes: The production of synthesis gas from an updraft gasifier stove using shower tree woody biomass as a fuel. The gasifier was a rectangular-shaped reactor (in the size of 33.5×83.5 cm, chamber volume of 0.052 m^3) made of mild steel with insulating shield and a combustion chamber with air holes for secondary air supply to be mixed with the product gas before combustion. The objective of the experiments was to assess the effects of operating parameters such as chip size, fuel moisture content and temperature on the thermal performance of the gasifier. The production of producer gas from an updraft gasifier stove using shower tree woody biomass as a fuel. Primarily, all the instruments for the experiments were installed. Subsequently, the moisture content and the bulk density of wood chips were measured. Then the gasifier was loaded with wood cubes and a measurement of the load was recorded. The blower was switched on and air was allowed to flow. Then the air flow was set to the desired level. The chips were ignited through the ignition port at the throat. As the production of gas started, the gas was ignited. After the system started gas production, readings such as air flow rate, temperatures and pressure measurements were recorded. A sample of product gas was collected for gas analysis. The experiments were conducted on burning charcoal and Golden Shower wood chip sizes of 3×13 cm and the 100 % air flow from a blower. 7 kg of Golden Shower tree woody biomass was dried in 1 day (6 hours). Shower tree woody biomass was weighed before and after the drying in order to estimate the rate of evaporation of water from the biomass. The air temperature throughout the experiment, the temperatures of an updraft gasifier stove were measured and recorded. The air temperatures in an updraft gasifier stove and the ambient air were measured as well. The K-type thermocouples were attached to the steel pipe on both the gas inlet and outlet sides. An environmental temperature was recorded by a data logger all three points; as shown in Fig. 1. Then plot the relationship between the temperatures of every tested point (temp-time of the test). The performances of a gasifier were calculated by the Eq. 1-3. The temperature results of the system were compared between the golden shower tree woody biomass and charcoal.

The calculation of the system can be calculated as follows;

$$\Delta Q = m_W C_W \Delta T_W + m_e L + m_{Al} C_{Al} \Delta T_{Al} \quad (1)$$

$$\eta_t = \frac{\Delta Q}{(m_f \times HHV)} \times 100\% \quad (2)$$

$$A_a V_a = A_g V_g \tag{3}$$

2.1. Details of the Test Updraft Gasifier

The gasifier used for this experiment was small size in terms of capacity. The main reason for the selection of the smaller capacity gasifier was to reduce the cost of running the unit. The gasifier is an updraft type with a reactor Inner Square of 0.23 m. Rubber wood is fed in from the top and the charging door is kept closed throughout the operation. The outer surface of the gas stove is made from galvanized iron with a thickness of 1.2 mm. A drain pipe of 50 mm in diameter is located at the end of the drum to extract any water that condenses out during the drying process. Air is sent to the combustion zone through air blower of 25 mm diameter, located 100 mm above the throat. The throat is lined with high alumina castable and is surrounded by firebricks to withstand the high temperature in the hearth zone. The throat diameter is 100 mm and consists of a divergent angle of 54 degrees. The length of the gasification zone is 22 mm from the throat. Below the gasification zone lays the grate to hold unreacted char and the ash chamber is situated beneath the grate. A galvanized steel pipe of 50 mm in diameter is used to transport the product gas from the system. A high temperature resistant (up to 1300 °C) ceramic tube was used to install the R-type thermocouples at the center of the gasification zone. The constructed gasifier, the R-type thermocouple position and the dimensions are shown in Figure 2. The gas flow measurement apparatus is illustrated in Figure 3.

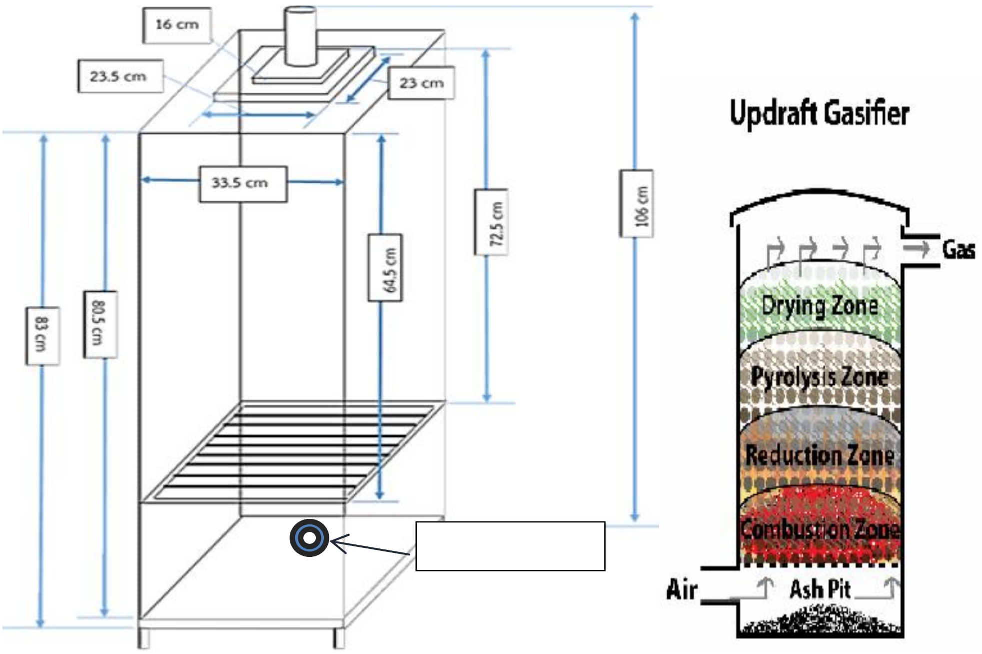

Fig.2. The details of updraft gasifier and the operating zone

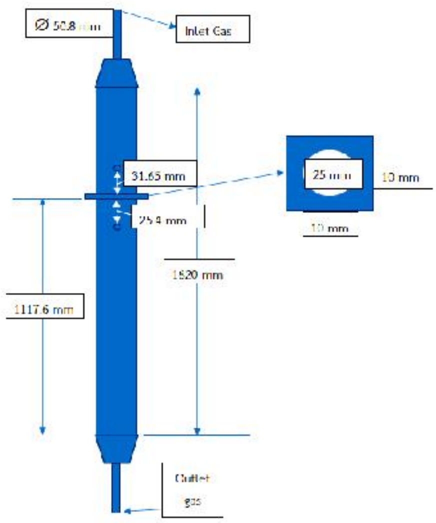

Fig.3. Gas flow measurement apparatus

3. EXPERIMENTAL SETUP RESULTS AND DISCUSSION

The experimental test rig consists of an updraft wood gasifier in the volume of 0.052 m^3, air blower, air flow meter, data logger (Graptec model gl 820), laptop computer, orifice plate, manometer, sample collector, thermocouples and scales. Figure 2 shows the experimental system. An orifice plate was fabricated according to the Australian Standard (1993) to measure the gas flow rate. Orifice plate with pipe was used to measure the mass flow rate of the product gas. The inlet and outlet pipes of the orifice plate were made from galvanized iron and the flanges were made from mild steel. Stainless steel was used for the orifice plate. A manometer was used to measure the pressure drop across and at the upper stream of the orifice plate. The cooling system consists of a coiled tube made from copper. The coiled tube was immersed in ice to condense the water vapors in the gas. The gas was collected in a special type of the sample bag. A data logger coupled with the computer was used to collect the temperature measurements made inside and outside wall of the gasifier. The experiments conducted on July 25-26, 2018 at Faculty of Industrial Technology, Vallaya Alongkorn Rajabhat University, Pathum Tani Province, Thailand.

The first step is to weigh the charcoal or dry wood prepared for incineration. The experiments will be carried out to weigh in at the specified quantities of 5 and 7 kilograms, respectively, to determine the amount of gaseous combustion. These levels are then recorded. Wood chip was prepared for the combustion, wood were cut in the same size of 122×22×19.5 mm and were dried in the open-air for a week. Wood was weighed in wet and dry basis and their size was recorded as shown in Figure 4-5.

Fig.4. Wood preparation before the combustion test

Fig.5. Weight measurement of Golden Shower tree biomass and charcoal

Second step uses the air control valve to pass air to the furnace by observing the degree of valve opening. The degrees to be used in the experiments were 75 and 100 % to determine the volume of gas produced.

Fig.6. Air intake valve position, velocity measurement

Third step, a test procedure to find out the amount of gas by the time of combustion in the experiment was done. Investigate which type of biomass has the longest period of combustion time and the boiling water test to determine the heat of the gas obtained from biomass of two types of biomass charcoal and the Golden shower tree wood as shown in Figure 6-7.

Fig.7. Updraft wood gasifier with gas flow meter experimental setup

Fig.8. Water boiling by using Golden Shower tree biomass and charcoal as fuel

Fig.9. Gasifier combustion and ash weight measurement subsequently the test

Figure 8 shown water boiling to find out the absorbed heat by using 7 kg of Golden Shower tree biomass and charcoal as fuel. Subsequently gasifier combustion and ash weight measurement was executed as shown in Figure 9. The preparation of measurement and equipment for the experiment (R type Thermocouple, glass thermometer, anemometer, data logger) was conducted as shown in Figure 10.

Fig.10. Measurement and instrumentation preparing for the experiment. (R type Thermocouple, glass thermometer, anemometer, data logger and hole drilling to insert thermocouple probe in the combustion chamber)

3.1. CALCULATION

1) Heat calculation (Shrestha, 2001) at the air flow rate of 9.52×10-3 m^3/s using Golden shower tree biomass

The amount of heat $\Delta Q = m_W C_W \Delta T_w + m_e L + m_{Al} C_{Al} \Delta T_{Al}$

Where:

m_W mass of water kg

C_W heat capacity of water 4.190 kJ/kg

ΔT temperature different °C

m_e mass of evaporative kg

L latent heat of water 2,260 kJ/kg

m_{Al} aluminum container kg

C_{Al} heat capacity of aluminum 0.896 kJ/kg °C

Calculate:

$m_W = 1$ kg

$m_e = 1 – 0.8 = 0.2$ kg

$m_{Al} = 0.4$ kg

$\Delta T_W = 81 – 33 = 48$ °C

$\Delta T_{Al} = 86 – 33 = 53$ °C

From the equation

$\Delta Q = m_W C_W \Delta T_w + m_e L + m_{Al} C_{Al} \Delta T_{Al}$

ΔQ = (1 kg)(4.190 kJ/kg °C)(48°C) + (0.2 kg)(2,260 kJ/kg)+ (0.4 kg)(0.896 kJ/kg °C)(53 °C)

ΔQ = 201.12 kJ + 452 kJ + 18.9952 kJ

ΔQ =672.1152 kJ

2) Determine the efficiency of biomass stoves (Bhattacharya, S.C, et al., 2002)

By measuring the amount of heat used to cook (The amount that causes water at room temperature to become vapor) on the amount received from fuel combustion

$$\text{The efficiency of gasifier } (\eta_R) = \frac{(\text{Total heat that water absorbed}) \times 100\ \%}{\text{Total fuel mass}}$$

$$(\eta_R) = \frac{\Delta Q \times 100\%}{(mf)(HHV_f)}$$

Where: ΔQ heat kJ

m_f fuel mass kg

HHV_f fuel heating value kJ/kg

$$\text{The efficiency of biomass stoves} = \frac{(\Delta Q) \times 100}{(mf)(HHV_f)}$$

$$= \frac{(672.1152) \times 100}{(7\text{ kg}-0.8\text{ kg})\times(16{,}313\text{ kJ/kg})}$$

$$= 0.6645\ \%$$

The efficiency of biomass stoves (η_R) at the air flow rate of 9.52×10^{-3} m^3/s was 0.6645 %

Air flow rate calculation

The diameter of the blower =3.4 cm, radius R = 1.7 cm

Velocity of air =10.5 m/s, from $A = \pi R^2$

From $Q_a = Av$

$A = \pi R^2$, r=air duct diameter = 1.7 cm = 0.017 m

v = 10.5 m/s

$Q_a = \pi R^2.v$

$Q_a = (3.14)(0.017\text{ m})^2(10.5\text{ m/s})$

$Q_a = 9.52\times10^{-3}\text{ m}^3/\text{s}\ (3{,}600\text{ s})$

$Q_a = 34.30\text{ m}^3/\text{h}$

Air flow rate Q=10.5 m/s = 9.52×10^{-3} m^3/s or 34.30 m^3/h

4. EXPERIMENTAL RESULTS

Golden shower wood measurement was performed. Wood sampling is done by cutting the trunk to the same size. They are piled on the ground and measured with a Vernier calliper and weighed wet weight (before drying), then dried it for 2 weeks and weighed the dry weight before burning. The data on the wood weight measurement are presented in Figure 8 below.

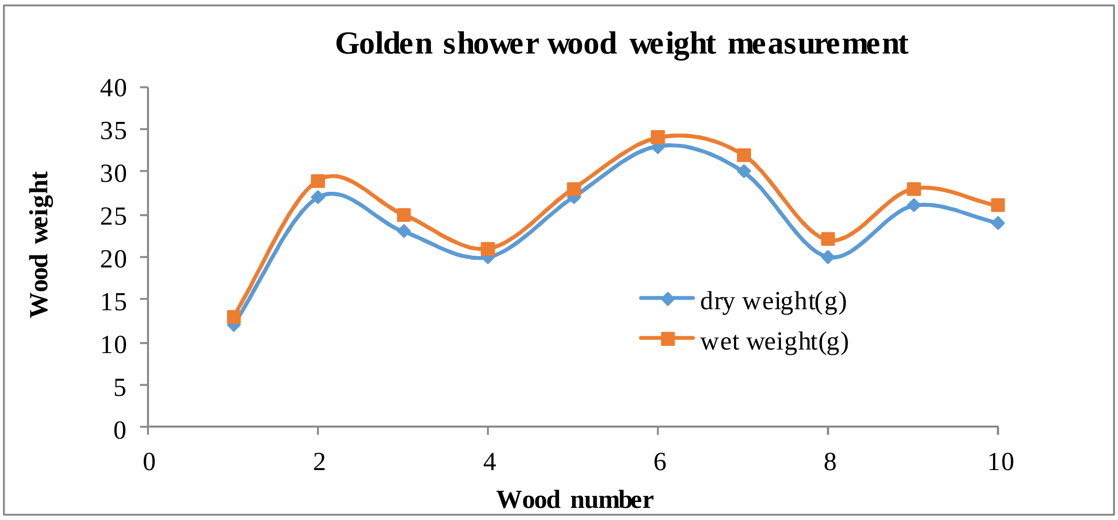

Fig.11. Golden showers, wood weight measurement

Charcoal combustion experiment, the flow rate of the air entering the combustion zone was 0.009528 m^3/s while the wood charcoal was 7 kg. The duration time was 1 hour and 46 minutes. The temperature in the combustion chamber using R type thermocouple is represented as T_1 and K type thermocouple were represented as T_2 and T_3 at the outlet and at the top of the stove, respectively. The data of temperature were recorded in the data acquisition (Graptec Midi Logger model gl 820).

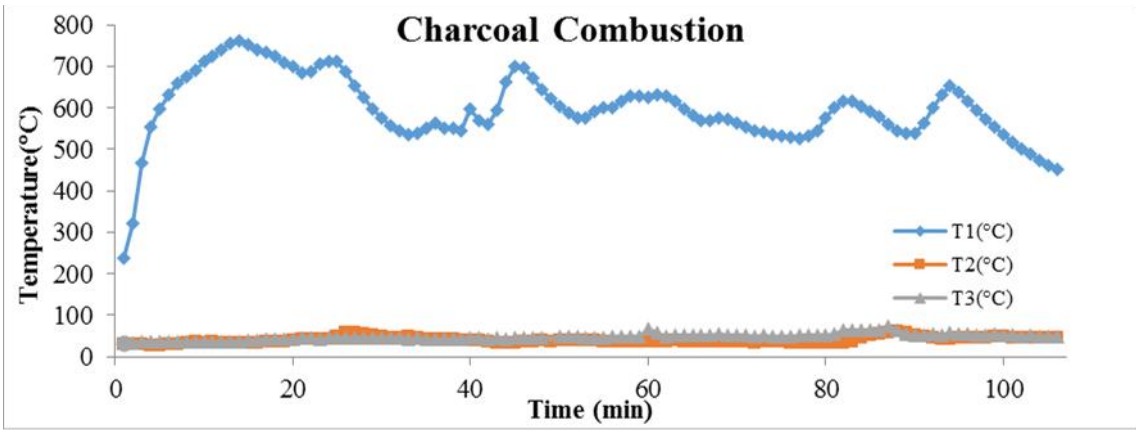

Fig.12. Variations of the temperature of each position with time of charcoal combustion

From the above graph, it was found that the maximum temperature of the combustion chamber was 761.5 °C over 14 minutes and the temperature of producing issued gas was

710.7 °C completed in 25 minutes. Golden Shower tree combustion experiment, the flow rate of the air into the combustion zone was 0.009528 m^3/s and the weight of the Golden Shower tree was 7 kg. The duration time was 2 hours 36 minutes.

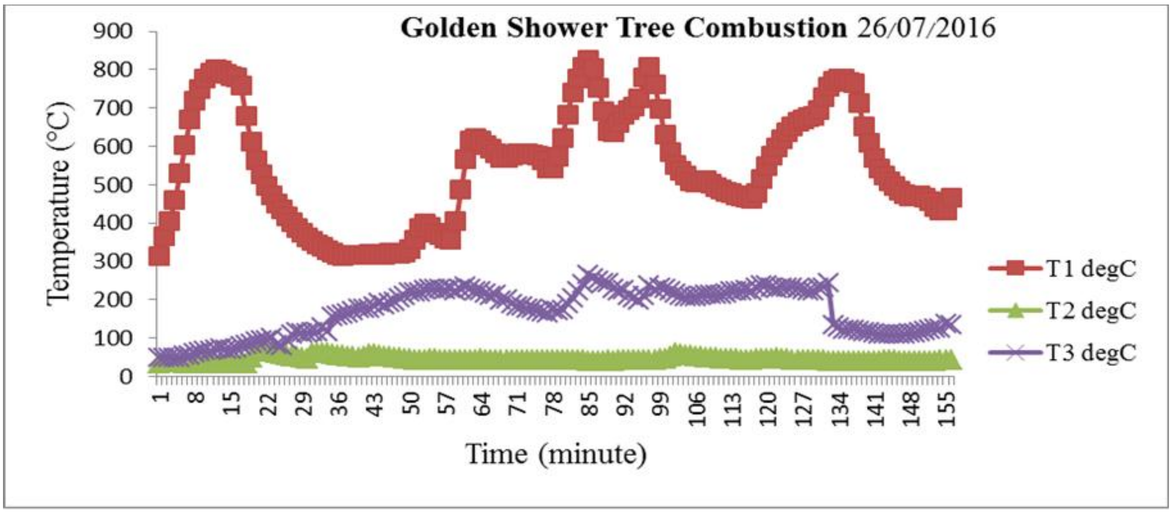

Fig.13. Variations of the temperature of each position with of Golden Shower tree combustion

The graph shows that the maximum temperature of the combustion chamber was 824.6 °C in 85 minutes and the temperature of the issued gas was 759.7 °C in 17 minutes.

5. CONCLUSION

In this study, an updraft gasifier for producer gas production has been experimentally investigated. The actual heat input to the water was measured at different temperatures. The thermal efficiency of the system depends on biomass type. From the experiment the conclusion could be made:

1. The charcoal tests by indicating that the maximum combustor temperature was 761.5 °C over 14 minutes, the issued gas temperature was 710.7 °C in 25 minutes.

2. The golden shower, wood tests by indicating that the maximum combustor temperature was 824.6 °C over 85 minutes, the issued gas temperature was 759.7 °C in 17 minutes.

3. The golden shower chips moisture content was assessed in a decrease from 20 to 10.61 MC (% d.b.) in 6 hours.

4. By using charcoal as a fuel, at the air flow rate of 9.52×10-3 m^3/s the water absorbed heat

672.115 kJ and golden shower tree woody biomass at the same air flow rate the water absorbed heat 753.159 kJ.

5. The thermal efficiency of an updraft gasifier was on the average of 28.31% when golden shower was used as fuel.

The golden shower biomass is suitable for local use in Thailand for heat generation in the household and the scale of industrialization. The Golden shower, wood chip has low ash content, but relatively high moisture and volatile matter contents. The latter result in high tar content in gas produced by the up draught gasifier system.

6. Good-quality charcoal has low moisture, volatile matter and ash contents that is why it is suitable and feasible for almost all gasifier types. But there are two main disadvantages of charcoal: relatively high cost, which reduces the competitiveness comparing with liquid fuels; energy losses, which occur during conversion of wood to charcoal (more than 70% of the original energy presented in wood may be lost).

7. The high temperature air gasification of biomass (830°C) in an updraft gasifiers decrease the tar content and raises the lower calorific value of producer gas. Updraft gasifiers are suitable for gasification of biomass containing high ash (more than 15 %) and high moisture content (over 50 %) and generate synthetic gas having greater tar content (50–100 g/Nm^3).

6. REFERENCES

[1] Chopra S, and Jain A. A Review of Fixed Bed Gasification Systems for Biomass Agricultural Engineering International: the CIGR E.J., 2007, 5(9)

[2] Kucuk M, Demirbas M, Demirbas A. Biomass conversion processes. J. of Ener. Con. and Man., 1997 (38), 151-165

[3] Pathak BS. Biomass to power rural development. In: Proc of National Seminar on Biomass Based Decentralized Power Generation, ed. B.S.Pathak and N.S.L. Srivastava, 1-6 Vallabh Vidhyanagar Sardar Patel. Ren. Ener. Res. Ins., 2005

[4] Sims R. Climate Change Solutions from Biomass, Bioenergy and Biomaterials Agricultural Engineering International: the CIGR. J. of Sci. Res. and Dev. Invited Overview., 2003, 10

[5] Mukunda HS, Dasappa S, Paul PJ, Rajan NKS, Shrinivasa U. Gasifiers and combustors for biomass technology and field studies, J. Ener. for Sus. Dev., 1994, 1(3) 27-38

[6] Jain, AK. Correlation models for predicting heating value through biomass Characteristics. J. of Agr. Eng., 1997, 34(3), 12-25

[7] Sokhansanj S, Cushman J, Wright L. Collection and Delivery of Feedstock Biomass for Fuel and Power Production. Journal of Agricultural Engineering International: the CIGR Journal of Scientific Research and Development Invited Overview., 2003, 5

[8] Zhou X, Dong R, Li S, Peng G, Zhang L, Hou J, Xiao J, Zhu B. Agricultural Engineering in China Agricultural Engineering International: the CIGR Journal of Scientific Research and Development Invited Overview Paper., 2003

[9] Barker SN. Gasification and pyrolysis- routes to competitive electricity production in the UK. J. of Ener. Con. and Man., 1996, 37(6-8), 861-866

[10] Carlos L. High temperature air/steam gasification of biomass in an updraft fixed batch type gasifier. Ph.D. thesis, Royal Institute of Technology, Energy Furnace and Technology, Stockholm, Sweden., 2005

[11] VTT. Review of Finnish biomass gasification technologies. In: OPET Report No 4 Technical research centre of Finland, Finland., 2002

[12] Rajvanshi, AK. Biomass gasification. J. of Alt. Ener. in Agr., 1986, 2, 83-102

[13] Yang W, Ponzio A, Lucas C and Blasiak W. Performance analysis of a fixed–bed biomass gasifier using high-temperature air. J. Fuel Pro. Tec., 2006, 87, 235-245

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