ABSTRACT

Biomass is one of the renewable energy resources and it is a manifestation of solar energy. Biomass gasification is a set of thermo-chemical reactions, by which the solid biomass is converted to a gaseous fuel called producer gas.

Although wood is the widely used feedstock for gasifiers, its limited availability and increasing cost have necessitated the utilization of bioresidues like rice husk, shells of various nuts, corn cobs, etc. in gasifiers. The global availability of groundnut shells alone is about 11.2 MMT. But, bioresidues pose certain problems during gasification, thus warranting thorough investigation.

In the present work, groundnut shells were gasified in loose form and the results were compared with that of wood gasification. Besides, certain parameters like pressure distribution in the gasifier, propagation of reaction zones, changes in properties of bed particles during gasification, etc. were investigated for both biomass.

For conducting experiments, a complete biomass gasification-engine-electrical generator system comprising of a co-current gasifier, producer gas scrubbing and cooling components, diesel engine and electrical generator was designed and developed. Both air and biomass enter the
gasifier at its top and descend downwards co-currently through the gasifier. It has provisions for pressure and temperature measurements besides sampling-cum-viewing ports along its height. As the hot producer gas from gasifier contains tar and particulates, it cannot be directly used in diesel engine. So, the producer gas scrubbing and cooling section consisting of cyclone separator, dust filter, gas cooler, and tar adsorber was also fabricated. In the gasification system, instruments for measuring air flow, producer gas flow, pressure and temperature distributions in the biomass bed, pressures and temperatures at salient points in the system, cooling water temperature at the gas cooler exit, producer gas composition, tar and particulates are incorporated.

The cleaned and cooled producer gas is then supplied to a diesel engine-electrical generator set. In the set, instruments for measuring diesel consumption rate, air flow rate, engine speed, voltage, current, energy generated, exhaust gas temperature, cooling water temperature, oxygen and carbon dioxide contents of exhaust gases are provided. The various experiments which were conducted are listed below:

a) Determination of pressures along the gasifier height in unfired condition of the gasifier for six biomass namely wood pieces, charcoal, groundnut shells, wood shavings, coir pith, and saw dust under two configurations:
   (i) without connecting producer gas scrubbing and cooling section to the gasifier, and
(ii) with producer gas scrubbing and cooling section connected to the gasifier

b) Gasification of wood pieces and loose groundnut shells individually and determination of gasification parameters like pressure and temperature distributions in the bed, changes in properties of bed particles, and other performance parameters
c) Study of the effect of biomass bed height during gasification
d) Determination of properties for wood pieces and loose groundnut shells and their comparison
e) Tests on diesel engine
   (i) Determination of diesel injection pump parameters
   (ii) Performance of engine in diesel alone mode drawing air
       1. directly through air filter, and
       2. through gasification system in unfired condition of gasifier
   (iii) Performance of engine in dual fuel (producer gas + diesel) mode

In unfired gasifier, the pressure distributions obtained along the gasifier height for six types of biomass with and without producer gas scrubbing and cooling section were useful in identifying suitable bioresidues for fixed bed gasifier. Among the six, since saw dust resulted in maximum pressure drop of 110 mm of WC, its gasification in fixed bed can be considered the most difficult. When producer gas scrubbing and cooling
section was connected to the gasifier, the gasifier inlet air pressure increased 2.2 – 3 times for wood pieces and loose groundnut shells.

From the gasification experiments, bed temperature profiles inside the gasifier were obtained for wood pieces and loose groundnut shells. The oxidation zone always had a tendency to propagate upwards through the bed under unsteady state. Its velocity depended on air flow rate and biomass bed height for both biomass. Wood gasification was investigated to determine reduction of mass, volume, density, and volatile matter content of bed particles down the gasifier axis. Mass reduction percentage was greater than volume reduction percentage. At 350 mm above the grate, about 99% of initial volatile matter content of wood was driven out. Thus, the lower limit of devolatilization zone in the gasifier can be arrived. When a higher bed height was maintained, the top side heat loss from biomass bed was lesser.

Initially, the diesel injection pump parameters viz injection quantity, timing, pressure were determined by conducting tests. Diesel injection timing was determined to be 23° crank angle before TDC. Since diesel injection quantity was little in dual fuel operation, the injection pump of the engine was found to perform poorly. Proper control of quantity, timing, and pressure by electronically controlled diesel injection system may improve the performance in dual fuel mode. In dual fuel mode, air/fuel ratio became as low as 2:1 against 27:1 in the case of diesel alone mode. It was possible to conserve diesel by replacing it with producer gas to an extent of 75 – 80%.