Simulation of Biomass Gasification in Fluidized Bed Using Aspen Plus

K. Anand Kishore¹ and K. A. V. Ramanjaneyulu²

Abstract—Gasification is a thermo-chemical process to convert carbon-based compounds such as biomass and coal into a gaseous fuel. Among the various types of gasification methods, fluidized bed gasification is one which is considered as more efficient method than others as biomass is fluidized in a mixture of air/oxygen and steam. In the present study, a comprehensive steady state process model has been developed for biomass gasification in atmospheric fluidized beds using Advanced System for Process Engineering (ASPEN PLUS) simulator. Three ASPEN PLUS reactor models namely, RYIELD for drying and decomposition of biomass into its elements, RGIBBS for achieving both chemical and phase equilibrium of volatile matter available in biomass and RCSTR for carrying out char gasification have been used. The fluidized bed reactor has been divided into finite small elements because there exists change in number of moles, change in partial pressures of all the compontents along the height of the reactor as the reactions take place inside the reactor. To consider the change in superficial velocity which results from change in number of moles along the height of the reactor, each of these elements has been simulated by one RCSTR. Finally, the effects of steam to biomass ratio, equivalence ratio and temperature on the composition and lower heating value of product gas have been studied. Using optimization tool available in Aspen Plus, the optimum values of steam to biomass ratio and equivalence ratio have been found out.

Keywords—Biomass, gasification, Aspen Plus, gas composition, heating value, optimization, steam to biomass ratio and equivalence ratio.

I. INTRODUCTION

BIOMASS refers to plant based materials such as dead trees, branches, wood chips and even municipal solid waste. The process of conversion of biomass (or any other carbonaceous material) to syngas is called as gasification. Gasification occurs when oxygen and/or steam is reacted at high temperatures with available carbon in biomass within a gasifier. Air gasification produces a poor quality gas with respect to the heating value, around 4-7 MJ m⁻³, while O₂ and steam blown processes result in a syngas with a heating value in the range of 10-18 MJ m⁻³. However, gasification with pure O₂ is not practical for biomass gasification due to prohibitively high costs for O₂ production using current commercial technology (cryogenic air separation). The syngas thus produced can be combusted in gas turbine or in an engine to generate electricity and heat.

II. SIMULATION DETAILS

In a typical atmospheric fluidized bed gasifier, feed together with bed material are fluidized by the gasifying agents, such as air and/or steam, entering at the bottom of the bed. The objective of this study is to develop simulation capable of predicting the steady-state performance of an atmospheric fluidized bed gasifier by considering the hydrodynamic and reaction rate kinetics simultaneously. The products of homogeneous reactions are determined in RYIELD reactor and RGIBBS reactor, and reaction kinetics are used to determine the products of char gasification. A drawback in using ASPEN PLUS is the lack of a library model to simulate fluidized bed unit operation. However, it is possible for users to input their own models, using FORTRAN codes nested within the ASPEN PLUS input file, to simulate operation of a fluidized bed. The work presents the simulation of fluidized beds for biomass gasification in Aspen Plus. Fig. 1 shows a simple schematic diagram fluidized bed gasifier. A preheated mixture of oxygen and steam is introduced at the bottom of the gasifier and flows upward with biomass to react with.

![Fig.1 Schematic illustrative diagram of fluidized bed gasifier.](image)

III. RESULTS AND DISCUSSION

Effect of Temperature on Syngas composition:

The effect of gasifier temperature on produced syngas composition is shown in Fig.3. The temperature considered varies from 700 °C to 1000 °C. The composition of syngas varying with a small range with increasing gasifier temperature. It can be seen that H₂ composition and CH₄ composition are almost independent of temperature. According to Le Chatelier’s principle, higher temperatures favour the
reactants in exothermic reactions and favour the products in endothermic reactions. Therefore the endothermic reaction that is steam gasification was strengthened with increasing temperature, which resulted in an increase of CO composition.

Effect of Steam to biomass Ratio on syngas composition:
Over the S/B range from 0 to 4, carbon conversion efficiency exhibited decreasing trend, which can be explained by that excessive quantity of low temperature steam lowered reaction temperature and then caused gas quality to degrade. As shown in Fig.4, in the S/B range from 0 to 4, the composition of H₂ increases, this can be explained by more steam gasification reaction is taking place because of increased steam quantity. The change in CH₄ composition is very small with increasing steam-fuel ratio.

Effect of Air to Biomass Ratio on syngas composition:
The effect of Air to Biomass ratio on the Syngas composition is shown in Fig. 5. The effect of this ratio range from 0.5 to 1.8 was observed. In this range the mole fraction of H₂ decreases because increasing of Air to Biomass ratio indirectly means that it will reduce the reaction temperature so that the endothermic reaction that is steam gasification reaction is weakened. In Fig.5 increasing the Air to Biomass ratio increases the mole fraction of CO₂ because of increasing the flow rate of oxygen favours the oxidation reaction to occur.

IV. CONCLUSION
A model was developed for the gasification of biomass in an atmospheric fluidized bed gasifier using the ASPEN PLUS simulator. To provide the model, several ASPEN PLUS unit operation blocks were combined with number of separator blocks and a mixer block. The simulation analysis for the product gas composition versus temperature, air to biomass ratio and steam to biomass ratio was done. Higher temperature improves the quality of syngas by increasing the production of carbon monoxide and decreasing the mole fraction of carbon dioxide. Increasing steam to biomass ratio increases the production of hydrogen and carbon dioxide and decreases the carbon monoxide. Increasing air to biomass ratio decreases the production of hydrogen and increases the carbon dioxide production.

REFERENCES
