Technological Review on Biomass Gasification Models

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Abstract - *At present times many renewable process of power generation are being used to cope up with the never ending energy demands of the mammoth population but amongst them biomass gasification is widely applicable because it is economical and environment friendly. Gasification models are helpful in the designing and development of gasifying systems with the variation of different parameters that influence the performance of the gasifiers. Different models like CFD, ANN, APENS are devised and are in the process of improvement day by day. This article presents the basic and fundamental understanding of the widely used biomass gasification models and their applications in different gasifiers.*

Key Words: Gasifier, CFD, biomass, gasification model, ANN, APENS Plus.

1. INTRODUCTION

The world is dealing with huge energy demands and also difficulties in solving of these problems with the existing conventional sources of energy. The problems are increasing on a daily basis because the consumption of electricity and its usage is increasing tremendously. The Central Electricity Authority (CEA), Government of India, anticipated a base load energy deficit of 5.1% for the fiscal year 2014– 15 in their Load Generation Balance report [1]. Based on the progress report on village electrification by CEA, 25894 villages are not electrified [2]. According to data reported by Ministry of Coal, Government of India, the total import of coal and products, i.e. coke, for the year 2013– 14 is 154.55 million tones [3].

Power generation through renewable sources are on the peak of its production and also accounts for a good percentage of the energy production demands. Renewable sources like solar, wind, gasifiers, and hydro are on the rise for energy production and if talking about India then it is the fifth largest producer of wind energy in the world. 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 [4]. In India, the rural-urban gap in energy access levels has been significant. This indicates the need and importance of fast tracking access and smart micro/mini grid systems to energy especially in the rural India [23]. However, biomass gasification is the most preferable alternative in India for various reasons:(1) availability and uniform distribution of biomass in the country, (2) it is available throughout the year at cheap rates, (3) capital investments for gasifier, duel fuel or 100% producer gas generator, gas cleaning system and other accessories are quite low, and (4) technology is simple and unskilled/semi- skilled labor can handle operation and maintenance of the plant [5]. Renewable energy sources are not only contributing in the energy production but also playing a vital role in the limitation of pollution and conservation of environment. Gasification can be simply be understood as the conversion of solid and liquid hydrocarbon into syn gases.

This conversion process is influenced by various factors like feedstock type, type of gasifier being used, and temperature of the gasifier. The size of a gasifier could not be based on criteria like volumetric energy release rates as it is done at times for combustors [6]. The gasifier reactor needs to be designed either based on experimental data on similar fuel fed into a gasifier of similar size or by using mathematical models of the gasification process in the reactor [7]. A good model could help in identifying the sensitivity of the gasifier performance, to the variation in different operating and design parameters [8]. The proper conversion and right utilization of wasteful energy into useful energy is the main aim of the concerned process [14].

2. GASIFICATION PROCESS

Biomass gasification process usually involves the reactions pertaining to various phenomena such as drying, pyrolysis, oxidation, and reduction. In the drying stage, moisture content of the biomass is reduced. It occurs at 100–200°C and decreases the moisture content of the biomass as low as 5%. In general, the moisture content of raw biomass ranges from 5% to 35%. In the pyrolysis stage, the thermal decomposition of biomass occurs in the absence of oxygen or air and volatile matter is released as a consequence of the thermal breakdown of biomass.

As a result, the mixture of gases containing carbon monoxide, hydrogen, carbon dioxide and hydrocarbon gases from the biomass is released and biomass is reduced to solid charcoal. The hydrocarbon gases condense at a low temperature to generate liquid tars. The gases released from drying and pyrolysis zones may or may not pass through the oxidation zone depending upon the type of gasifier [7]. It is meaningful process which provides its contribution in the field of renewable sources of energy.

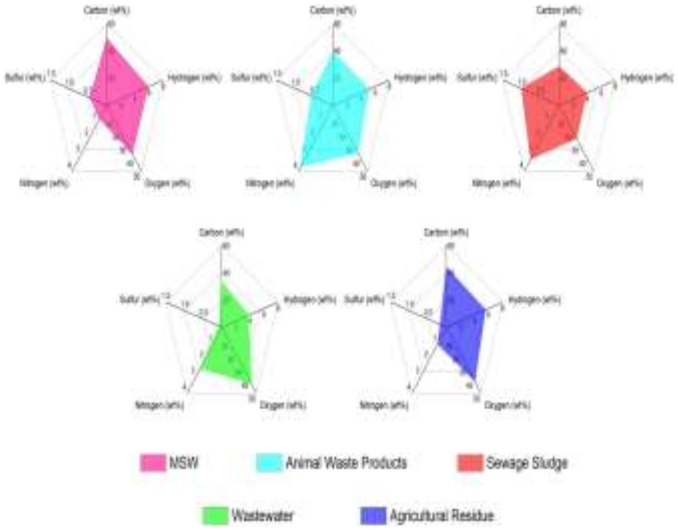

Fig-1: Average ultimate analysis results of previous gasification studies using biowaste feed stocks: municipal solid waste (MSW), sewage sludge (SS), wastewater (WW), agricultural residues (AR), and animal waste products (AWP) [22].

3. CFD Model

Computational Fluid Dynamics plays an important role in the modelling of fluidized bed gasifiers. CFD model includes the application of the conservation equations of mass, momentum and energy. Solutions of such a sophisticated approach can be achieved with commercial software such as ANSYS, Fluent, Phoenics and CFD 2000. CFD appears to be a cost- effective option to explore the various configurations and operating conditions at any scale to identify the optimal configuration depending on the project specification [7]. However, some simplified CFD models had been established to simulate the gasification behavior by Fletcher et al. [9], Yu et al. [10] and Janajreh et al. [11].

CFD modeling involves advanced numerical methods for accounting solid phase description, gas phase coupling and also focuses on the mixing of the solid and gas phase. The turbulent mixing may be modeled by the application of several equations such as Direct Numerical Simulation (DNS), Large-eddy simulation (LES) and Reynolds-averaged Navier–Stokes (RANS) equations. Furthermore, complex parameters such as drag force, porosity of the biomass and turbulence attenuation are mostly taken into consideration [7]. Currently there are three numerical techniques used for the studying combustion and gasification in fluidized beds in literature and these are Eulerian-Lagrangian with single particle or a particle parcel and a group of particles, Eulerian-Eulerian TFM and Discrete Element Method (DEM-CFD) within Eulerian-Lagrangian concept [12].

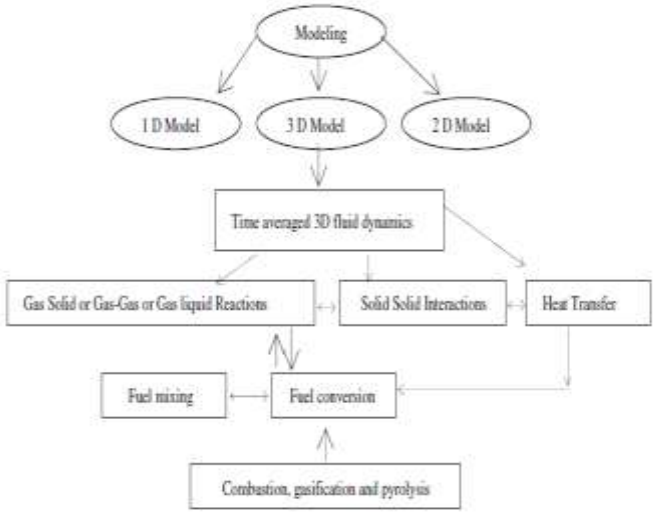

Fig-2: Framework for CFD modeling [12].

4. ANN Model

Artificial neural networks (ANNs) modeling may be considered as a computational paradigm in which a dense distribution of simple processing element is supplied to provide a representation of complex process including nonlinear and discrete systems [7]. ANN is a standard modeling tool consisting of multilayer perceptron (MLP) paradigm [13]. The neurons in the input layer, consisting of inputs and weights, simply forward the signals to the hidden neurons. However, each neuron in the hidden and output layers has a threshold parameter known as bias [7]. The characterization of ANN model is done as non-equilibrium, non-analytical and non-mechanistic model. The application of ANN model includes the processing of signals, approximation of function and simulation. ANN is a useful tool especially when the primary aim is to optimize the process parameters and output of a complex system. It does not require any information on the mathematical description of the process, the only input required is the inlet datasets. Therefore ANNs are best suited for simulation and scaling-up of a process. Thus, ANNs modeling may not be the viable option for a new technology such as biomass gasification as the number of experimental datasets is limited [7]. Maur Ãcio Bezerra et al. [15] proposed an artificial neural network for circulating fluidized bed gasifier. The neural network simulation of downdraft gasifier requires an extensive set of database, which consists of a large amount of experimental downdraft biomass gasification data. Thus, collected data is used as input in artificial neural network modeling. The next step involves the training of the network and its validation [7].

4. ASPEN Plus Model

ASPEN Plus is a chemical process optimization software, which was developed at Massachusetts Institute of Technology (MIT). It uses unit operation blocks, such as reactors, heaters, pumps, etc. These blocks are joined using material and energy streams to create a flow sheet for the process. The simulation calculations are performed using the in-built physical properties database. The program uses a sequential modular (SM) approach, i.e. solves the process scheme module by module, calculating the outlet stream properties using the inlet stream properties for each block. This simulation package has been used for modeling coal and biomass power generation systems in many research projects [7]. Mansaray et al. [16-18] developed model for rice husk gasification using fluidized bed gasifier. De Kam et al. [19] studied the scheme of the co-products of the dry grind ethanol and Corn Stover for the generation of combined heat and power. Ramzan et al. [20] developed a steady state computer model for hybrid biomass gasifier using commercial simulation software ASPEN Plus. The model used gasification of three different biomass feed stocks, i.e. food waste (FW), municipal solid waste (MSW) and poultry waste (PW). The gasification process has been modeled in three stages. In the first stage moisture content of the fuel is reduced before feeding to the reactor. In second stage biomass is decomposed into volatile components and char. The yield distribution for this stage has been specified by using a FORTRAN statement in calculator block. The third stage models the partial oxidation and gasification reactions by minimizing Gibbs free energy [7]. The developed model of gasification was also validated with the experimental data of Jayah et al. [21].

5. CONCLUSION

The modeling of biomass gasification systems is a rising need in the present and future times and also are the important areas of research and applications which require more attention. Researchers have been tirelessly working on the possible models which could be more feasible and conducive. The models of gasification that are presented in the article have proved to be of great importance in the gasification method of power generation. The models proves prepared are optimized for the attainment of best and applicable outputs. Thermodynamic equilibrium model is considered to be widely opted for the research purposes as it is easy and simple to develop. CFD models are the tools considered for the development of two and three dimensional models with precision and accuracy.

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