Development of a Small Scale Biomass Gasifier and Testing of Various Feedstock

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Abstract: ***Biomass is good source of energy in the field of renewable energy. Conventionally, use of biomass was made for simple firing purposes, for cooking and heating. However, more extensive use of biomass is seen in gasification process that may permit electrical utilities to obtain a portion of their fuel requirements from renewable energy sources. Gasification processes convert biomass into combustible gases. Biomass Gasification is a chemical process that converts biomass into useful convenient gaseous fuels or chemical feedstock. It has emerged as a promising technology to fulfill the increasing energy demands of the world, as well as to reduce significantly the volume of biomass waste generated in developing societies [1]. Maize cones, Maize steam, Pine needle and Cones, Hog Plum Seeds, Furniture Waste, Sugarcane Waste, etc. which has no food value can be used to produce syngas. Maize cones, Pine cones, Hog Plum seeds are compact and need no fuel modification while Pine Needles need to be modified because of its low density. Maize Steam, Furniture wastes and Sugarcane wastes may or may not require fuel modifications. For this academic research, three different fuels – corncobs, sugarcane residue and wood had been selected. Proximate analysis was done at National Product Research laboratory, Kathmandu and syngas composition and temperature were found by experimental setup on 12 KW downdraft gasification systems, manufactured at Gasifier Engine Research Laboratory of Kathmandu University.***

Keywords: Biomass, Gasification, Syngas

1. Introduction

Biomass is one of the major sources in the sector of renewable energy. Combustion of biomass in improved biogas gasifier aids in application of improved conversion methods, such as gasification, that match biomass energy to processed liquid and gaseous fuels so that it could be utilized for energy generation. Rural areas of developing countries are very dependent on biomass fuels such as firewood and dried dung for their energy consumption. This use of energy is often coupled with many problems such as deforestation, land degrade, various health and social problems as well as giving raise to emissions of greenhouse gases[2]. In many areas biomass can be used as a replacement for these fuels and can help solve many of the problems that are associated with fossil fuels.

Biomass is converted into combustible gases by gasification. This thermo-chemical conversion of biomass leads to generation of gas generally termed as producer gas or syngas. The syngas is a combustible mixture consisting of mostly carbon monoxide and hydrogen. The main purpose of biomass gasification or syngas is to substitute the fossil fuel consumption in IC engines throughout the load and speed ranges [3]. Gasification is a chemical process that converts carbonaceous materials like biomass into useful convenient gaseous fuels or chemical feedstock. Pyrolysis, partial oxidation, and hydrogenation are related processes. Combustion also converts carbonaceous materials into product gases, but there are some important differences. For example, combustion product gas does not have useful heating value, but product gas from gasification does. Gasification packs energy into chemical bonds while combustion releases it. Gasification takes place in reducing (oxygen-deficient) environments requiring heat; combustion takes place in an oxidizing environment giving off heat [4].

2. Problem Statement

People need good access to energy systems for smooth development of the society. But there are still some rural locations in Nepal where people don't have access to regular supply of energy/electricity provided by Nepal Electricity Authority. Thus, Gasifier system is considered to be one of the easy and portable systems to install in locations where these communities can have good access to energy systems.

Objectives

The bio-based energy sources are one of the major renewable energy sources to meet demand for access to clean, safe and sustainable domestic energy services for people. It may also serve to meet demand for transportation fuels. Keeping this in mind, the main aim of this research was targeted to select a best feedstock for the designed biomass gasifier from among some of the available feed stocks in context of Nepal. The specific objectives of the research were:

- To develop small scale biomass gasifier at Gasifier Engine Research Lab, Kathmandu University
- To make comparative analysis between wood (Alnus Nepalensis), Sugarcane Residue (Bagasse) and Corn Cobs on the basis of Temperature achieved, Hydrocarbons and Gas Composition
- To recommend best alternatives among selected feedstock for downdraft biomass gasifier designed in Gasifier Engine Research Lab, Kathmandu University

Development of Downdraft Biomass Gasifier at the Laboratory

The design and development of 12kW downdraft biomass gasifier was prime necessity for the test using selected feedstock as fuels to make analysis regarding time, temperature and gas compositions to suggest the best alternative for the design.

Thus a downdraft Gasifier was developed at the laboratory by utilizing locally available materials, including Liquefied

Petroleum Gas Cylinder, Mild Steel Sheets and Stainless Steel Pipes. It consisted of five main parts i.e., fuel storage hopper, reaction chamber, primary air inlet, combustion chamber and pot support. Each parts of the stove were independent, assembled together and disassembled by bolts and nuts.

Figure 1: Gasifier Developed at Laboratory based on the CAD Model

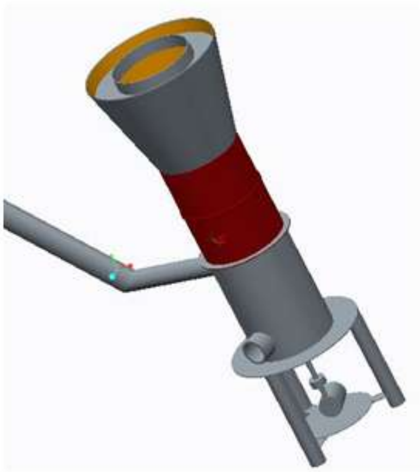


Figure 2: CAD Model Developed for Initial Analysis

Figure 3: Alnus Nepalensis wood being sun-dried

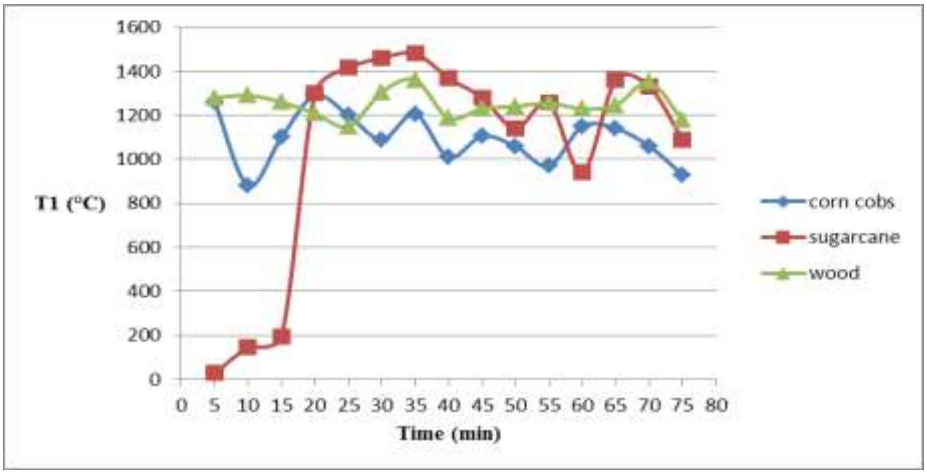
Figure 4: Corn Cobs broken into pieces and sun-dried

Comparative Analysis between Wood (Alnus Nepalensis), Sugarcane Residue and Corn Cobs

To overcome fuel bridging, Wood of Alnus Nepalensis, Sugarcane Residue and Corn Cobs required pre-processing of cutting/chipping into pieces ensuring smooth flow in the hopper and combustion zone. All feedstock were sundried and made ready for feeding the gasifier system.

3. Result Characteristics

1) **Time vs. Temperature of Combustion Zone (T1) Graph of Corncobs, Sugarcane and Wood**

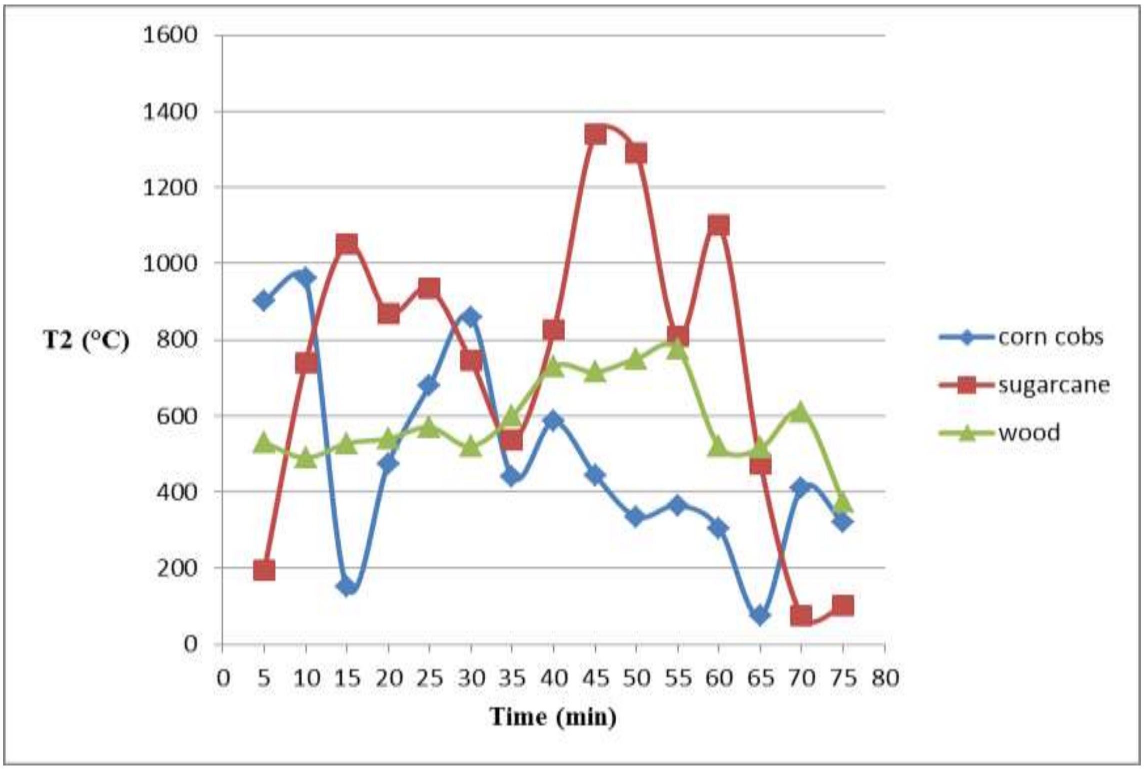


Time vs. Temperature of Combustion Zone (T1) Graph

The above mention graph is of the temperature at combustion zone of all the feedstock that we have used at test. From above graph, we found that the overall combustion temperature ranges from 800°C to 1500°C. Here in graph, wood temperature was obtained constant throughout the test. The highest temperature was obtained by sugarcane residue which was 1480°C. The drastic change in temperature was also seen in sugarcane. The temperature shown by the corn cobs was also constant but lower in value than that of wood. What we can conclude through this graph is that constant temperature can be obtained in our designed gasifier setup if we use wood as a feedstock.

2) **Time vs. Temperature of Pyrolysis Zone (T2) Graph of Corncobs, Sugarcane and Wood**

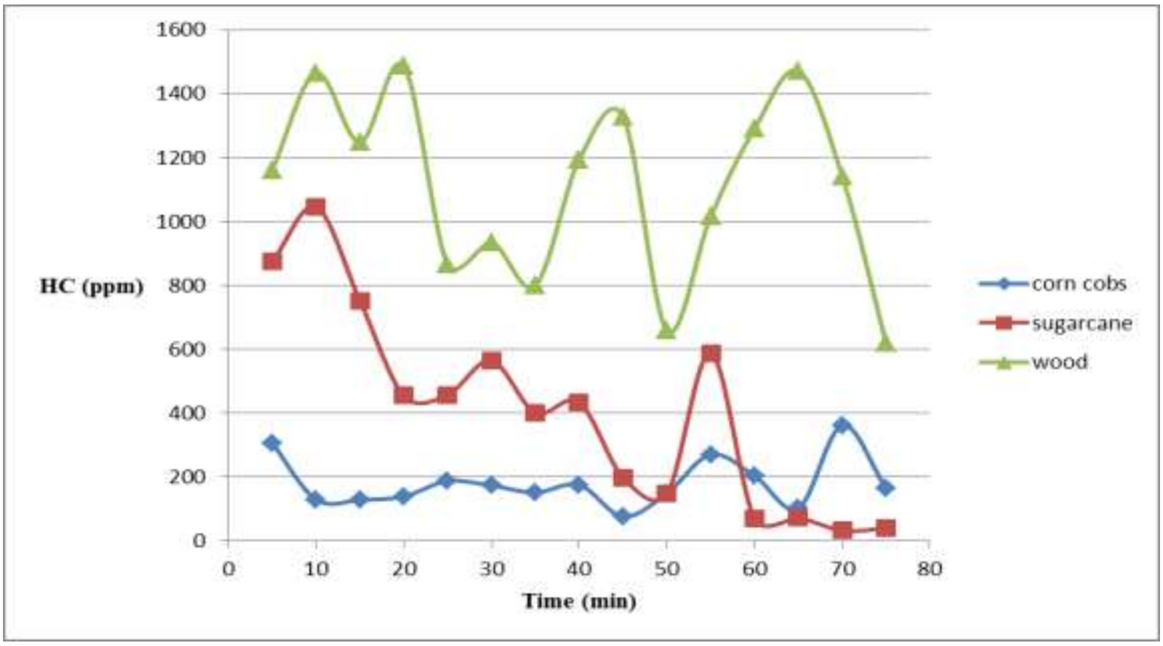
The below mention graph is of temperature at pyrolysis zone. Wood showed almost constant temperature graph whereas sugarcane and corn cobs showed fluctuating graph. From this concluded that feed in pyrolysis zone is heated constantly in wood but varies in case of sugarcane and corn cobs. Due to this constant heat gained by the wood, it helps in proper combustion and helps in minimizing tar production by keeping temperature constant. In sugarcane, temperature is not constant due to which the problems could be encountered in proper combustion of fuel. The overall temperature ranges from 75°C to 1340°C. Drop in temperature shown by the corn cobs is due to the sudden fall of feed from pyrolysis zone to the combustion zone. Constant temperature shown by wood results in smooth flow of feed.



Time vs. Temperature of Pyrolysis Zone (T2) Graph

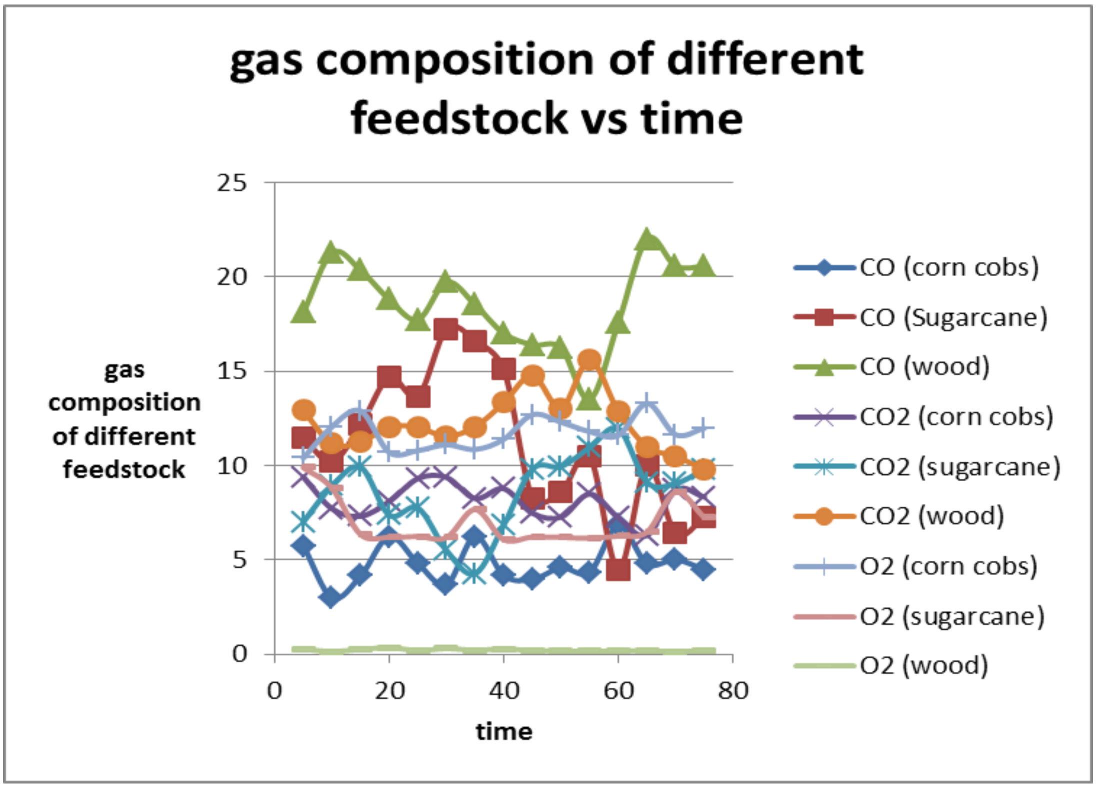
3) **Time vs. Hydrocarbon(HC) Generation Graph of Corncobs, Sugarcane and Wood**

The value of HC of different feedstock with time is shown by the graph below. Here, we can see value of HC is gradually decreasing in all feedstock as time passes on. Lowest value of HC was obtained by sugarcane, then by corn cobs and then by the wood. We can see constant value of HC for corncobs but for other two feedstock we get fluctuating value. Both wood and sugarcane have high value of HC at beginning but get decreases as the time moves forward. The graphical result of HC of different feedstock vs. time shows the decreasing value of HC so that our designed gasifier seems to be cracking tar well.



Time vs. Hydrocarbon (HC) Generation Graph

4) Time vs gas composition of Corncobs, Sugarcane bagasse and Wood



Time vs. gas composition Graph

The above mention graph shows comparison of gas composition of different feedstock with respect to time. Gases like Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Oxygen (O_2) shows different values as time passes on. The inverse relation of CO and CO_2 of all the feedstock can be seen in the above graph. We can also see the amount of oxygen obtained during the test of feedstock. The lowest amount of oxygen was obtained in wood, than in sugarcane and then in corn cobs. We found that wood is the best fuel for the designed gasifier.

4. Conclusion

The tests on these three biomass shows that Alnus Nepalensis can be the best option for designed gasifier as it contained low HC i.e. 620 ppm (can further be reduced to 300 ppm on decreasing air flow velocity) and very high CO i.e. 22.01% among all tested fuels. At lab, we varied flow rate of air from blower but result we obtained was not satisfactory. If we lower flow rate of air form blower, there won't be proper combustion and producer gas results in low

CO and high CO_2 which is not good for the design of downdraft gasifier. The highest temperature obtained in the combustion chamber was 1360°C in case of wood, which is good enough for cracking of tar. Similarly, O_2 content in wood test was 0.15% (as the lowest amount) which is also desirable quantity. Thus, it is best fuel for the use on the designed downdraught gasifier for energy production. This implies that Alnus Nepalensis wood which were unused, or only used as firewood or furnishing purposes, could be used to generate a good form of renewable energy using gasification process.

References

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