SIMULATION OF HORIZONTAL BIOMASS GASIFICATION REACTOR IN DIFFERENT TURBULENCE MODEL

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ABSTRACT

Computational Fluid Dynamics (CFD) simulation of horizontal biomass gasification reactor has been carried out. The gas-solid interaction, thermal-flow behavior, thermo-chemical analysis and biomass gasification process inside a horizontal biomass gasifier were analyzed using the commercial CFD solver ANSYS CFX software. The influence of gasification air velocity, species mass fractions of biomass, turbulence eddy dissipation and eddy viscosity are examined for horizontal biomass gasifier. All phases are described using an Eulerian approach to study the exchange of mass, energy and momentum. The analysis includes two cases, in first case the flow process is analyzed without biomass and reaction modeling. It is found that superficial gas and mass fraction of biomass has influences the outlet gas velocity. In this research theoretical approach using mathematical model was used to simulate the effects of the parameters such as inlet air velocity that influences the process of gasification. Pyrolysis zone of gasifier is mathematically examined through a coupled of chemical equations such as chemical kinetics, mass transfer and heat transfer. Mathematical models have certain advantages as compared to experimental method of any system. ANSYS CFD can produce a large number of data points with less experimental data. An ANSYS CFD CFX model can develop accurate geometry of the gasifier reactor as compare to other software. The main purpose of the numerical mathematical models involve understanding and quantifying the thermo-chemical processes during biomass gasification and investigate the influence of the main input parameter such as inlet air velocity, temperature, producer gas.

Keyword: - *ANSYS CFX, eddy viscosity, biomass, biomass gasifier, Navier Stokes equation, momentum.*

1. INTRODUCTION

As the price of oil and gas as well as the energy crisis are continuously increasing, there is a need of energy which is environmentally friendly and less expensive. Biomass is one of the choices among these kinds of energy resources in India. This oldest source of energy known to the mankind does not make any addition to the earth's carbon dioxide levels, because most of the biomass grow through photosynthesis by absorbing carbon dioxide from the atmosphere. When it converts to energy, only recently absorbed carbon dioxide will release. Biomass can be reproduced and does not take millions of years to develop, which is considered as a renewable energy and time taken is also less. Besides, a wide variety of biomass can be used as raw material for the production of energy such as waste wood chips, agricultural crops, domestic waste and animal waste etc. In this respect, biomass is one of the most promising energy sources in the immediate future. Biomass can be converted via biochemical route and thermo chemical route. For thermo chemical conversion, production of thermal energy is the main driver for this conversion. Biomass is converted into gases and then synthesized into the desired chemicals or used directly. Direct combustion, pyrolysis and gasification can be included as thermochemical process. Traditional combustion of biomass shows low efficiency in utilizing energy and therefore cannot compete with fossil fuels. Biomass gasification for combined heat and power (CHP) production offers much higher energy efficiency. This technology has been commercialized successfully in some countries.

1.1 Thermodynamic property of biomass

Biomass gasification process involves a series of thermo-chemical reactions. Therefore, in order to achieve proper reactions in different stages and to optimize the process, the study of the biomass thermodynamic properties is necessary. Specific heat capacity or specific heat in short indicates the heat capacity of a substance and it shows the amount of heat contained by the biomass. It depends upon temperature, moisture contained and the type of biomass.

Table 1: specific heat of different biomass

Fuel	Specific heat in KJ/kg· K	Validity (C)
Wood char	$Cp(dry) = 1.39 + 0.00386T$	400-1600
Softwood	$0.00546T + 0.524$	40-140
Char from softwood	$-.0038*10^{-3}T^2 + 0.00598T - 0.795$	40-350
Various wood	$Cp(dry) = 0.266 + 0.00116(T - 273)$ $Cp(wet) = Cp(dry)(1 - M_{wet}) + 4.19M_{wet}$	0-90

1.2 Physics of fluid

In the process of gasification the gas as well as water vapor is generated which are considered as fluid. The properties of fluid include velocity, pressure, temperature, density and viscosity. Fluid density is given by mass per unit volume. If the density of fluid is constant the fluid is called incompressible and if fluid density varies, fluid is called compressible. Water is treated as an incompressible fluid and equation of density can be given by.

$$\rho = \frac{M}{V}\frac{kg}{m3}$$

The viscosity is an internal property of a fluid that offers resistance to flow. For example, to stir water is much easier than to stir honey because the viscosity of water is much smaller than honey.

$$\mu = \left[\frac{Ns}{m^3}\right] = [Poise]$$

1.3 Law of Conservation

Computational fluid dynamics (CFD) is governed by Navier Stokes Equation which is based on conservation laws of physical properties of fluid. The conservation law says

- Mass is conserved
- Energy is conserved
- Momentum is conserved

For example, the change of mass in the object is as follows

$$\frac{dM}{dt} = \dot{m}_{in} - \dot{m}_{out}$$

If $\dot{m}_{in} - \dot{m}_{out} = 0$

We have

$\frac{dM}{dt} = 0$ Which means M= const

1.4 Navier Stokes Equation

Applying the mass, momentum and energy conservation, we can derive the continuity equation, momentum equation and energy equation as follows.

1.4.1 Continuity Equation

$$\frac{Dp}{Dt} + \frac{\rho \partial U}{\partial x} = 0$$

1.4.2 Momentum Equation

$$\frac{\rho\, \partial U}{\partial t} + \frac{\partial U}{\partial x} = -\frac{\partial P}{\partial x} - \frac{\partial \tau}{\partial x} + \rho g$$

Where

$$\tau_{ij} = -\mu\left(\frac{\partial U}{\partial x} + \frac{\partial U}{\partial x}\right) + \frac{2}{3}\delta\mu\frac{\partial U}{\partial x}$$

1.4.3 Energy Equation

$$\frac{\rho c \partial T}{\partial t} + \frac{\rho c U \partial T}{\partial x} = -\frac{P \partial U}{\partial x} + \frac{\lambda \partial T}{\partial x 2} - \frac{\tau \partial U}{\partial x}$$

2. OBJECTIVES

1. CAD modeling of horizontal biomass gasification reactor of specific length and diameter.
2. CFD analysis using different turbulence model and energy models available.
3. Comparative analysis of eddy dissipation contour on different model.
4. Simulation on biomass gasification reactor for different biomass fraction.

3. ASSUMPTIONS

Following assumption has been considered in this analysis

1. Due to non-availability of mathematical equation for batch process with respect to biomass consumption, the analysis was performed in pseudo static stage.
2. Flow of fluid is under steady state conditions
3. Vertically oriented up-draft gasifier parameters for gasification process were considered for CFD simulation.

4. MODEL DESCRIPTION

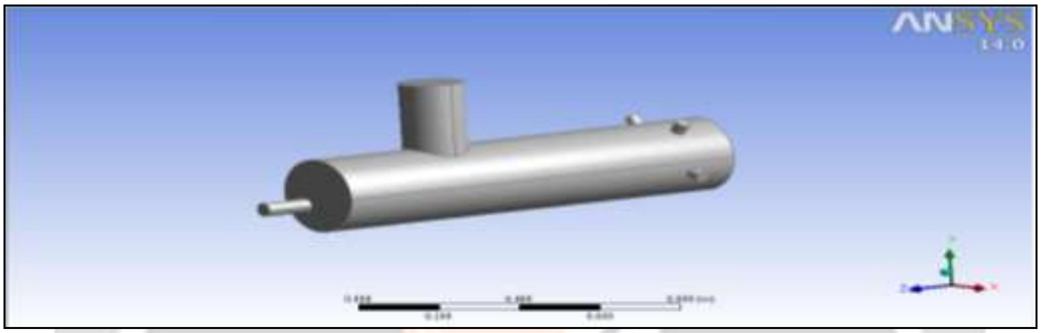

Fig-1: Imported CAD model of gasification reactor in ANSYS

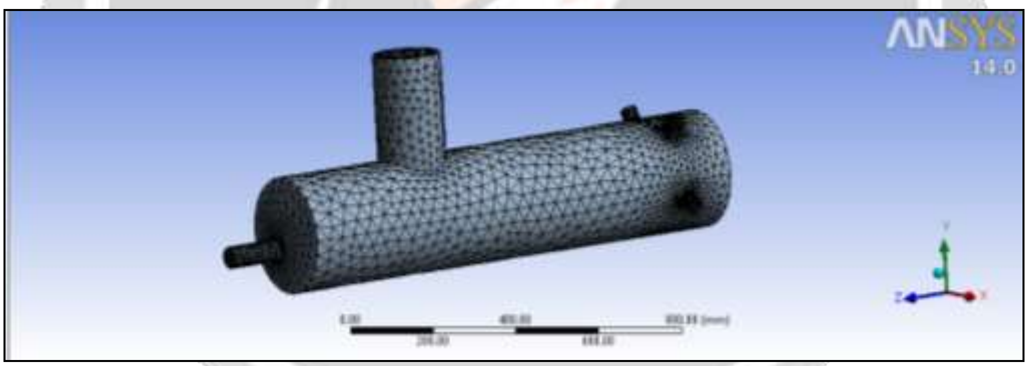

Fig-2: Meshed model of gasification reactor in ANSYS

5. RESULTS

The whole process of conducting CFD analysis was to study the effect of air flow distribution inside the reactor, turbulence eddy dissipation, on biomass gasifier. The CFD analysis was divided into 3 models and 2 cases to get detailed understanding of flow pattern and eddy dissipation.
Case-1: Simulation without biomass, without inflow of biomass

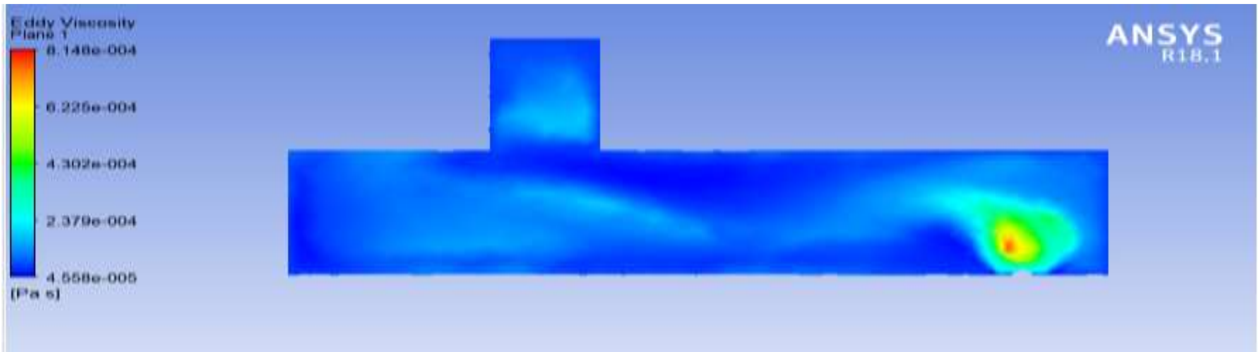

Fig-3: Eddy viscosity plot using K-epsilon turbulence model

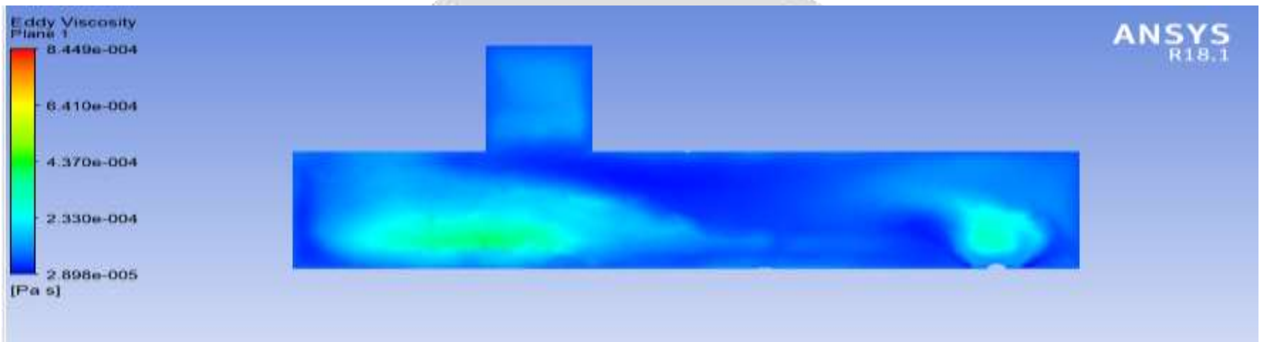

Fig-4: Eddy viscosity plot using RNG K-epsilon turbulence model

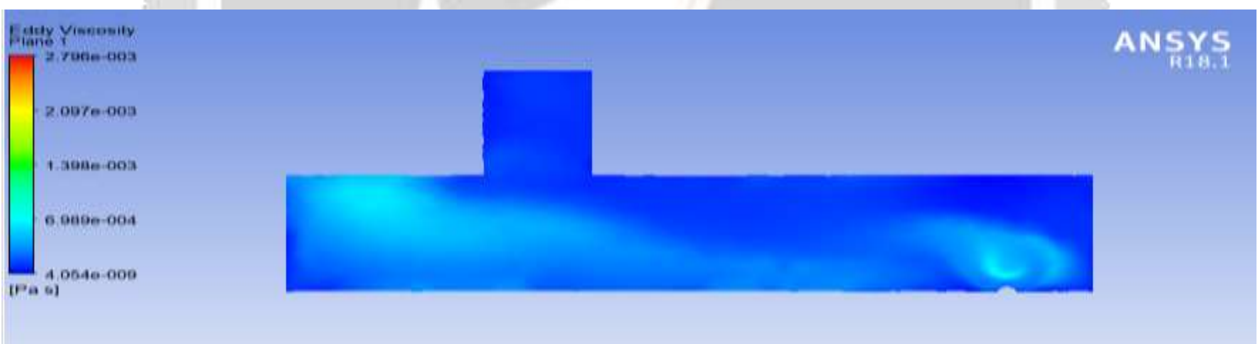

Fig-5: Eddy viscosity plot using K-omega turbulence model

Case-2: Simulation with biomass, without inflow of biomass

In this case biomass mass fraction is taken as 0.7 and air inlet velocity is considered as 3.5 m/sec. for this input simulations result is discussed below

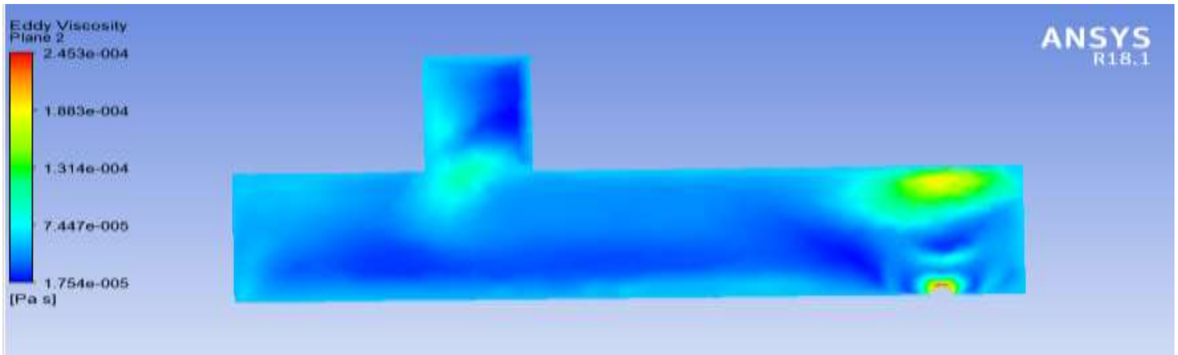

Fig-6: Eddy viscosity plot using K- epsilon turbulence model

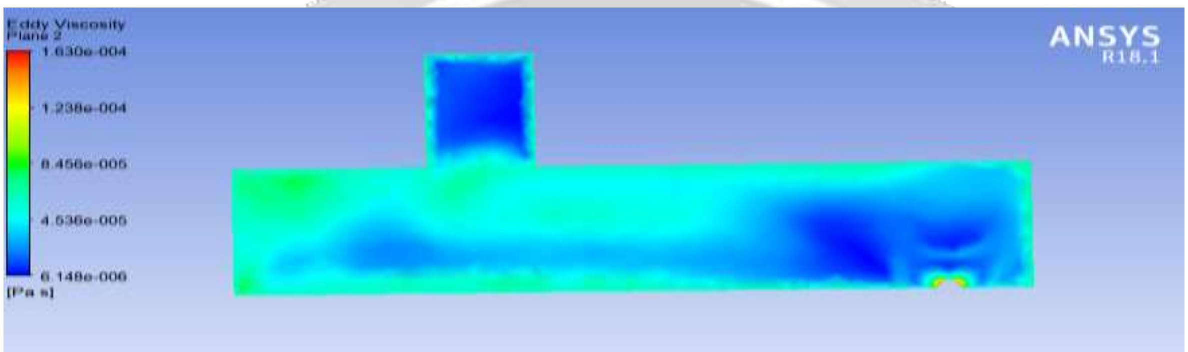

Fig-7: Eddy viscosity plot using RNG K-epsilon turbulence model

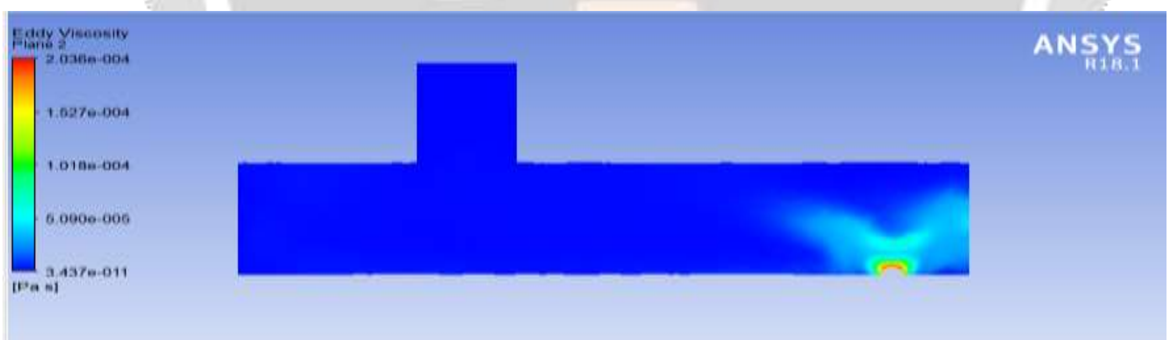

Fig-8: Eddy viscosity plot using K-omega turbulence model

6. CONCLUSIONS

From the analysis of biomass gasification reactor under different conditions and simulation the following conclusions are considered

1. In the first case when simulation is conducted without biomass the eddy viscosity is found to be highest with k-epsilon turbulence model.
2. In the second case when simulation is conducted with initial biomass content and without constant inflow the eddy viscosity is lowest using k-omega turbulence model.

7. REFERENCES

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