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Fuels From Biomass Through Thermal Conversion Technologies

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Increased use of fossil fuels causes rise in global temperature, responsible for the sudden change in the systematic cycle of the ecosystem to cause natural disasters such as droughts, floods and early frosts. India has always been looking for more alternative energy sources for sustainable development. About 32% of the total primary energy use in the country is derived from biomass and more than 70% of the country's population depends upon it for its energy needs. The current availability of biomass in India is estimated at about 750 million metric tonnes per year and, out of which 230 million tons are surplus (MNRE). Biomass not only support in economic development but also creates an eco-friendly environment in sustainable way producing of biofuels viz., char, biooil, producer gas, biohydrogen and biomethanol can be produced from biomass through thermochemical processes.

Keywords: Biomass, pyrolysis, gasification, combustion and liquefaction

Introduction

Biomass normally includes firewood, agricultural residues such as bagasse, crop stalks, animal dung, food wastes, sewage and waste generated from agro-based industries. It can be used as a solid fuel, or can be converted to useful secondary energy forms such as heat, gaseous fuels, solid fuels, organic chemical and liquid fuels. Biomass when subjected to heat undergo irreversible chemical changes and are transformed into useful solid, liquid and gaseous products. The quantity of solid, liquid and gaseous products depends on the relative amount of air supplied and the range of temperatures. Thermal conversion technologies used to generate energy from biomass are: (i) Pyrolysis; (ii) Gasification, (iii) Combustion and (iv) Liquefaction.

Pyrolysis

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Pyrolysis process was applied exclusively to produce charcoal or biochar for many centuries. Pyrolysis is the process of heating biomass in the complete absence of oxygen. The three major products of pyrolysis are biochar or charcoal, biooil and producer gas. The nature of the products depends on the material being pyrolyzed, the final temperature of the process and the rate at which it is heated up.

Types of pyrolysis

Depending upon the temperature and time of the pyrolysis process, pyrolysis processes are classified into (i) slow pyrolysis; (ii) intermediate pyrolysis and (iii) fast or flash pyrolysis. Typically, slow pyrolysis is conducted for hours to days at the temperature range of 350 to 500ºC and yield 35% to 40% of biochar by weight. Recently, fast pyrolysis become of huge interest, due to the fact that it can directly give high yields of liquids, biooil, which can be used in a variety of applications. Biooil is a complex oxygenated compound comprised of water, water soluble compounds, such as acids, esters, etc., and water-insoluble compounds. Efficient bio-oil production involves rapid heating rates and higher temperatures than slow pyrolysis. The ideal conditions for fast pyrolysis involve rapid heating rates (>240ºC per second) and temperatures usually in excess of 500ºC. In general, higher percentage of char will be produced from slow pyrolysis and higher percentage of biooil will be produced from intermediate and fast pyrolysis.

Fig.1 Slow pyrolyser

Applications of products of pyrolysis

Charcoal can be used as a fuel for heat generation, find its wide usage in metallurgical processes as a substitute for coke and a soil conditioner for providing and recycling valuable minerals to the soil, which is of huge importance for sustainable agriculture. Charcoal may also be used for the production of activated carbon, an adsorbent to treat waste water in the waste water treatment plants and carbon sequestration, which solves all the environmental problems affecting air and water. Use of biochar in agricultural systems is one viable option that can enhance natural rates of carbon sequestration in the soil, reduce farm waste and improve the soil quality. The application of biochar in soils is based on its properties such as: (i) agricultural value from enhanced soils nutrient retention and water holding capacity, (ii) permanent carbon sequestration, and (iii) reduced GHG emissions, particularly nitrous oxide (N_2O) and methane (CH_4) release. The goal of fast pyrolysis is to produce more liquid fuel viz., bio-oil or pyrolytic oil. Biooil can be utilized as a substitute for fuel oil in any application. Biooil may be refined and upgraded to produce refinery grade crude oil and high value chemicals. Bio oil in small amounts may be co-fired with diesel.

Gasification

Gasification is the thermo-chemical transformation of biomass into a combustible gaseous product in a controlled amount of oxidant supply. The reactions are carried out at elevated temperatures of 500-1300°C and atmospheric or elevated pressures up to 33 bar. As the biomass flows through the gasifier, it gets dried, pyrolyzed, oxidized and reduced. Carbon and hydrogen of biomass reacts with oxygen and yield carbon dioxide and steam respectively and are then reduced to carbon monoxide and hydrogen in the reduction zone of the gasifier. The product gas is termed as producer gas, clean, odourless and colourless and has a calorific value of 950 -1200 kcal/m^3. Producer gas can have end use for thermal application or for mechanical and electrical power generation.

Chemistry of gasification

In conventional producer gas theory, the reactions take place in four zones of a deep fuel bed, namely the oxidation, reduction and pyrolysis and drying zones. In the pyrolysis zone, biomass is converted to char, tar and oils and gas. In the oxidation zone, oxygen in the air-steam blast reacts with the carbon. In the reduction zone, CO_2 from the oxidation zone reacts with carbon to produce CO, one of the major components of producer gas.

$C + O_2 \rightarrow CO_2 + 393800$ kJ/kg mol (Combustion reaction)

$C + H_2O \rightarrow CO + H_2 - 131400$ kJ/kg mol (Water gas reaction)

$CO + H_2O \rightarrow CO_2 + H_2 + 41200$ kJ/kg mol (Water shift reaction)

$C + CO_2 \rightarrow 2CO - 172600$ kJ/kg mol (Boudouard reaction)

$C + 2H_2 \rightarrow CH_4 + 75000$ kJ/kg mol (Methane reaction)

Gasifiers

Gasifier is an equipment which can gasify a variety of biomass such as wood waste, agricultural waste etc. It is essentially a chemical reactor where the biomass gets dried, heated, pyrolysed, partially oxidized and reduced as it flows through it. It consists of grate, air supply system with blower and gas scrubbing unit. The commonly used gasifiers for biomass gasification are as below.

- **Up draft gasifiers: -** In Up draft gasifiers, air enters below the combustion zone and the producer gas leaves near the top of the gasifier. The gas produced has practically no ash but contains tar and water vapour because of passing of gas through the unburnt fuel. These gasifiers are suitable for tar free fuels like charcoal, especially in stationary engines.
- **Down draft gasifiers: -** In down draft gasifiers, air enters at the combustion zone and the gas produced leaves near the bottom of the gasifier. The gas produced has less tar and more ash. These gasifiers are suitable for fuels like wood and agricultural wastes. They may be used for power generation upto 150 kW.
- **Cross draft gasifiers: -** In cross draft gasifiers, the gas produced passes upwards in the annular space around the gasifier that is filled with charcoal. The charcoal acts as an insulator and a dust filter. They are usually suitable for power generation upto 50 kW.
- **Fluidized bed gasifier: -** Fluidized bed generally contains either inert material (sand) or reactive material (limestone or catalyst). These aid heat transfer and provide catalytic or gas clearing action. The bed material is kept in fluid state by the rising column of the gas. Normally the operating temperature of the bed is maintained within the range of 750-950°C, so that the ash zones do not get heated to its initial deformation temperature and this prevents clinkering or slagging.

Recent gasification technologies

- **Plasma gasification: -** An important evolution in gasification technology, plasma gasification which uses plasma torches, provides very high temperature which aids in thermal degradation of any organic matter into its constituent elements and inorganic portion as vitrified slag. The main advantage of plasma gasification over conventional gasification was increased rate of reaction due to high temperature ionized gas and is a successful technology for thermal conversion of municipal solid waste to useful gases.

- **Hydrothermal gasification: -** In this technology, biomass is treated with hot compressed water above 350°C and 20 MPa pressure to get a combustible gas. As the reactivity of water is high at these conditions, this method enables quick and complete gasification of biomass. In hydrothermal gasification, almost complete gasification is possible when reaction condition is properly adjusted. This technology is suitable for wet biomass, which could not be subjected to thermochemical gasification.

Applications of producer gas

Producer gas can be used for combustion and production of liquid fuel. After careful cleaning and conditioning, can be used to run internal combustion engines for power generation. Producer gas requires less modification of existing engines. It may also be used as a transport fuel.

Combustion

Plants absorb the sun's energy through photosynthesis and release the chemical energy as heat when it was burnt with excess air. Combustion is a process in which biomass is burnt with oxygen to produce heat. It is the most direct process of biomass conversion into energy that can be used for a variety of applications such as cooking, process heating, power generation and cogeneration. The combustion efficiency is mainly determined by the completeness of the combustion process which depends on the moisture content of biomass, excess air suppled and the flame temperature. The goal of good combustion is to release all the heat in the fuel. This is accomplished by controlling the "three T's" of combustion which are (1) Temperature high enough to ignite and maintain ignition of the fuel, (2) Turbulence or intimate mixing of the fuel and oxygen, and (3) Time sufficient for complete combustion.

Liquefaction

Liquefaction of biomass is associated with the production of liquid fuels directly or indirectly from thermal conversion of biomass. The two ways for the liquefaction are direct liquefaction processes and indirect liquefaction processes. In direct liquefaction processes, biomass slurry is directly converted into hydrocarbon fuels whereas in indirect liquefaction processes, biomass is first converted to synthesis gas and the gas is further transformed into liquid fuels. The efficiency of the final product depends on the heating value of synthesis gas.

Hydrothermal liquefaction is another technology in which wet biomass is thermally treated at elevated temperatures (300-360°C) and pressures (15-20 MPa) to produce biocrude. Biocrude yield of around 50% on carbon basis can be achieved through the process and the oil can be upgraded to a hydrocarbon product consistent with petroleum products.

Conclusion

Demand for renewable energy sources has risen due to scarcity and unstable price of fossil fuels. Concerns about climate change brought on by greenhouse gas emissions from the use of fossil fuels led to the shift toward biomass. It is important to say that biomass absorbs the same amount of CO_2 in growing that it releases when burned as a fuel in any form. Efficient use of biomass by converting it as a useful bioproduct can lay a path for secured energy and biomass disposal issues.

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