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CFD Numerical model survey of Biomass combustion with wind as means

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Abstract--- Increased energy demand stems from rapid expansion of industries, automobile population, and more complicated human existence, depleting traditional fuels and posing a serious environmental hazard. Biomass will play an essential role as a source of green energy all over the world as a result of strict emission-reduction measures. Biomass gasification not only generates substantial amounts of hydrogen, but it also burns waste from a variety of sources. Gasification is a thermochemical process that converts biomass into useful chemicals using a medium such as steam or air. Gasification is only effective if usable amounts of fuel gases are produced.The use of gasification technology needs theoretical simulation, which must be confirmed via experimental investigation. A variety of numerical models for simulating gasification were given by a number of academics. The current research describes a species transfer-based fluid dynamics simulation of gasification. CFD is a well-defined method for improving design, fluid flow visualization, and operational efficiency. With air as the medium intake to the reactor, a CFD research is performed for various temperatures (1023K, 1073K, and 1123K). When utilizing an advanced methodology, CFD predicts better. Based on the results of the CFD simulation, the various components of gaseous such as H_2, CH_4, CO, and CO_2 are computed at various temperatures.

Keywords:

1.INTRODUCTION

Because the majority of energy resources use fossil fuels as a medium, they are rapidly decreasing, causing environmental impact. Thermochemical conversion is a process that transforms biomass into a fuel with useful heating potential. P.C. Murugan et al. incorporated numerous zones of the gasifier in their simulation using CFD, as well as an experiment using rice husk as a biomass source in a 40 kW downdraft gasifier. According to studies, the air to fuel ratio is a critical parameter for modeling, and its values are taken into account when the pyrolysis fraction variable is changed. When the air-to-fuel ratio is higher, the pyrolysis fraction variable value used is the least, according to RatnakarChodapaneedi*et al.*S. Sivakumar et al. designed and simulated a down draft gasifier with a capacity of 100 kW using CFD. The significance of temperature during gasification was explained via simulation by QitaiEri et al., while the quantity of steam relative to biomass (SBR) had no effect on the simulated results.

The process of gasification and the pyrolysis products, according to P. Ranganathan et al., are a range of non-condensable gases, liquids, and char. All of these studies suggest that energy supplies are depleting at an alarming rate, necessitating humanity to develop a renewable and environmentally friendly energy source. Because most of the fuels used are highly polluting, affecting the environment and, in certain circumstances, human life, the choice should be based on both concern for living beings and concern for the environment. Gasification is the process of converting solid fuels to gas by converting the solid fuel's chemical energy into usable gas.The chemical energy contained in the biomass dictates the chemical composition of the gas produced, which determines the fuel quality. Combustible gases in higher concentrations, such as H2, carbon monoxide, and methane, boost the amount of energy in the resulting gas during combustion. As a result, hydrogen, one of the most well-known sources of clean energy, has a high heating value, produces no pollution when burned, and is readily available from a variety of sources. Rice husk and dried neem leaf are used in all of the gasification processes, which would otherwise be dumped as trash. Here, rice husk gasification was carried out using air as the medium. Gasification is rendered unworkable if any of the operational parameters are insufficient.Finding the best conditions for gasification is a time-consuming process. CFD is used to simulate the gasification process, and the results are compared to experimental values. One of the advantages of CFD is that if the computational results are validated with experimental data, the remaining tests can be simulated rather than performed experimentally, which minimizes both work and cost. In CFD, basic components such as rice husk are fixed so that effective comparisons may be made. The gasification reactions are simulated by building a CFD model of gasification using the species transport model for various operating temperatures.The boundary condition is determined based on the fixtures, and the material selection is based on the requirements. The goal of this study is to see how temperature affects the concentration of syngas produced by causing biomass to react with air. As a result of the simulations, a solid theoretical framework for gasification has been established.

2.DESCRIPTION OF MODEL

The gasification reactor is depicted in Figure 1. The reactor's cross section is 100 mm in diameter, and the reaction zone heights are 180 mm and 120 mm, tapered at a 28° angle.

The reactor's top has a 30mm diameter medium input and exit. Air can enter the reactor through the medium input, while gas can depart through the medium outlet. The biomass is fed through the conventional inlet at the bottom of the reactor, and the heat is delivered by the furnace.

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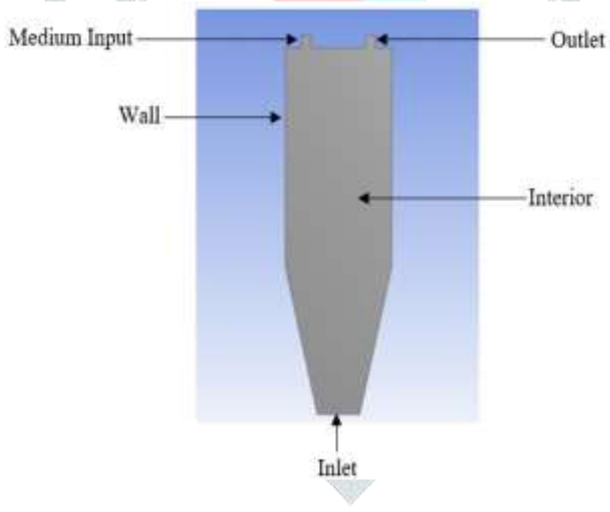

Fig. 1 Geometry model of gasifier

3.GOVERNING MATERIALS AND EQUATIONS USED IN SIMULATION

3.1 Material fixtures

When performing similar simulations, many researchers have found that utilizing the k-epsilon model yields results that are within an acceptable range. Furthermore, as compared to other models, the processing power required is smaller, and the model is weaker. The eddy dissipation model is used because species mixing causes turbulence in nature. A chemical algorithm is used to calculate mass fractions for various gaseous components. As shown in Fig. 2, the appropriate materials are selected based on the requirements. The mass fraction of the mixtures is determined by the CHNS/O analysis of rice husk.

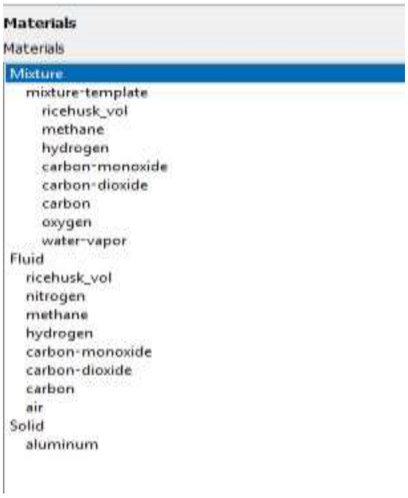

Fig.2 Material fixtures

3.2 Continuity equation and Momentum conservation equation

The continuity equation, which asserts that the rate of mass entering the system equals the total mass leaving the system plus mass accumulation in the system, is defined by fluid mechanics. Each cell in the mesh is formed using this equation. The continuity equation is shown in differential form below. $\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$

Energy, such as momentum, is always preserved. Here is the momentum conservation equation:

$$\frac{\partial}{\partial t}(\rho\vec{v}) + \nabla \cdot (\rho\vec{v}\vec{v}) = -\nabla p + \nabla \cdot (\bar{\bar{\tau}}) + \rho\vec{g} + \vec{F}$$

3.4 Species transport

The species transport model is a variation of the continuity equation that includes mass change in various species due to chemical reactions as well as mass inflow due to the velocity of each species engaged in the species reaction. The following is a differential representation of the species transfer equation:

$$\frac{\partial}{\partial t}(\rho Y_C) + \nabla(\rho \vec{v} Y_C) = -\nabla.\vec{J_C} + R_C$$

$$\frac{\partial}{\partial t}(\rho Y_{H_2}) + \nabla(\rho \vec{v} Y_{H_2}) = -\nabla.\vec{J_{H_2}} + R_{H_2}$$

$$\frac{\partial}{\partial t}(\rho Y_{CO}) + \nabla(\rho \vec{v} Y_{CO}) = -\nabla.\vec{J_{CO}} + R_{CO}$$

$$\frac{\partial}{\partial t}(\rho Y_{O_2}) + \nabla(\rho \vec{v} Y_{O_2}) = -\nabla.\vec{J_{O_2}} + R_{O_2}$$

$$\frac{\partial}{\partial t}(\rho Y_{H_2O}) + \nabla(\rho \vec{v} Y_{H_2O}) = -\nabla.\vec{J_{H_2O}} + R_{H_2O}$$

$$\frac{\partial}{\partial t}(\rho Y_{N_2}) + \nabla(\rho \vec{v} Y_{N_2}) = -\nabla.\vec{J_{N_2}} + R_{N_2}$$

$$\frac{\partial}{\partial t}(\rho Y_{H_2O(l)}) + \nabla\left(\rho \vec{v} Y_{H_2O(l)}\right) = -\nabla.\vec{J_{H_2O(l)}} + R_{H_2O(l)}$$

$$\frac{\partial}{\partial t}(\rho Y_{CO_2}) + \nabla\left(\rho \vec{v} Y_{CO_2}\right) = -\nabla.\vec{J_{CO_2}} + R_{CO_2}$$

$$\frac{\partial}{\partial t}(\rho Y_{CH_4}) + \nabla\left(\rho \vec{v} Y_{CH_4}\right) = -\nabla.\vec{J_{CH_4}} + R_{CH_4}$$

3.5 Reaction values

The number of reactors required must be determined based on the equation acquired, including the raw material (rice husk) equation, once all of the equations have been examined. First, fix the rice husk composition, then move on to the others. These are carried out in order to facilitate the chemical reaction that is taking place within the reactor.

3.6 Boundary conditions

CHNS/O analysis on rice husk is used to determine the fraction of mass, rate of flow, and temperature of each species. The mass flow intake and medium inlet are assigned to the reactor model. The boundary conditions of the reactor model are set up so that the gas exit is fixed as a pressure outlet and the gasifier wall is not a slip adiabatic wall.

3.7 Grid independency

After the solution converges, the CO, CO_2, CH4, and H_2 compositions are analyzed using grid independence to assess whether the domains are split into 25,000 coarse cells. The number and fineness of the cells are then increased before the compositions are examined. As a result, these values are considered to be the best for cell numbers in this investigation.

4.Results and Discussions

The temperature, heating value, equivalency ratio, and composition of the gas are revealed through numerical simulation. Particle tracking is utilized with the geometric model to determine the composition of producer gas at different gasification zones.

4.1 CFD Modelling

4.1.1 Reactor with different inlet and wall temperature

With an equivalency ratio of 0.2, 0.3, the reactor is fed with intake temperatures of 1073K, 1123K, and 1173K and a wall temperature of roughly 850K. Using two equivalence ratios, Figure 3 displays the yield of gaseous products at various temperatures. When the temperature rises, hydrogen levels rise, and when the moisture content lowers, hydrogen levels fall dramatically.

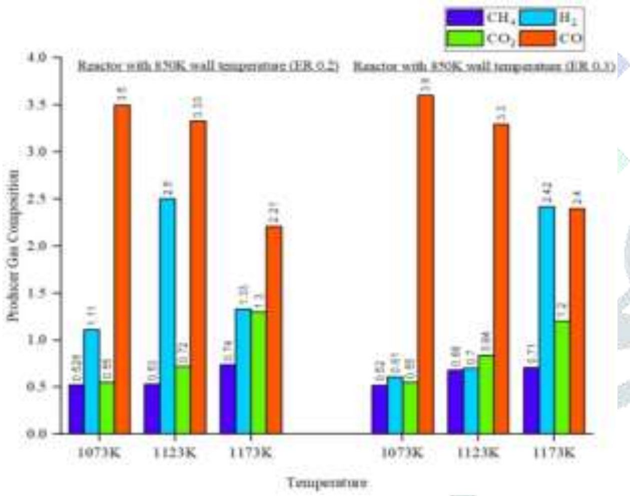

Fig. 3 Reactor with different inlet and wall temperature

4.1.2 Reactor with same inlet and wall temperature

This reactor uses a similar method, but the temperature is different. The reactor is fed with inlet and wall temperatures of 1073K, 1123K, and 1173K throughout the operation. Using two equivalency ratios, Fig. 4 displays the amount of gas produced inside the reactor at various temperatures.

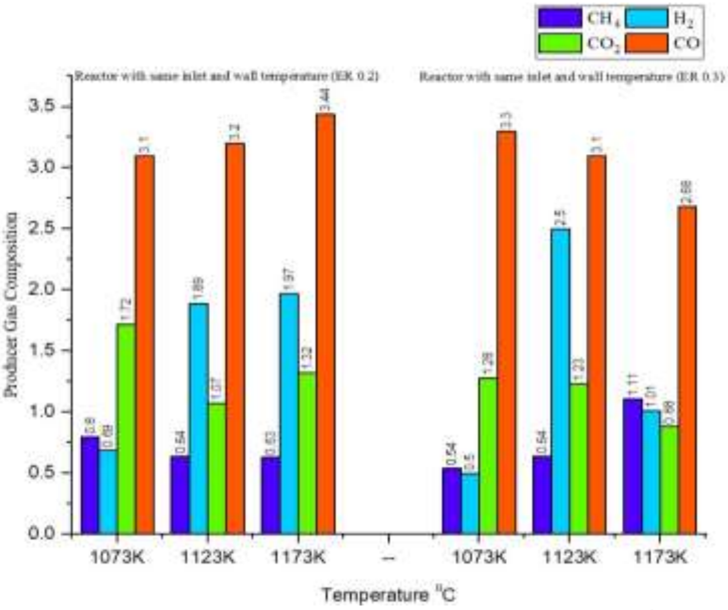

Fig. 4 Reactor with same inlet and wall temperature

4.2 Effect of ER on the gaseous constituents

The Equivalence Ratio (ER) of the biomass is calculated using the air available and the stoichiometric air necessary.

$$E.R. = \frac{Actualairsupplied}{Stoichiometricairrequired}$$

The formula M = [0.1153*C+0.3434*(H-O/8) + 0.0434S] is used to compute the amount of stoichiometric air necessary] kg/kg dry fuel. The composition of the gaseous products is determined both numerically and empirically. The results showed that at an equivalency ratio of roughly 0.30, the amount of CO, CO2, CH4, and H2 is greater. Any deviation from this number in the equivalency ratio (higher or lower) resulted in a reduction in the composition of flammable gas.

4.3. Effect of Temperature

The importance of temperature in pyrolysis reactions cannot be overstated. At lower temperatures, the reactions are more likely to be incomplete, resulting in a lower gas product yield. Excess combustion occurs at higher temperatures, resulting in heat waste during the gasification process. As a result, in this study, the wall temperature was kept constant (850K), but the inlet temperature was altered to 1073K, 1123K, and 1173K, and the fluctuation in output gas concentrations was investigated. The wall temperature was then increased until it was equivalent to the inlet temperature, as shown in Fig. 4.

5.CONCLUSION

In the CFD analysis, the species transport model is applied. Initially, the fractions of CH4, H2, CO2, and CO were 0.526, 1.11, 0.55, and 3.5 at a constant wall temperature of 850K and an ER of 0.2 with an inlet temperature of 1073K, respectively. When the temperature is raised to 1123K, there is a rise in hydrogen, but there is a huge drop in hydrogen when the temperature is raised to 1173K, which is due to a decrease in moisture content. When the ER is increased to 0.3, the concentration of H2 does not improve, which is due to excessive feed stock burning. 4. The ER (0.2,0.3) is varied in the simulation, but the wall and inlet temperatures stay constant.
With an ER of 0.3 and a temperature of 1173K, the highest H2 output is achieved. This simulation result could be used as a starting point for gasifier experimentation.

REFERENCE

1 P.C. Murugan. Species – Transport CFD model for the gasification of rice husk (Oryza Sativa) using downdraft gasifier (2017).

2 QitaiEri, Jing Peng ,Xinjun Zhao. CFD simulation of biomass steam gasification in a fluidized bed based on a multi-composition multi-step kinetic model (2018) 1358– 1368.

3 RatnakarChodapaneedi, NarsimhuluSanke, Dr.D.N.Reddy. CFD Simulation of an Advanced Biomass Gasifier 46 (2016) 174–184.

4 S.Sivakumar, K.Pitchandi, and E.Natarajan. Design and analysis of down draft biomass gasifier using computational fluid dynamics (2015).

5 P. Ranganathan, S. Gu, Computational fluid dynamics modelling of biomass fast pyrolysis in fluidised bed reactors, focusing different kinetic schemes, Bioresour. Technol. 213 (2016) 333–341.