Design Analysis and Equilibrium Modeling Of Downdraft Biomass Gasifier

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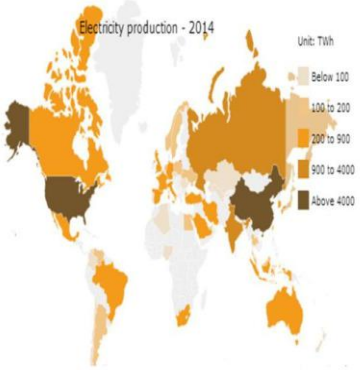
Abstract:-India's power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, natural gas, oil, hydro and nuclear power to viable non-conventional sources such as wind, solar, and agricultural and domestic waste. Electricity demand in the country has increased rapidly and is expected to rise further in the years to come. In order to meet the increasing demand of electricity in the country, the use of Biomass as a source of energy has been enhanced in recent years and special attention has been paid on biomass gasification.

Gasification is an efficient process to obtain valuable products from biomass with several potential applications. Biomass gasification has become a potential renewable energy source for the last few decades. Due to the increasing interest in biomass gasification, several models have been proposed in order to explain and understand this complex process and the design, simulation, optimization and process analysis of gasifiers have been carried out. Further development of gasification technology requires innovative and economical gasification methods with high efficiencies.

Keywords—biomass, biomass gasification, gasifier, simulation, optimization

I. INTRODUCTION

The world's energy consumption is continuously increasing as the population of the world is increasing from approximately 7 billion in 2013 to approximately 9 billion (estimated) in 2050.[1], meeting the future energy demand will be a key challenge. The International Energy Agency estimates that,in 2013, total world energy consumption was 13,541 Mtoe, equal to an average power consumption of 18.0 terawatts. In 2013, world energy consumption by power source was oil 31.1%, coal 28.9%, natural gas 21.4%, biofuels and waste 10.2%, nuclear 4.8%, hydro 2.4%, and other (solar, wind, geothermal, heat, etc.) 1.2%. Oil, coal and natural gas were the most popular energy fuels [2].Recently, due to the growing concerns about pollution from energy sources that come from fossil fuels such as oil, coal and natural gas and the continuous depleting resources of fossil fuels there is increase in use of other renewable energy resources (solar, wind, ocean, etc.) which are in abundance and less harmful compare to other fossil fuels.



Country	Power production (TWh)
China	5583
U.S	4430
India	2767
Russia	1064
Japan	996
Canada	640
Germany	616
Brazil	584
France	562
South Korea	540

Figure 1.1: Energy Production Worldwide [1]

TABLE I. Major power production Countries [1]

Renewable energy is the energy which is collected from resources which are naturally replenished such as sunlight, wind, rain, tides, etc. Renewable energy contributes 19% of global energy consumption and out of which 9% is from biomass, 4.2% from heat energy (non-biomass), 3.8% from hydroelectricity and 2% is from wind, solar, geothermal, ocean, etc.

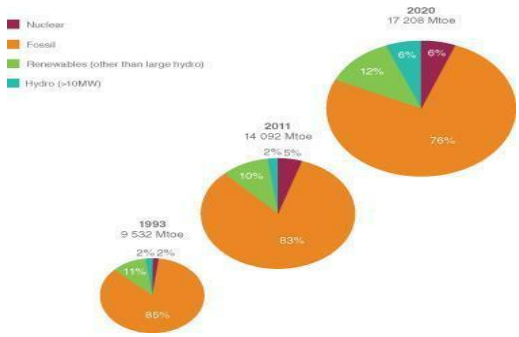


Figure 1.2: Power production from sources[1]

Bioenergy contribute 1377 Mtoe to the world energy. Most of this is consumed for cooking and heating.

A. Power Generation In India

India's power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, natural gas, oil, hydro and nuclear power to viable non-conventional sources such as wind, solar, agricultural and domestic waste. India's current installed capacity (till March

2016) is 2, 98,059 MW from all sources. Power generation capacity is based on thermal and hydro, nuclear and renewable energy sources and generated by state, central and private organizations [3].

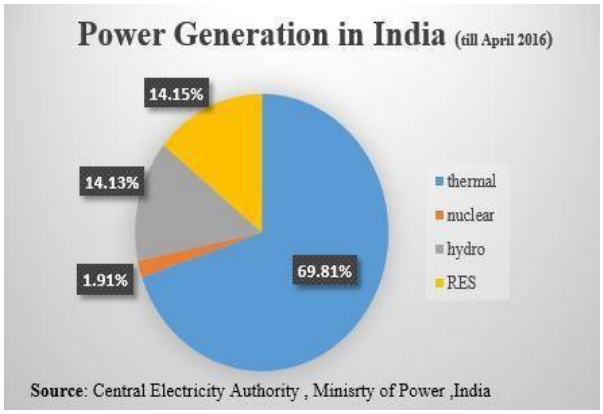


Figure 1.3: Power generation India [2]

B. Non-conventional Energy in India

As the energy demand rapidly increasing whereas the conventional energy sources like coal, oil, gas etc. resources are continuously depleting and because of high pollution in environment because of burning of these fuels made people to think about the alternate option for power generation and non-conventional energy sources such as solar, wind, ocean, bio energy, geothermal *etc.* comes out be better option. Energy extracted from other than convention fossil fuel is known as non-conventional energy. Non-conventional energy sources are available in plenty in the nature and that are renewable as well. Renewable energy sources like solar, tides, geothermal, biomass *etc.* is significantly contributing in the power generation in India. The installed capacity of power is includes about 11% from renewable energy sources such as solar, wind, small hydro, bio-power *etc.* The installed capacity of renewable energy is 38821.51 MW [3]. Wind energy and solar energy contribute maximum in renewable energy generation together which is about 66% whereas about 15% is from biomass and small hydro power. Power generation from wind energy in India is 25088 MW which is highest in renewable energy followed by solar energy of 4878 MW.

India is the fourth largest importer of oil and the 15th largest importer of petroleum products and LNG globally. The increased use of indigenous renewable resources is expected to reduce India's dependence on expensive imported fossil fuels. The government is playing an active role in promoting the adoption of renewable energy resources by offering various incentives, such as generation-based incentives (GBIs), capital and interest subsidies, viability gap funding, concessional finance, fiscal incentives etc.

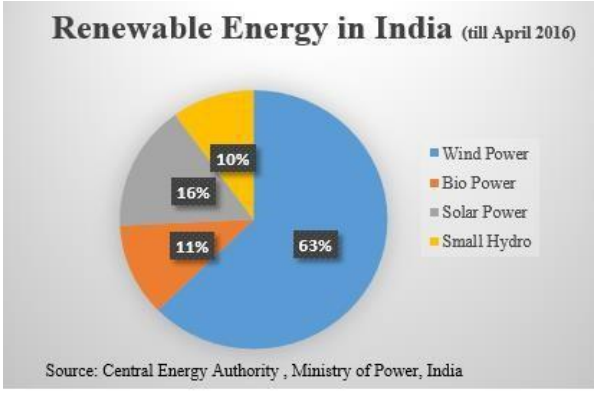


Figure 1.4: Renewable Energy in India [4]

C. Biomass: An Energy Source

Biomass is biological material derived from living, or recently living organisms. It is fuel that is developed from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material. It is carbon based and is composed of a mixture of organic molecules containing hydrogen, usually including atoms of oxygen, often nitrogen and also small quantities of other atoms, including alkali, alkaline earth and heavy metals.

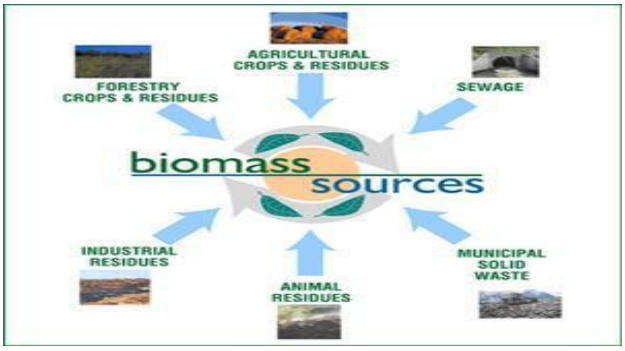


Figure 1.5: Biomass sources [5]

India has huge potential of different kind of biomass in every state of the country. Biomass has always been an important energy source for the country considering the benefits it offers. It is renewable, widely available, and carbon-neutral and has the potential to provide significant employment in the rural areas. Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Its advantage is that it can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels. Biomass is an important source of energy and the most important fuel worldwide after coal, oil and natural gas. Biomass is also capable of providing firm energy. About 32% of the total primary energy use in the country is still derived from biomass and more than 70% of the country's population depends upon it for its energy needs [4].

D. **Biomass Conversion Technologies**

Biomass can be used for different applications such as cooking, process heating, electricity generation, steam generation and mechanical or shaft power. There are a number of technological options available to make use of a wide variety of biomass types as a renewable energy source. Conversion technologies may release the energy directly, in the form of heat or electricity, or may convert it to another form, such as liquid biofuel or combustible biogas. Figure 6 shows the different methods for converting biomass into convenient fuel.

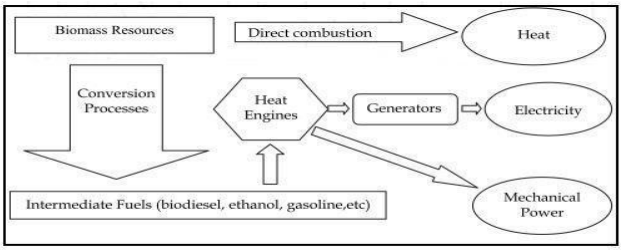


Figure 1.6: Methods of Using Biomass [5]

There are basically three conversion technologies classified according to purpose of use of biomass:

Thermo chemical Conversion

In this method, application of heat and chemical process to convert biomass feedstock or residue into form of energy. This method includes direct combustion, Pyrolysis and Gasification.

Biochemical Conversion

In this conversion process, application of biochemical process and microorganism to breakdown biomass and convert that into other fuels. Biochemical Conversion includes anaerobic digestion, fermentation and composting.

Chemical Conversion

In chemical conversion, use of chemical processes and chemical agents to convert biomass into other form such as biofuel for various applications and more conveniently handling and transportation *etc.*

E. Biomass Gasification

Various different methods and technologies came in to existence to convert biomass into other form of energy. Biomass gasification was one of those technologies which was discovered to convert solid biomass into form of a combustible gas known as producer gas. Gasification was discovered very earlier but that was use for coal gasification but biomass gasification has become popular later to the coal gasification.

In the very early time, Gasification was discovered in both England and France independently in 1798. It was the coal gasification which was use to produce manufactured gas or 'town gas". By the 1850 this technology had been developed to the point that it was possible to light much of London with this "town gas" from coal. And then by 1920, this technology has become more popular in United States and most of the American towns and cities supplied gas to the residents for cooking and lighting. Gasifies, to operate boats, trains and small generators, were developed around the time of World War I. As the gasoline price was continuously increasing after World War I and simpler use of biomass, gasification technology has been developed so much between two world wars. At the beginning of World War II, there was a great deal of interest in all forms of alternative fuels. By 1943, 90% of vehicles in Sweden were powered by gasifiers. By the end of the war, there were more than 7, 00,000 wood-gas generator powering trucks, cars and buses in Europe and probably more than a million worldwide.

Biomass gasification is a thermo chemical conversion process to convert solid biomass into combustible gas (producer gas) by partial combustion of solid biomass. The reactor in which partial combustion takes place is called "Gasifier".

The products from complete combustion of any biomass generally contain nitrogen (N2), water vapour, carbon dioxide (CO2) and surplus of oxygen. However in biomass gasification where incomplete combustion takes place because of surplus of solid biomass the products comes out as producer gas which is again combustible gas and this produce gas contain combustible products carbon mono oxide (CO), hydrogen (H2), and traces of methane (CH4) and some non-useful products like tar and dust.

The generation of producer gas occurs basically in two significant stage containing oxidation and reduction. In the oxidation process, sub-stoichiometric oxidation leads to loss of volatiles from biomass and is exothermic; it results in peak temperatures of 1400 to 1500 K and generate gaseous product carbon dioxide, carbon monoxide, hydrogen in some proportions and water vapour. In second part, endothermic reaction takes place by reduction of gaseous product from first stage and composition of gas reduced into carbon monoxide (CO), hydrogen (H2), and some traces of methane (CH4) and other hydrocarbons. Reduction of gases is takes place when gases from oxidation of biomass pass through char bed in the reduction zone of gasifier.

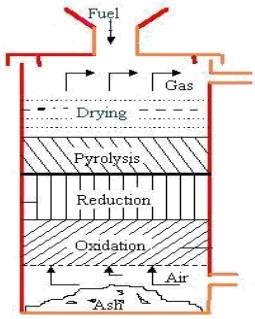


Figure 1.7: Biomass gasifier[6]

F. Classification Of Gasifier

According to supply of air into gasifier, classification of gasifier is as follow:

i) Updraft gasifier

This is oldest, simplest and most common type of gasifier and has been using since many years, in which air is introduced at bottom of gasifier and producer gas leaves at the top.

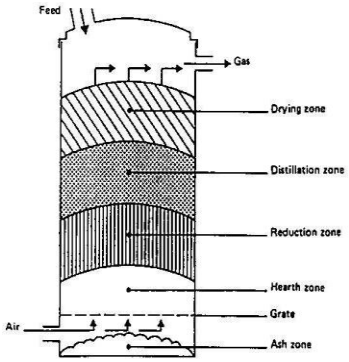


Figure 1.8: Updraft gasifier**[7]**

ii) Down draft gasifier

The name "Down Draft" of gasifier because air introduce at mid of gasifier instead of at bottom and air goes downward in it. Reduction zone in downdraft gasifier is at bottom to the oxidation zone.

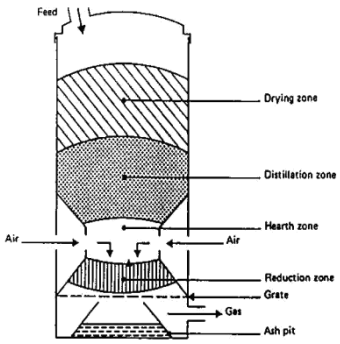


Figure 1.9: Downdraft Gasifier[7]

iii) Cross draft gasifier

Cross draft gasifier exhibits many of operating characteristics of downdraft gasifiers. Air is introduced from the side near bottom while the producer gas is drawn off on the opposite side.

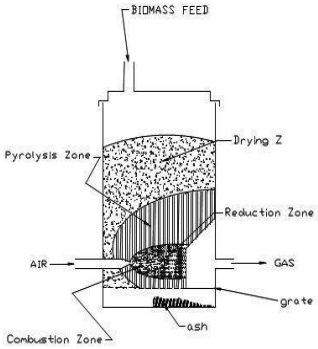


Figure 1.10: Cross draft Gasifier **[8]**

II. RELATED WORK

Biomass gasification is a new technology which is developed in recent years. This is a new area of interest for many scientist and researchers after the energy crisis begin in the world and search for new sustainable, promising and less harmful to environment source of energy. Lot of research and development work has been done in this field since many years.

In this context, the downdraft biomass gasifier was tested for two types of fuels i.e. wood chips and wood pellets. The fuels were processed before loading into the fuel chamber. The average sizes of the woodchips were 30-70mm and wood pellets were 15-30mm. Wood chips/pellets were naturally dried for 2 days and electrical oven dried at 105°C for 3-4 hours**[9]**.

Based on these, few modifications were conducted in design. During the first run, unstable flame and tar came out through the burner. The reasons identified were the low temperature in the oxidation zone, short residence time of the tarry vapours due to high gas velocity in the hot zone and wet wood chips. Therefore the gas outlet pipe was replaced with a larger bore (OD=34 mm) steel pipe. Another important modification was made in the burner to reduce gas velocity.

III. CONCLUSION

Biomass gasification offers one of the most promising renewable energy systems for developing countries. A more extensive and attractive system could be a downdraft gasifier capable of generating sufficiently low tar content syngas for engine applications. The biggest challenge in gasification system is reliable and economical cooling and cleaning technology.

Majority of the work has been done on experimental work to find the composition and quality of gas and the effect of gasification parameters on the quality of gas, apart from the experimental, lots of work have been done in simulation or equilibrium modelling to predict the gas composition and variation of composition with gasification parameters. There are very limited work has been done on gasifier or design of gasifier The major and prime objective of this survey paper is to cover two different kind of works; first is design of open-top downdraft gasifier and the second is, equilibrium modelling to predict the composition of producer gas using different biomass fuels.

IV. Acknowledgement

All the above mentioned information is true as per my consideration, I hope this paper will be useful for persons who are the part of technology sector and tries to improve the utilization of renewable energy sources in India.

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