International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol. 2, Issue. 5, Sep.-Oct. 2012 pp-3622-3627 ISSN: 2249-6645

Effect of Air Velocity, Fuel Rate and Moisture Content on the Performance of Updraft Biomass Gasifier using Fluent Tool

Hina Beohar[a], Bhupendra Gupta[a*], Dr. V. K. Sethi[b], Dr. Mukesh Pandey[b], Hemant Parmar[c]

[a]*Jabalpur Engineering College, Jabalpur, M.P.*
[b]*UIT, RGPV, Bhopal, M.P.*
[c]*Ujjain Engineering College, Ujjain, M.P.*

Abstract: *The use of biomass gasification for conversion of hydrocarbons to permanent fuel gas mainly composed of H_2, CO, CO_2 and CH_4. In this study the performance of Updraft gasifier is carried out with ANSYS FLUENT software, to study the effect of various operating parameters such as air velocity, fuel rate and moisture content on the performance of updraft gasifier are discussed. It was found incredible effect to varying the different operating parameters in different range.With increasing air velocity and moisture content, the value of H_2 first increased then decreased but CO initially decreased then increased, CO_2 increased gradually.When increasing fuel rate, the value of H_2 and CO_2 first decreased then increased, and the value of CO increased then decreased. So it was found the optimum value of air velocity, fuel rate and moisture content is 5.4 m/s, 8.8 kg/h and 25% respectively.*

Key words: *Biomass, up-draft gasifier, air velocity, fuel rate and moisture content, gascomposition, FLUENT simulation.*

I. Introduction

In India, biomass has always been an important energy source. Although the energy scenario in India today indicates a growing dependence on the conventional forms of 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.Our current work focused on thecomputational modeling of updraft gasifier which using the long stick wood as a biomass material. CATIA V5R16software used to construct the model and ANSYS FLUENT was employed to analysis the various parameters of updraft gasifier system.

Nomenclature

$A_g$crass section area of gasifier (mm)	V_a velocity of air flow (m/s)
D typical dimension (mm)	C species concentration (%)
$F_m$moisture content (%)	$P_g$producer gas
F_{O2}fraction of oxygen (%)	E activation energy (J/mol)
L length of the wood (mm)	L_c length of the charcoal gasification (mm)
mmass flow rate of fuel (kg/h)	***Greek symbols***
T temperature (K)	αmass fraction
t_c char gasification time (s)	ε_i volume fraction of phase
V volume of the wood (m^3)	μviscosity, kg/ms
V_f velocity of fuel flow (m/s)	ρdensity, kg/m^3

II. Literature Review:

Marta Muilenburg et al [7]focused on the computational modeling of downdraft gasifier bed which will be implemented by the University of Lowa Oakdale power plant. Gambit software was used to construct the meshes and ANSYS FLUENT was employed to test the various factors so as to complete the modeling of the down draft gasifier system for this project.

S. Murgia et al [11] presented a comprehensive CFD model of an air blown up-draft gasifier has been setted up and tested using the CFD code MFiX. This paper the performance of gasifier characterize by two parameters such as Temperature and Gas composition in the function of time.

Avdhesh Kr. Sharma [3] Presented 75 kWth, downdraft gasifier system has been carried out for obtaining temperature profile, gas composition, calorific value and trend for pressure drop across the porous gasifier bed. In firing mode, the higher temperature in bed tends to better conversion of non-combustibles component (like CO_2, H_2O) into combustibles component (like CO, H_2) in the resulting gas and thus improves in calorific value of product gas.

Weihong Yang et al [13] Present work an experimental fixed bed gasifier is utilized to investigate the gasification of biomass using higher temperature air up to 1473K.A model has in bed been formulated for the prediction of the main chemical and physical processes and used to study the influence of oxygen concentration, air flow rate, gas composition. The temperature of feed gas increased a higher gasification rate and higher molar fraction of feed gases (CO, H_2). Increased oxygen concentration leads to higher peak values of the fuel gas concentrations, a higher gasification rate.

P. Abdul Salam et al [8] paper presents the experimental study on air gasification of charcoal biomass gasifier. Performance of a gasifier depends on the design of the gasifier, type of fuel used and air flow rate. The experiments were carried for an equivalence ratio of 0.25.The effect of air velocity and type of the distributor on the gasification performance was discussed .The concentration of CO_2 (12.4–15.4 vol %) is found to show increasing trend with increase in velocity of air. The concentration of CH_4 was low in the range of 0.51–0.94 vol% and remained almost constant with the increase of air velocity.

A. Saravanakumar et al [1] present work focus of made on development of a gasifier using long sticks of wood as feed materials.And the performance of gasifier is characterized in terms of air flow rate, fuel flow rate, gas composition. When increased air flow rate the higher rate O_2 oxide that caused composition H_2 increased and CO decreased. When fuel flow rate increased the biomass consumption rate is decreased that reasons H_2 decreased.

A. Saravanakumar et al. [2]this concept a 25m^3/hr capacity gasifier was design and constructed.Since this gasifier attains ahigh-energy release rate per unit area due to high inlet air velocity and activated reduction in the combustion zone. In all zones, the heat balance equations show agood fit between the theoretical and experimental value. The gasifier was operated in a batch mode, both bottom-lit and top-lit,andair flow and gas out flow were measured.

D.F Fletcher et al [5] content the description of CFD model to simulate flow and reaction an entrained flow biomass gasifier. ANSYS CFX used to provide detail information of gas composition and temperature at the outlet of gasifier.

M. Miltner et al [6] this paper show the joint application of process simulation and CFD.And modeling approach is essentially focused on treatment of heterogeneous combustion and prediction of gases emission such as carbon monoxide and nitrogen oxide.

PengmeiLv et al [9]This study applies a self heated gasifier as the reactor and uses char as catalysis to study the characteristics of hydrogen production from biomass gasification. Air and oxygen/stream are utilized as gasification agents. The experimental result indicate that compared to biomass air gasification, oxygen/steam gasification improve hydrogen yield depending on the volume of downdraft gasifier, and also nearly doubles the heating value of fuel gas.

III. Modeling of Gasifier

The work includes three parts. In first part we create model using CATIA V5R16 software. In second part put all input parameters for simulation and third part simulation done and results analyzed by the FLUENT ANSYS software.

(i)Design of gasifier:

In Present work long stick wood up-draft gasifier was constructed. The gasifier in fig.1was design and construct using mild steel material. It is rectangular in cross-section.the total height of gasifier is 1.34 m. and total length and breadth of gasifier is75cm and 60cm respectively. The hopper is the primary storage area for the fuel wood. Long sticks wood packed upto the full capacity of the hoper. Theair enters, air nozzle itsdiameter is 1.5 inch. There are two air nozzle fixed with adjacent side of hearth of gasifier.

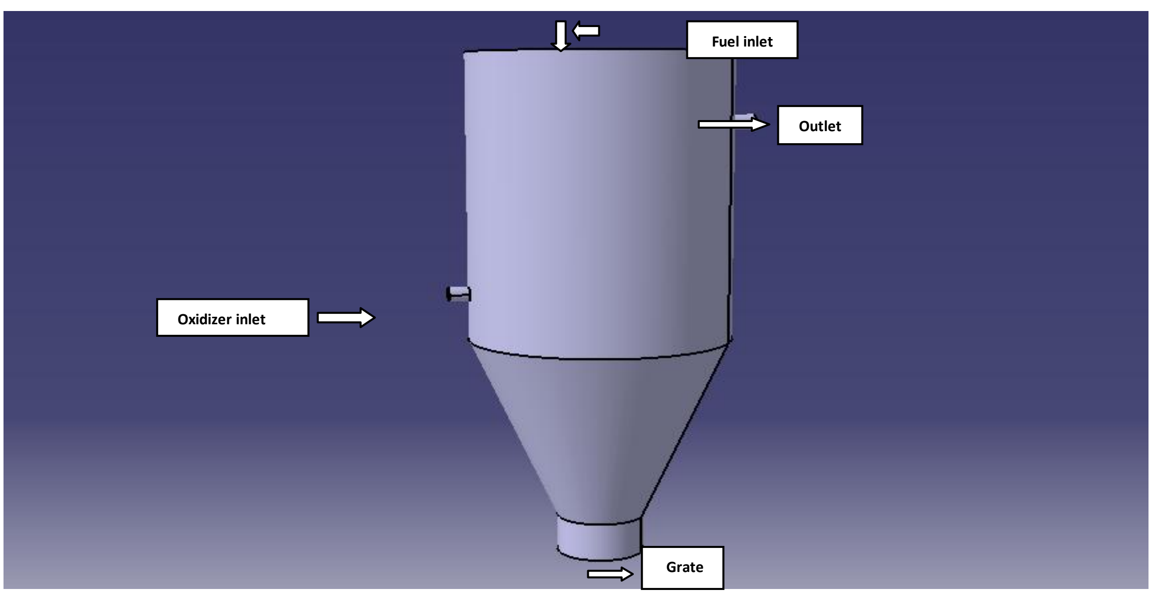

Fig. 1: Model of up-draft gasifier

(ii)Design inputs for simulation of gasifier:

The performance detail of gasifier is given Table 1.Accordingly, with the help of experimental data the performance of gasifier is evaluated in the terms of parameters. The air velocity, fuel rate and moisture content varying different range and more wood are gasified completely. The ranges of air velocity, fuel rate and moisture content taken 3.7m/s-6.4m/s, 6.9 kg/h-13.6 kg/h and 5%-40% respectively

Table 1: Range of different measured parameters of gasifier.

Measured parameters	Range of parameters
Fuel rate	6.9 kg/h- 13.6 kg/h
Air velocity	3.7-6.4 m/s
Moisture content	5-40 %

(iii)CFD modeling used in this work:

Computation fluid dynamic is a design and analysis tool to simulate fluid flow, heat and mass transfer, chemical reaction, solid and fluid intersection and other related phenomena. Comparing to physical experimental operation, CFD modeling is cost saving, timely, safe and easy to scale – up. The most widely used numerical techniques in CFD are finite difference, finite elements and finite volume methods. Finite volumes are now most commonly used approach in CFD. The most routinely used commercial codes include ANSYS FLUENT, ANSYS CFX, STAR-CD and PHOENICS.

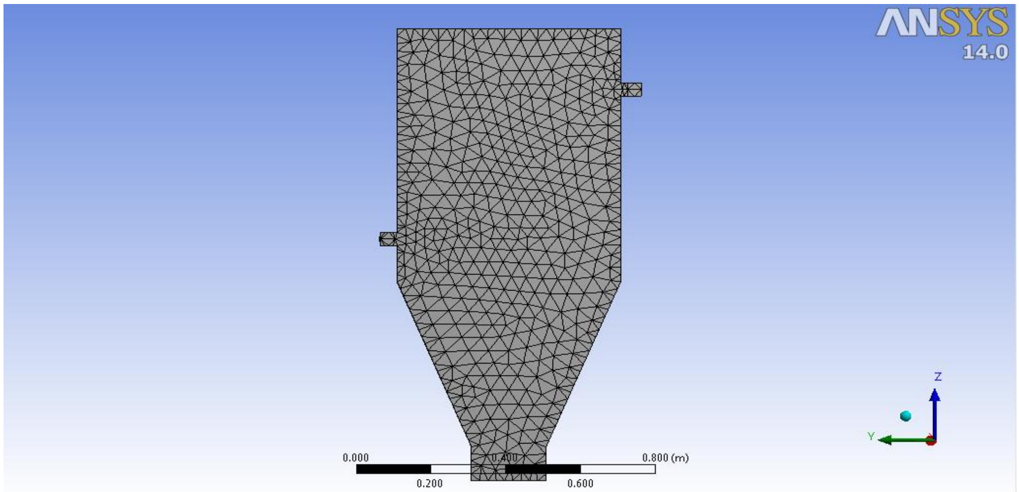

Fig.2: Mesh model of updraft gasifier

The model select of this study focus on the combustion zone of updraft gasifier. CATIA V5R16 software was used to create a three dimensional model of updraft gasifier. ANSYS FLUENT was then used to set the parameters of the model. Finite rate combustion was chosen as the solver for this project. Energy flow model in FLUENT solves the conservation of mass and momentum and the energy equation as well. The species transport solution is solved using the pressure based solver.The Boundary conditions applied for the work is given in the table 2.

Table 2: Boundary condition

Zone	Boundary Type
Oxidizer inlet	Velocity inlet
Output	Pressure outlet
Symmetry	Symmetry
Fuel inlet	Velocity inlet

***Velocity inlet*:** Velocity inlet boundary conditions are used to define velocity and scalar properties of the flow at inlet boundary.

***Pressure outlet*:** Pressure outlet boundary condition is used to define the static pressure at flow outlets. The uses of a pressure outlet boundary condition instead of an outflow condition often result in a better rate of convergence when backflow occurs during iteration.

***Mass flow inlet*:** Mass flow inlet boundary condition are used in compressible flow inlet to prescribe a mass flow rate at the inlet it is not necessary to use mass flow inlets in incompressible flow because when density constant.

IV. Result and Discussions

The simulationwas performed on the above model with given boundary conditions. Results are obtained and analyzed. The results analyzed are presented here in three parts. In first part, the effect of air velocity on gas composition,in second part, the effect of fuel rate on gas composition and third part shows the effect of moisture content on gas composition.

(i)Effect of air velocity variation on the value of gas composition

Air velocity is the important variable in gasifier operation. In this analysis air velocity was varied from 3.7 m/s to 6.4 m/s while keeping the fuel feed rate constant at this case. An increased in air velocity suggest an increase oxidation of fuel, and the higher production of $CO_2$from element C and more conversion of CO into CO_2. This is also indicated by the decrease mole fraction curve of CO with a simulation increasing in the mole friction of CO_2. A higher amount CO_2 present in the reactor tends to water gas shift reaction toward greater production of H_2O at higher temperature. When the velocity is increasing 3.7 m/s to 5.4 m/sthis is seen in the increasing trend of mole fraction curve of $H_2$is 14% to 21% and then they decreased. Table.3shows the effect of variation of air velocity on gas composition

Table3: Effect of air velocity on gas composition.

Air Velocity (m/s)	H_2 (%)	CO (%)	CO_2 (%)	CH_4 (%)
3.7	14	25	10	6.3
4.2	15	23	11	6.2
4.6	16	21	12	6.1
5	18	20	14	5.8
5.4	21	19	15	4.9
5.9	16	20	17	4.7
6.4	15	22	19	4.4

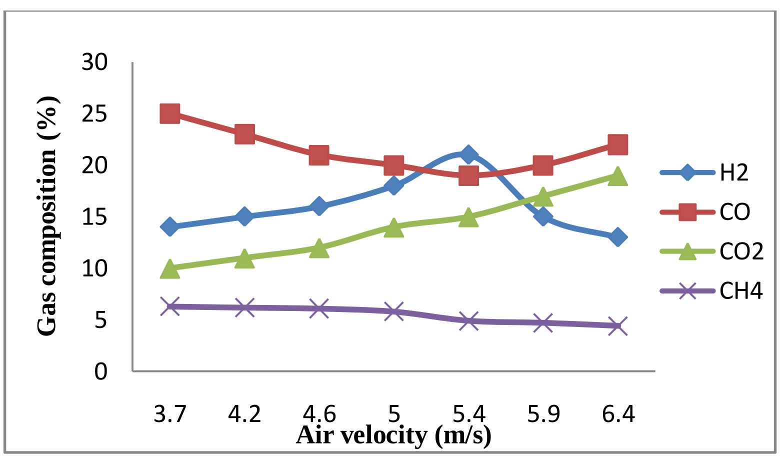

Figure3: Graph between Air velocity and gas composition

(ii)Effect of fuel rate variation on the value of gas composition:

The input fuel rate to the simulation was varied from 6.9 kg/h to 13.6 kg/h and individual gas composition of producer gas compared with variation of fuel rate. The result from simulation show the figure.4 .when the increased of fuel rate the value of H_2firstlydecreased from 24% to 17% and then increased. And the value of COfirst increased from 18% to 22% then decreased by effect of decreasing bed temperature. And CO_2 first decreased then increased by increasing the value of feed fuel velocity.

Table 4: Effect of fuelrate on gas composition.

Fuel rate (kg/h)	H_2 (%)	CO (%)	CO_2 (%)	CH_4 (%)
6.9	24	18	17	4.3
7.4	21	19	16	4.4
8.2	19	21	15	4.9
8.8	17	22	13	6.4
10.7	19	20	14	6.6
11.3	21	18	16	7
13.6	23	16	17	7.1

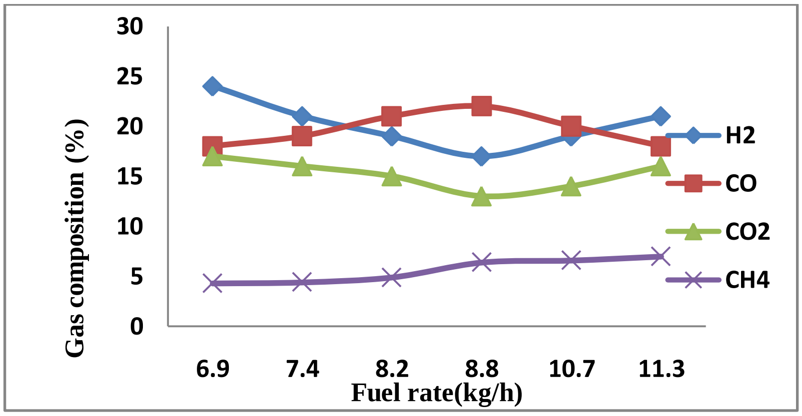

Figure 4.Graph between fuelrate and gas composition

(iii)Effect of moisture content variation on the value of gas composition-

The biomass generally associated with some moisture when feed to the reactor. This analysis was conducted to study the effect of variation of moisture content on the composition of producer gas. This analysis moisture content was varying 5% to 40%. Increasing the level of moisture content of gasification, present CO produce H_2 by water gas shift reaction and this effect increasing H_2 content of producer gas. An increasing CO_2 could also mean increase in combustion due to increased amount of oxidant in the reactor. The concentration of H_2 increased 15% to 24% with change of moisture content from 5% to 35% and then they start to decreased.

Table 5: Effect of moisture content on gas composition

Moisture Content(%)	H_2 (%)	CO (%)	CO_2 (%)	CH_4 (%)
5	15	37	11	4
10	16	35	13	5.5
15	18	34	15	5.6
20	19	31	17	5.7
25	21	31	18	5.8
30	23	34	20	5.8
35	24	39	20	6.7
40	20	41	21	6.8

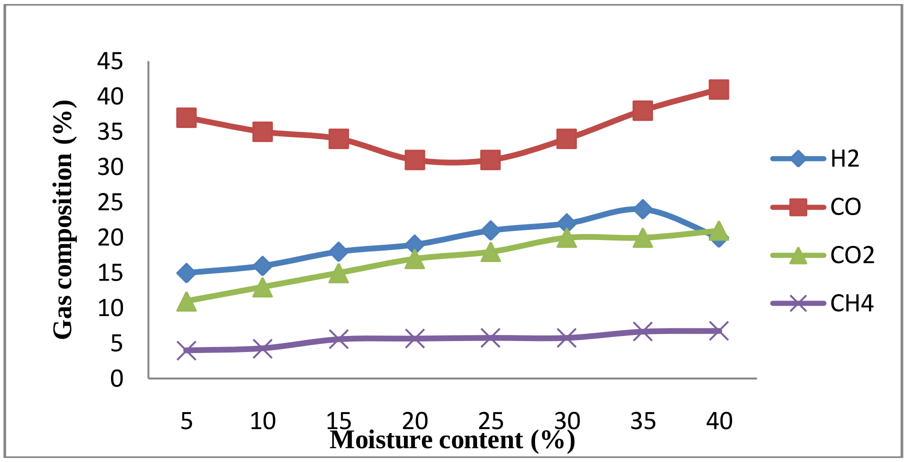

Figure 5.Graph between moisture content and gas composition

V. Conclusions

The detailed CFD model of an up-draft gasifier has been developed, based on FLUENT package. Models of finite rate chemistry in the gas phase and char reactions have been added to the standard model. Simulation performed to predict the gas composition for varying air velocity, fuel rate and moisture content.

- The simulation result shows that,as the *air velocity*increases,the value of H_2firstly increases from 14% to 21% then decreased andCO concentration first decreased from 25% to 19% then increased.because at one optimum point the air velocity so high that causes on that point gasification not proper done and the value of H_2 decreases and CO increases.CO_2concentration increased from 10% to 19% because of large amount of element C react with O_2 and produce CO_2.AndThe Maximum value of $H_2$is 21% is obtained at air velocity of 5.4 m/s.
- When increasing *fuel rate*, concentration of H_2 and CO_2decreased from 24% to17% and 17% to 13% respectively then increased by increasing the fuel rateand the concentration of CO first increased 18% to 22% then decreased 20% to 16%. Because the air is not enough to gasification that reason the temperature of bed decreased. For decreasing bed temperature value of H_2 start to increase and CO start to decreased. So the optimum value of fuel rate is 8.8 kg/h.
- When increasing the *moisture content*in gasification, the value of H_2 first increased from 15% to 24% then decreased because the level of moisture contents so high. And the value of COfirst decreased 37% to 31% and then increased 31% to 41%.And the CO_2 concentration increasing gradually.So the optimum value of moisture content is 25%.

References

1) A. Saravanakumar et al. (2007), Experimental investigations of long stick wood gasification in a bottom lit updraft fixed bed gasifier, *Fuel Processing Technology 88, 617–622.*
2) A. Saravanakumar et al. (2005), Operation and modeling of an updraft long-stick wood gasifier,*Energy for Sustainable development Volume No.4.*
3) Avdhesh Kr. Sharma (2010),Experimental study on 75 kWth downdraft (biomass) gasifier system, *Renewable Energy* 34, 1726–1733.
4) Avdhesh kr. Sharma (2010), Modeling and simulation of a downdraft biomass gasifier 1. Model development and validation, *energy conversion and management* 52, (2011) 1386-1396.
5) D.F. Fletcher et al. (2000), A CFD based combustion model of an entrained flow biomass gasifier, *Applied Mathematical Modeling* 24, 165-182.
6) M. Miltner et al. (2007), Process simulation and CFD calculations for the development of an innovative baled biomass-fired combustion chamber, *Applied Thermal Engineering*, 27, 1138–1143.
7) Marta muilenburget al. (2011), Computational modeling of the combustion and gasification zones in a downdraft gasifier. ASME
8) P. Abdul Salam et al. (2006), A comparative study of charcoal gasification in two types of spouted bed reactors. *Energy 31, 228–243*
9) PengmeiLv et al. (2007), Hydrogen-rich gas production from biomass air and oxygen/steam gasification in a downdraft gasifier, *Renewable Energy 32, 2173–2185.*
10) PrabirBasu (2010) Biomass Gasification and Pyrolysis for practical design and theory, *Published by Elsevier.*
11) S. Murgia et al. (2011), Comprehensive CFD model of an air-blown coal-fired updraft gasifier, *Fuel*.
12) Sirigudirahulrao (2002)Biomass to ethanol: process simulation, validation and sensitivity analysis of a gasifier and a bioreactor,*National Institute of Technology Karnataka.*
13) Weihong Yang et al.(2007),Performance analysis of a fixed-bed biomass gasifier using high-temperature air, *Fuel Processing Technology 87, 235 – 245.*
14) Yaji Huang et al.(2007), Effect of operating conditions on gas components in the partial coal gasification with air/steam, *Korean J. Chem. Eng., 24(4), 698-705.*
15) Yiqun Wang et al.(2008), *Review* CFD Studies on Biomass Thermochemical Conversion, *Int. J. Mol. Sci.* 2008, *9*, 1108-1130.