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Gasification-Contributing to the Energy Production Demands

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Abstract

At present juncture we are facing a drastic depletion of our available energy resources in the form of fuels for automobiles, as a major source for the functioning of power plants and industries, in combustion, etc. If the consumption of the non-renewable energy resources continued in the same manner then the day is not far enough when there will be disastrous consequences existing on this planet. In order to cope up with this serious issue, use of renewable energy resources must be practiced and implemented on a large scale. There are several sources of renewable energy available nowadays. One of the solutions for these problems is gasification- a process in which there is production of energy from biomass, solid waste, etc. which is easily available in our surroundings and is produced on a high rate on daily basis. This will be contributing towards the growth of renewable sources of energy. In this article an attempt has been made to study about the gasifying process, gasifiers, types of gasifiers, need of gasifiers, importance of gasifiers, reactions involved in the process, advantages of gasifiers.

Keywords:- Gasification, energy resources, biomass, gasifier.

Introduction

India is the fourth largest energy consumer in the world after the United States, China, and Russia **[1].** Due to the rapid growth and development the requirement and consumption of the energy demands are increasing on a large scale which are continuously resulting in exhausting of the natural resources available to us. The continuous growth of global energy consumption raises urgent problems related to energy availability, safe operation and its efficiency **[2].** Nearly 80 % of the world's energy consumption is fossil fuel based which is causing environmental and health concerns due to increased emissions of CO_2, NO_x and SO_2**[3].** In order to secure our future with the benefits of the remaining energy deposits we must be able to produce energy from different sources which can be obtained and utilized from our nearby surroundings. A possible way to deal with these problems is the development of cleaner and renewable energy sources. Modern use of biomass is an interesting option, because biomass is worldwide available, it can be used for power generation and biofuels production, and it may be produced and consumed on a CO2-neutral basis **[4].** Biomass is used since millennia for meeting myriad human needs including energy. Main sources of biomass energy are trees, crops and animal waste. Until the middle of 19th century, biomass dominated the global energy supply with as seventy percent share **[5].**The term biomass is used for all organic materials which are combustible in nature, mainly plant and animal origin present in land and aquatic environments.Biomass includes by product and residue of crop farming and processing industries such as straw, husk, cobs, stalks, leaves, bark, fruits, cutting vines, in addition to animal refuses and plant products used in agro-industrial processing such as grains, bean, flower and some special products such as cassava, seaweeds **[6-8].**Biomass is considered carbon neutral, because the amount of carbon it can release is equivalent to the amount it absorbed during its life time. There is no net increase of carbon to the environment in the long term when combusting the lignocellulosic materials. Therefore, we can say that biomass is a renewable source of energy and can play vital role in responding to concerns over the protection of the environment and the security of energy supply **[9, 10].** While the urban-rural difference in energy supply could be reduced through renewable energy, it is more complex to overcome the widening gap between developed and not so developed states **[11].**Sustainable and renewable natural resources as biomass that contains carbon and hydrogen elements can be a potential raw materials for energy conversion **[12].**The nature has always given us its production but we are returning to it in negligible amounts thus, misbalancing the ecological cycle. Harvesting the renewable energy in decentralized manner is one of the options to meet the rural and small scale energy needs in a reliable, affordable and environmentally sustainable way **[13, 14].** Taking the example of India-In India, a survey (The Hindu, 2005) showed that in 2001, 56% of households did not have access to electricity. Most of these regions are rural based and the agricultural activity generates large amounts of residue biomass and by-products. In order to cope up with the increasing energy demands we should opt for renewable energy resources and one of the techniques is “gasification”. Gasification is the thermo chemical breakdown of carbon-containing constituents of biomass to yield a gaseous fuel (termed producer gas or syngas) **[15].** The technology of the process of gasification started in 1800s but because of the increasing energy demands and over consumption leads to the enhancement of the technology with better processing devices and raw materials. One important parameter to indicate the overall performance of the gasifier system in relation to the existing fossil fuel system is the amount of biomass used to replace a liter of diesel **[16].** The first attempt to use producer gas to fire internal combustion engine was carried out in 1881 **[17].**Gasification has excellent environmental performance such that some states' Public Utility Commissions have identified Integrated Gasification Combined Cycle (IGCC) plants for power generation as the best available control technology (BACT). In addition, the uncertainty of carbon management requirements and the potential suitability of IGCC for CO2 controls make it an ideal choice for power **[18].**A gasifying system consists of different components namely reactor, cyclone, filter and blower and the fuel obtained from this process is a clean fuel which is a very useful source of energy and can be used in multiple ways. The technology may be regarded as fuel switching to convert solid fuel to gaseous fuel. Gasification is achieved in the presence of heat and a limited supply of oxygen, resulting in incomplete combustion of the solid biomass material **[19].**

Meaning of Gasification

Biomass gasification is the conversion of an organically derived, carbonaceous feedstock by partial oxidation into a gaseous product, synthesis gas or "syngas," consisting primarily of hydrogen (H2) and carbon monoxide (CO), with lesser amounts of carbon dioxide (CO2), water (H2O), methane (CH4), higher hydrocarbons (C2+), and nitrogen (N2). The reactions are carried out at elevated temperatures, 500-1400oC, and atmospheric or elevated pressures up to 33 bar (480 psia) **[20].** The mixture of combustible gases thus produced is termed "Producer Gas". It is also called as Low Btu Gas or Low Calorie Gas, because of its low energy content **[21].** Raw materials like saw dust, rice husk, bagasse, cobs, charcoal, and other agricultural waste are used for the production of producer gas. Globally, the energy content of biomass residues in agriculture industries annually isestimated at 56 exajoules, nearly a quarter of global primary energy use of 230 exajoules **[22].** The main advantage of biomass gasification is that the resultant gaseous fuel can be used in an engine directly. Since gas engines are readily available, through biomass gasification one can produce electricity. It is certainly possible to get electricity from directly burning biomass, but that would require, first, a boiler for making steam and then a steam turbine **[23].** Waste-to-Energy reduces the amount of materials sent to landfills, can prevent air/water contamination, improves recycling rates and lessens the dependence on fossil fuels for power generation **[24].**

Bio Energy

Bio energy refers to bio mass power, bagasse cogeneration, waste to energy, biomass gasifier, bio ethanol, bio diesel etc. Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities.

Biomass takes carbon out of the atmosphere while it is growing, and returns it as it is burned. If it is managed on a sustainable basis, biomass is harvested as part of a constantly replenished crop. Municipal solid wastes, animal and poultry wastes are also referred to as biomass as they are

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biodegradable in nature. The main biomass sources are as listed below:

- *Wood and wood waste*: forest wood, wood from energy plantations, saw dust, tree branches and leaves etc.
- *Agricultural residues*: rice husk, bagasse, groundnut shells, coffee husk, straws, coconut shells, coconut husk, arhar stalks, jute sticks etc.
- *Aquatic and marine biomass*: algae, water hyacinth, aquatic weeds and plants, sea grass beds, kelp, coral reef etc.
- *Wastes*: municipal solid waste, municipal sewage sludge, animal waste, paper waste, industrial waste etc**[25].**

Mechanism and Processes involved in gasification:

The basic gasification reactions are either endothermic or exothermic and their rates depend on temperature, pressure and oxygen concentration **[26].**The following major reactions take place in combustion and reduction zone **[27]:**

(1).Combustion zone

The combustible substance of a solid fuel is usually composed of elements carbon, hydrogen and oxygen. In complete combustion carbon dioxide is obtained from carbon in fuel and water is obtained from the hydrogen, usually as steam. The combustion reaction is exothermic and yields a theoretical oxidation temperature of 1450 ^{0}C**[28].** The main reactions, therefore, are:

$C + O_2 = CO_2$ (+ 393 MJ/kg mole) (1)

$2H_2 + O_2 = 2H_2O$ (- 242 MJ/kg mole) (2)

(2). Reaction zone

The products of partial combustion (water, carbon dioxide and uncombusted partially cracked pyrolysis products) now pass through a red-hot charcoal bed where the following reduction reactions take place**[27].**

$C + CO_2 = 2CO$ (- 164.9 MJ/kg mole) (3)

$C + H_2O = CO + H_2$ (- 122.6 MJ/kg mole) (4)

$CO + H_2O = CO + H_2$ (+ 42 MJ/kg mole) (5)

$C + 2H_2 = CH_4$ (+ 75 MJ/kg mole) (6)

$CO_2 + H_2 = CO + H_2O$ (- 42.3 MJ/kg mole) (7)

(3). Pyrolysis zone

Wood pyrolysis is an intricate process that is still not completely understood**[28].** The products depend upon temperature, pressure, residence time and heat losses. However following general remarks can be made about them.

Upto the temperature of 200 ^{0}C only water is driven off. Between 200 to 280 ^{0}C carbon dioxide, acetic acid and water are given off. The real pyrolysis, which takes place between 280 to 500 ^{0}C, produces large quantities of tar and gases containing carbon dioxide. Besides light tars, some

methyl alcohol is also formed. Between 500 to 700 ^{0}C the gas production is small and contains hydrogen**[29].**

Types of gasifiers

- **Updraught or counter current gasifiers**

Also known as counterflow gasification, the updraft configuration is the oldest and simplest form of gasifier; it is still used for coal gasification. Biomass is introduced at the top of the reactor, and a grate at the bottom of the reactor supports the reacting bed. Air or oxygen and/or steam are introduced below the grate and diffuse up through the bed of biomass and char. Complete combustion of char takes place at the bottom of the bed, liberating CO2 and H2O. These hot gases (~1000oC) pass through the bed above, where they are reduced to H2 and CO and cooled to 750oC. Continuing up the reactor, the reducing gases (H2 and CO) pyrolyse the descending dry biomass and finally dry the incoming wet biomass, leaving the reactor at a low temperature (~500oC) **[30-32].**

- **Downdraught or co-current gasifiers**

Also known as co-current-flow gasification, the downdraft gasifier has the same mechanical configuration as the updraft gasifier except that the oxidant and product gases flow down the reactor, in the same direction as the biomass. A major difference is that this process can combust up to 99.9% of the tars formed. Low moisture biomass (<20%) and air or oxygen are ignited in the reaction zone at the top of the reactor. The flame generates pyrolysis gas/vapor, which burns intensely leaving 5 to 15% char and hot combustion gas. These gases flow downward and react with the char at 800 to 1200oC, generating more CO and H2 while being cooled to below 800oC. Finally, unconverted char and ash pass through the bottom of the grate and are sent to disposal **[31-33].**

- **Fluidized bed gasifier**

Fluidised bed (FB) gasification has been used extensively for coal gasification for many years, its advantage over fixed bed gasifiers being the uniform temperature distribution achieved in the gasification zone. The uniformity of temperature is achieved using a bed of fine-grained material into which air is introduced, fluidizing the bed material and ensuring intimate mixing of the hot bed material, the hot combustion gas and the biomass feed.

Two main types of FB gasifier are in use:

• circulating fluidised bed,

• bubbling bed.

A third type of FB is currently being developed, termed a fast, internally circulating gasifier, which combines the design features of the other two types. The reactor is still at the pilot-stage of development.

- **Circulating FB**

Circulating FB gasifiers are able to cope with high capacity throughputs and are used in the paper industryfor the gasification of bark and other forestry residues. The bed material is circulated between the reaction vessel and a cyclone separator, where the ash is removed and the bed material and char returned to the reaction vessel. Gasifiers can be operated at elevated pressures, the advantage being for those end-use applications where the gas is required to be compressed afterwards, as in a gas turbine.

- **Bubbling bed**

Bubbling bed FB gasifiers consist of a vessel with a grate at the bottom through which air is introduce.Above the grate is the moving bed of fine-grained material into which the prepared biomass feed is introduced. Regulation of the bed temperature to 700–900 _C is maintained by controlling the air/biomass ratio. The biomass is pyrolysed in the hot bed to form a char with gaseous compounds, the high molecular weight compounds being cracked by contact with the hot bed material, giving a product gas with a low tar content, typically <1–3 g=Nm^3 **[34].**

Advantages of gasification

Looking at the present scenario there is an urgent need of sources of renewable energy to compete with the non-exhausting needs of humans and fulfilling their demands. The advantage of this technology are:

- In order to decrease the waste production from power plants.
- Contributing to the never ending energy demands.
- In addition, a wide range of plastics cannot be recycled or cannot be recycled any further, and would otherwise end up in a landfill. Such plastics can be excellent, high energy feedstock for gasification **[35].**
- Use of cleaner fuel improves the heat transfer efficiency **[15].**
- Reducing the use of fossil fuels.
- Low initial investment and cost of power generation **[15].**
- Gasification can convert MSW (Municipal Solid Waste) that would typically be incinerated into a clean, useful syngas.
- Gaseous fuels take advantage of the high electric efficiency of gas engines and gas turbines compared to the conventional steam cycle **[36].**
- The gas, in particular syngas, can be used for production of transportation fuels or in chemical products like ammonia, fertilizers, plastics, paints etc. **[36].**
- Gasification is a way to increase the quality and value of the feedstock **[36].**
- The advantage of gasification over direct combustion is that at low power levels (from 3 kWe to a couple of MW), electric power can be generated economically by using the cooled and cleaned combustible gas as a fuel in internal combustion engines - reciprocating or gas turbine engines **[37].**

Applications of gasification

Gasification is equipped with a variety of uses and production.

- Majorly, the production of fuel gas.
- Irrigation Pumping, electrification of villages, industrial power.
- In thermal applications like ovens, heaters, kilns, boilers etc.
- Reduces the need of landfills.
- Reduces the contamination of surface water and ground water through landfills.

Discussions

Energy generation and its consumption had always been a part of mutual concern around the globe. Many solutions were devised to solve the scarcity of the energy demands. Renewable energy sources are contributing to the energy demands but on a small scale. Increment in this respect will only be done if more sources of renewable energy are devised and practiced in its full capacity so as to compete with the never ending demand of energy. Gasification is one of the solutions of the energy demands which is contributing its bit and without any cancerous effects on the environment. It is a process that converts the wastage into useful sources like energy production in different forms and other useful products. The advantages and needs of this topic explains the role of the gasifier in daily life. In this process there is “no burning” but simply conversion of energy from one form to the other.Biomass gasifier was found most applicable for industrial applications such as heating and drying of agricultural and industrial products.Bio oil produce through pyrolysis process have chemical properties similar to crude petroleum oil.There is huge possibility to utilize hydrogen generated during pyrolysis in fuel cell.The downdraft gasifier is suitable for both thermal and engine applications. The gasification of low-density biomass such as rice husk presents less problems in a throatless downdraft gasifier. Problems in a throatless downdraft gasifier can became lesser in gasification of low-density biomass such as rice husk. By the seperation in pyrolysis and gasification zones the tar content can be minimize. Nowadays installations of fixed bed gasification systems have in preference in many countries commercially.For the decentralizing thermal and power applications standard design and operating parameters of gasifier, fuel processing and gas cleaning systems needs to be popularize small scale bed gasification and gas cleaning systems. The development of biomass energy plants gives dual advantages of reducing our dependence on commercial energy and protecting our enviorment.

Conclusions

The process of gasification must be practiced on small as well as large scales, so that energy demands from oneself can be reduced and we can do our bit for the conservation of this ecosystem. It is one of the safest methods of renewable energies and can be performed easily at small levels increasing to industrial scale. The raw material for the production of energy from this method can be easily available in the form of agricultural bi products and municipal wastage which is created daily in huge amounts. As stated in this paper the applications of gasification are on a wide scale. Although gasification technologies have recently been successfully demonstrated at small scale by the researchers and several demonstration projects are under implementation they still face economic and other non-technical barriers when trying to compete in the energy markets. This can be achieved via economic development through biomass systems integration. Thus the innovation in practically all demonstration projects under implementation lies not only on the technical aspects of the various processes but also in the integration of the gasification technologies in existing or newly developed systems.

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