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A Gasification of Sawdust Using Cyclone Gasifier

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Abstract

Concerning global issues of sustainable energy and reduction in greenhouse gases, biomass energy as one of the key sources of renewable energy is getting increased attention as a potential source of energy in the future. Biomass gasification is a process to convert solid fuel into combustible gases of typically 3 – 5 MJ/m3. The characteristic of biomass fuel is the key design parameters when selecting a gasifier system. Sawdust is a fine biomass fuel abundantly available in Malaysia that can be utilized as a source of energy to produce power. However, the utilization of sawdust is limited by problems caused by the size of a particle in the fuel. A cyclone gasifier has been designed and developed at Universiti Sains Malaysia to gasify pulverized biomass fuel with a particle size of fewer than 500 microns. The system applied a novel technique to gasify sawdust through a cyclonic motion concept. The study involved both theoretical and experimental work to understand the operation as well as the performance and characteristics of a cyclone gasifier using sawdust as a biomass fuel. The objectives of the study are to (i) characterize the sawdust as biomass fuel for cyclone gasifier, (ii) determine the temperature profiles of the producer gas and wall temperature profiles inside the cyclone chamber, (iii) analyze the producer gas. The results found in this study were compared to other workers. Ground sawdust from furniture industries is used as a fuel with 80% of the size distribution ranging from 0.25 to 1 mm. The low heating value was found to be about 16.54 MJ/kg with the moisture content of 8.25%. Sawdust was injected into the cyclone gasifier with air as a gasifying agent. The gasification tests were made with varying air flow rate and fuel feed rate. Experiments were conducted with varying equivalence ratios from 0.19 to 0.53. The typical wall temperature for initiating gasification process was about 400ºC. The average temperature of producer gas was about 600 – 800oC. The highest low heating value of producer gas was 3.9 MJ/m3 with a volume flow rate of $0.01471m^3/s$. The highest thermal output from the cyclone gasifier was 57.35 kW. The highest value of mass conversion efficiency and enthalpy balance was 60% and 98.7% respectively. Generally, the efficiency of cyclone gasifier increases with the increase in equivalence ratios and the highest efficiency of the cyclone gasifier obtained was 73.4% and this compares well with other researchers. The thesis has identified the optimum operational condition for gasifying sawdust in the cyclone gasifier system and made conclusions as to how the steady-state gasification process can be achieved.

Key-word: - Biomass energy, sawdust, renewable energy, gasifier

1. INTRODUCTION

The demand for energy around the world has been increasing at a very fast pace especially in the developing countries. In light of global issues of sustainable energy and reduction in greenhouse gases, renewable energy is getting increased attention as a potential alternative source of energy. There are nine general sources of energy on earth. There are geothermal, nuclear, fossil, solar, biomass, wind, wave, hydro and tidal energies. Except for the first three, the remaining six are generally called renewable sources of energy, as they are not depleted with time. Compared to other sources of renewable energy, biomass is seen as an interesting source of renewable energy. The significance of biomass as fuel has been amplified during the past decades driven by several reasons. Biomass technology offers a technology where the fuels needed are sustainable, resources are often locally available and conversion into secondary energy carriers is feasible without high capital investments. Biomass technology is based on a wide range of feedstock as fuels. The main biomass sources in use for energy production varies from forest residues, agricultural residues, wood-based industry waste, animal waste, landfill gas to energy crops. There are several major biomass conversion processes including thermal, chemical, biological, and oxidative methods. Similarly,many potential valuable products may be produced from its conversion including heat energy, synthetic fuels, fertilizer, hydrogen, chemicals, bio-polymers, and even bio-pharmaceuticals.

Malaysia has recently adopted a five-fuel diversification policy, identifying oil, natural gas, coal and renewable energy as key fuels. The Malaysian Government has established a mandate that 5% of its energy basket should come from renewable energy by the year 2005 (Ministry of Energy, Water and Communications Malaysia). However, this target has not been achieved yet. The priority technology areas identified to be mini-hydro, biomass, landfill gas, solar and wind.

2. LITERATURE REVIEWS AND HYPOTHESIS

Development of biomass utilization technologies has been increasingly needed towards prevention of the global greenhouse effect and creation of the recycling-oriented society. Biomass gasification can increase options for combination with various power generation systems using gas engines, gas turbines, fuel cells and/or others to enhance power generation efficiency, and also can open the door to examining power generation system configurations meeting site conditions, such as kinds of collectable biomass, plant capacity, etc. Feasibility study on various power generation systems combined with gasification of various kinds of biomass inevitably requires the application of adequate study on the performance and characteristics of the gasifiers and the gasification processes.

A cyclone gasifier is specifically developed to gasify fine biomass material such as sawdust for power generation. Thus, it is important to study the performance and characteristics of the existing design. The experimental work consists of biomass fuel characteristics, investigation on fuel feeding and injection system, temperature profiles in the cyclone chamber and analysis of producer gas. Furthermore, during the experimental conduct, the important parameters such as fuel feed rate, airflow rate and equivalence ratio will be determined obtain stable and optimum gasification process condition. Therefore, a study on performance and a characteristic of the cyclone gasifier is essential for proving the workability of the system. Sawdust is chosen as the biomass fuel in this project because compared to other materials sawdust is easily and abundantly available as waste and generally disposed of in landfill areas, since this is the cheapest way to manage it. Sawdust is readily available in dry pulverized form which can be used directly without pretreatment process. The use of sawdust from wood-based industries must be carefully analyzed to offer the best technical, economic and environmental alternative. The characterization (quantity, type, chemical and energetic analysis) of the residues generated is essential to determine which technology is more suitable.

3. RESEARCH METHODOLOGY

There arae five main components in cyclone gasifier as shown in figure 1. The five components are fuel feeding system, cyclone gasifier unit, injector system heat-up system and removing compartment. The units for feeding system are downcomer, hopper and screw feeder . At first stage the sawdust is transfered to the downcomer from the hopper using the motion of the screwfeeder which was installed at the top of the units. Next ,the sawdust is injected tangentially using an air-driven injector into the cyclone. The injector directs the fuel and air mixture into the cyclone chamber in a tangential direction and generates swirl flow in the cyclone. The swirl will force the incoming sawdust particles to follow the trajectory close to the cyclone wall.Via vortex finder the gas exist from the cyclone, and the char falls toward the bottom outlet down to ash collector.

The cyclone gasifier units consist of conical and cylindrical parts which together form the body of the cyclone as shown in figure 1. The thickness body of the gasifier gasifier body is 6 mm made by a mild steel plate . The internal diameter of cylindrical body is 210 and have 1080mm height and a conical part connected to the bottom with the char collector . The inlet of the cyclone has an internal diameter of 28mm and mounted tangentially on to the sidewall of the cylindrical parts of the cyclone body . The vortex finder is fixed on top of the cyclone . The internal diameter of vortex finder is 80mm. to minimize heat loss some part of the bodyof the cyclone gasifier is insulted with refractory types of cement.

Two main parts of feeding system is hopper and screwfeeder.A hopper is used to store sawdust screw feeder is to feed the cyclone chamber. Sawdust falls to the screw feeder by gravity. The hopper designed applies funnel flow where the fuel flows through the core. The hopper has a maximum capacity of 30 kg sawdust and the sawdust is stored in the hopper manually. Screw feeder is used to feed sawdust from the hopper to the downcomer. The motor control the rotation of the screw feeder and the microinverter control the t motor. The injector system consists of a downcomer and a fuel injector. The fuel injector is used to supply air and inject sawdust into the cyclone chamber, while the downcomer connects the fuel injector and the screw feeder. The fuel injector is consists of air ejector and air supply nozzle. The air nozzle will force the sawdust whilst air ejector will induce the air/fuel mixture into the cyclone chamber. The cyclone chamber needs to be heated up before the injection process. LPG burner was used for the heating process.

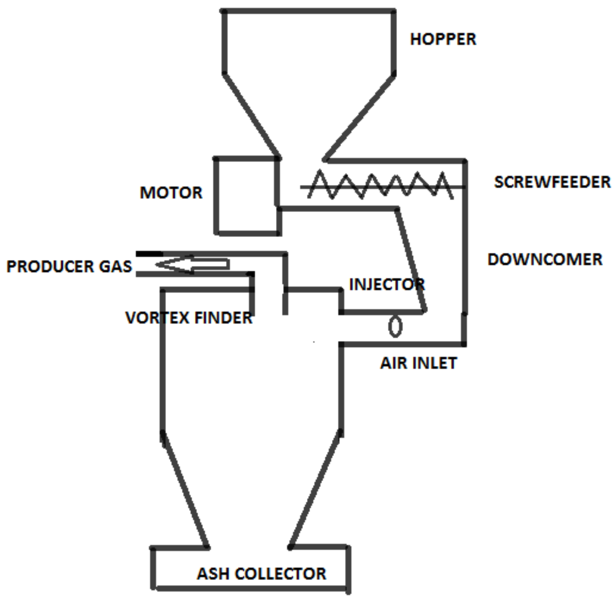

Figure 1 : Cyclone Gasifier Schematic of Diagram

The experiment is carried out by the sawdust gasification test which was made by a fuel feed rate of 13 to 37 kg/h corresponding to A/F equivalence ratios in a range of 0.19 to 0.53.Its starts by preheat the cyclone with an LPG burner until the wall temperature reaches about 400ºC, then the fuel injector starts. After about 15 min the system has reached stable conditions and runs smoothly. When the cyclone was run at the desired equivalence ratio, a gas sampling bag is used to collect the produce gas from the cyclone exit and the gas is test using chromatography for measuring the volumetric concentration of the components in the producer gas.

4. ANALYSIS

In terms of thermochemical phase, temperature profile are important to understanding the gasification process. It can also be used as a process control indicator inherently measuring disturbances occurring in the feed and the airflow rate. The effect of using different A/F equivalence ratios to the temperature profiles of the gasification process was investigated in the range of 0.19 to 0.53.

The amount of char that was separated and collected at the bottom of the cyclone is plotted against the equivalent ratio and is shown in figure 2. The char separation decreases with the increase in equivalence ratio.

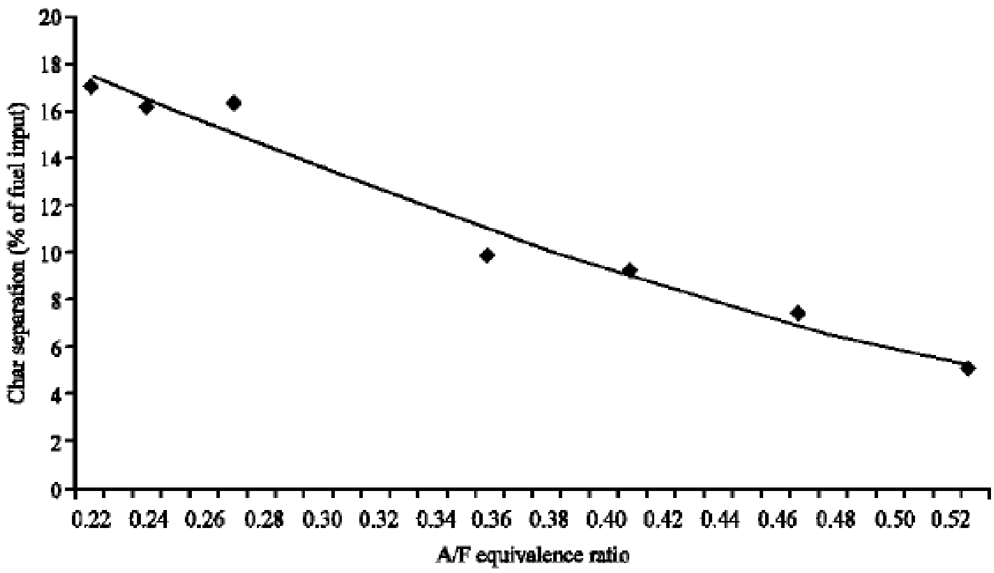

Figure 2 : Graph of Char Separation vs Equivalance Ratio

The percentage of the components of the producer gas against the equivalence ratio is shown in figure 3 . At an equivalence ratio of 22% The lowest amount of CO_2 concentration is about 18%. The decrease in the percentage of CO_2 shows better conversion into CO in the gasification process. At an equivalence ratio of 0.47The highest amount of CO concentration is about 11%. It was found that the highest concentration of H_2 was 21%. The most significant contributor to the calorific value of producer gas is H_2 because LHV of H_2 is higher than CO. It is relevant to increase the concentration to increase the calorific value of producer gas.

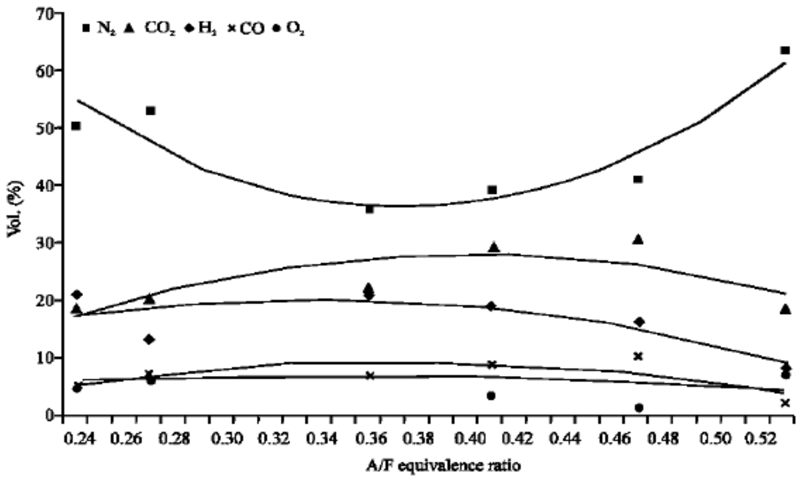

Figure 3 : Gas concentration variation vs A/F equivalance ratio

Referring to the approximate analysis moisture, the content of sawdust is around 8.25. The moisture content of the fuels will affect the performance of the gasifier so a pretreatment process is required to reduce the moisture content for to make operating condition is optimum. For the cocclussion the drying and devolatilisation zones are minimal and the fuel oxidized almost instantly. The drying and devolatilization zones is difficult to be determined experimentally but it can be hypothesize it was co-exist theoretically. The sawdust is in the particle form.When the sawdust was injected into the chamber, the reactant of the sawdust is almost as a gaseous fuel. We can say that sawdust can be considered to react and combust with the same behaviour as gaseous fuel and does not undergo drying and devolatilization processes. It goes straight to combustion. The result obtained for mass conversion efficiency is low because the water vapour was not condensed and ash particles cannot be determined because the cooling and cleaning system was not installed. The cyclone gasifier efficiency obtained is comparable with other researches Syred et Al (2004) found that the inverted cyclone gasifier efficiency was about 36 to 76% concerning different types of fuel and equivalence ratio from 0.17 to 0.

5. CONCLUSION

Experimental study at atmosphere pressure shows that it is possible to generate a combustible gas when injecting the ground sawdust from furniture industries with air as a gasifying agent. All the runs were performed using ground sawdust with particles size distribution in the range from 0.25 – 1mm compromising about 80%. Its is almost impossible to use raw sawdust directly in the cyclone gasifier because it contains different sizes and shapes of particles thus blocking the flow and become a problem at feeding and injector system. The low heating value of sawdust was found to be about 16.54 MJ /kg with a moisture content of 8.25%. the study confirmed that sawdust is suitable to be used for the gasification process and this proven via proximate and ultimate analysis. The temperature profile of producer gas inside the cyclone chamber is significant to understand the phenomena taking place for this cyclone gasifier system. Its have been shown that temperature levels in gasifier affected the gas compositions and calorific value of producer gas. Good heating up process in the initial stage results in the minimum wall temperature for initiating gasification process found to be about 400^{O}c at T_2 region. In addition, the average temperature of producer gas was about 600Oc. The higher low heating value of the producer gas is 3.9MJ/kg. The highest thermal output from the cyclone gasifier was 57.35 KW. The highest value of mass conversion efficiency was about 60% with enthalpy balance found to be 98%.

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