Teknovasi

Jurnal Teknovasi
Volume 08, Number 01, 2021, 14 – 19
ISSN : 2540-8389

Numerical Simulation of Downdraft Biomass Gasifier With Computational Fluid Dynamic

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Submited	:	12 Februari 2021
Revision	:	16 March 2021
Accepted	:	01 April 2021

ABSTRACT

World energy demand has resulted in a surge in renewable energy needs. One of them is biomass. The gasification process takes place in a reactor called a gasifier, and the most effective way is to implement the Fixed Bed method on the downdraft gasifier. The process was executed in a downdraft gasifier because of the gas-making process without stopping the ignition and producing a small amount of tar. The biomass raw material used in this study is wood pellets because of their abundant availability in Indonesia. This research discussed numerical simulations for downdraft gasifier by utilizing wood pellet biomass as a raw material. The simulation technique is computational fluid dynamic with the DPM (Discrete Phase Model) because it can predict the experiment result details more precisely. The simulation results have shown that the convergence rate got better with the longer process iteration time. The simulation results were close to 100% in real-scale laboratory research results.

Keywords : Numerical Simulation, Downdraft, Gasifer, Biomass, Computational Fluid Dynamic.

INTRODUCTION

Based on the world's energy needs, the need for energy continues to increase by approximately 30%, in the next 20 years, countries with rapid economic growth will experience a surge in energy needs of more than 60% of the world's oil needs. Image 1 explained that biomass is one of the alternative energy sources that can be developed to meet the world's energy needs. The distribution of renewable energy consists of biomass as much as 45% of the total energy requirement followed by hydroelectric as much as 25% and the smallest is geothermal as much as 2%.

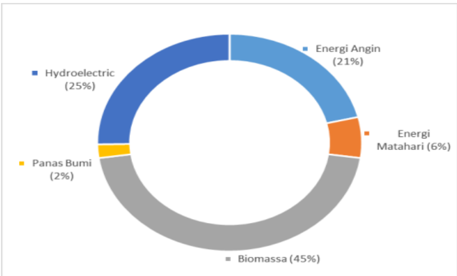

Figure 1. Renewable Energy Needs in the World

One of the renewable and abundant sources of energy is biomass which has been used for a long time. Biomass in the environment is in various forms in the form of pieces of wood in the form of stems, branches of wood, agricultural waste, oil palm trunks, oil palm fronds and others (Fermi, Muhammad Iwan, 2014).

Biomass gasification process is a chemical reaction process at high temperatures between biomass in the form of solid fuel and a gasifying agent to produce gaseous fuel which is known as producer gas. The gasification process takes place in a reactor called a gasifier. Gasifiers are grouped into three groups based on the behavior of the biomass in the gasifier, namely as follows: Fixed bed or moving bed, Fluidized bed and Entrained flow. Each type of gasifier has a different application range and different uses (Simanungkalit, 2013). The stationary bed or mobile bed is applied for power generation between 10 – 10,000 kW, fluidized bed for power generation between 5 – 100 MW, while the entrained flow gasifier is for power plants above 50 MW. Gasifier for fixed bed (Fixed Bed) is the simplest gasifier for low scale and easy to operate (Hsi et al., 2008).

The advantages of gasification using the downdraft gasifier type are that the gasification process can be continuously filled with fuel throughout the gasification process to produce producer gas without having to stop the ignition of the combustion, and besides that the downdraft gasifier produces a little tar, where this tar will reduce the efficiency of the biomass gasification process. Subroto, 2017). Biomass feed stock has its own characteristics that can be developed based on its availability. Sources of feedstock for biomass, especially in Indonesia, have abundant sources of raw materials such as oil palm and wood sources with various variations, one of which is in the form of wood pellets (Telmo & Lousada, 2011). In this study, we will discuss numerical simulations for the downdraft gasifier by utilizing biomass raw materials in the form of wood pellets. The simulation technique uses Computational Fluid Dynamic (CFD) because it has the advantage of being able to predict the details of the experimental results more precisely and the flow distribution is modeled naturally with the Lagrangian equation (Cloete & Amini, 2016).

METHOD

The biomass process used in this research is a gasification process using a thermochemical process. During the gasification process, it will be accompanied by endothermic process where heat is needed from outside the system to ensure the gasification process takes place inside the gasifier. In this study using a downdraft type gasifier with the process of entering wood pellet feedstock from the top of the gasifier, as well as air intake also through the top of the gasifier which is controlled by a flow meter with an air flow rate of 80 L/min. The process of entering the feedstock and oxidizer is shown in Figure 2. The gasifier used has specifications as shown in Table 1.

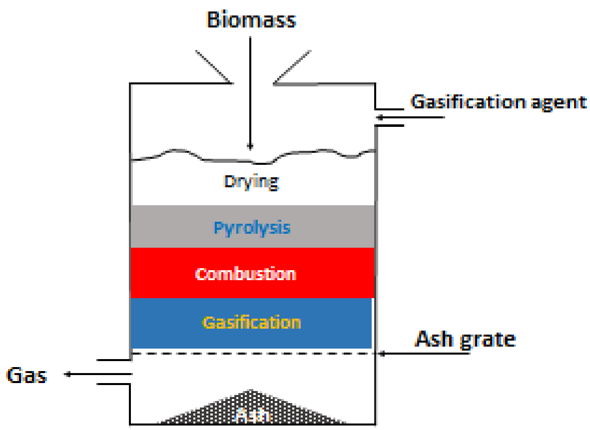

Figure 2. Downdraft Gasifier cross-section in general

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Table 1. Downdraft Gasifier Specification

Downdraft Gasifier Specification	
Diameter	120mm
Long	500mm
Material	Stainless Steel
feedstock	*Wood Pellet*
Oxidizer	Air

*Wood Pellet*as feed stock is used in this research because it has various advantages including having a lower water content compared to wood chip or other types of feed stock (Naryanto et al., 2019; Telmo & Lousada, 2011). The diameter of the wood pellet used on average is about 6 mm with a length of approximately 12 mm. Wood pellets are shown in Figure 3.

Figure 3. *Wood Pellet*for Stock Feeds

The simulation technique used in this study is DPM (Discrete Phase Model) where the gas phase in the simulation is solved using the Navier-Stokes equation and the particle phase motion is solved using Newton's second law of motion. The equations related to the gas phase involved in the mass conversion equation and the momentum conversion equation are as follows:

Where is the volume fraction of the gas phase, is the density of the gas phase, is the velocity of the gas phase, is the velocity of the solid phase, p is the gas pressure divided by both the gas phase and solid phase, is the stress tensor of the gas phase, g is the velocity gravity, and is the coefficient of momentum exchange between the phases from the solid to the gas phase per unit cell volume.

In this study using a downdarft gasifier modeling simulation with *Computational Fluid Dynamic*(CFD) Fluent Ansys 17.2 to get a simulation of counter pressure and velocity head on the gasifier, this aims to see the efficiency of the gasifier. The quantity model selected in Fluent corresponds to Figure 4, Figure 5 and Figure 6 showing the downdraft gasifier cross-section in the experiment and in the CFD simulation.

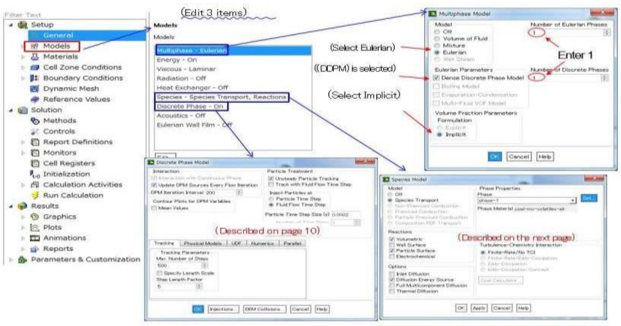

Figure 4. Simulation Menu Options Options on Fluent Ansys

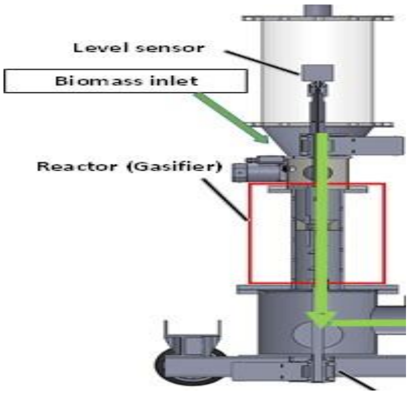

Figure 5. Downdarft Gasifier Cross Section in Experiment

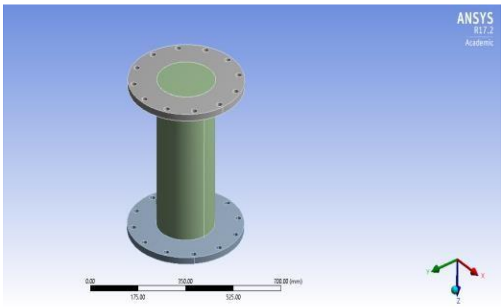

Figure 6. Downdraft Gasifier Section in CFD Simulation

RESULTS AND DISCUSSION

In the simulation process, the first stage must bedo is carry out the design process. After the design process of the gasifier is completed, the next process is to perform the meshing process so that the calculation of each node becomes easier and the calculation results become more precise. 150.37 nodes and 139.12 elements with unstructured grid mesh are used to perform the simulation process and the minimum orthogonal quality with a value of 0.55 and the maximum orthogonal skew quality with a value of 0.37 so that the meshing results are obtained as shown in Figure 7.

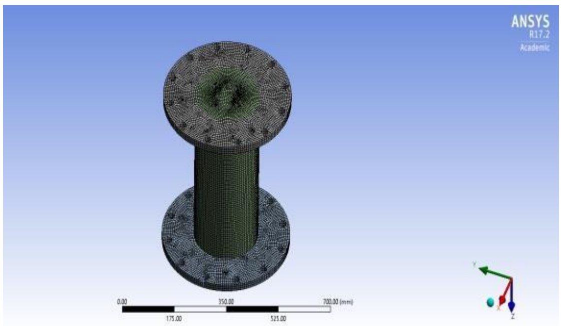

Figure 7. Meshing Results

After the meshing process, the next stage is the iteration process, using a maximum iteration of 50, a time step size of 0.001s and a number of time step 100 and a sampling interval of 1, so the iteration results are obtained as in Figure 8. The results of the residual iteration process show that iteration 3000 has The results are starting to converge, so it can be concluded that the longer the iteration process is carried out, the tendency for convergent results will be obtained and this proves that the simulation calculations are close to the accuracy of the actual results.

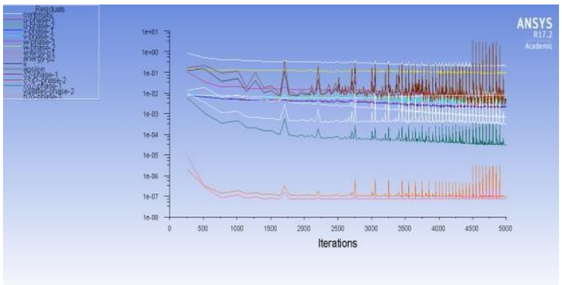

Figure 8. Residual Scaled Iteration Process

The contour of the pressure that occurs in the gasifier during the gasification process can be seen in Figure 9 where it can be seen that the pressure distribution will increase at the bottom of the gasification reactor which is marked in red with a maximum pressure of 2.30e+07. This indicates that the lower you go, the greater the pressure generated from the gasification process and shows that the feedstock is also being transformed into producer gas.

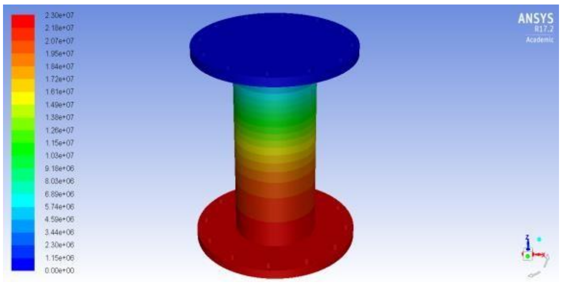

Figure 9. Contour of Pressure

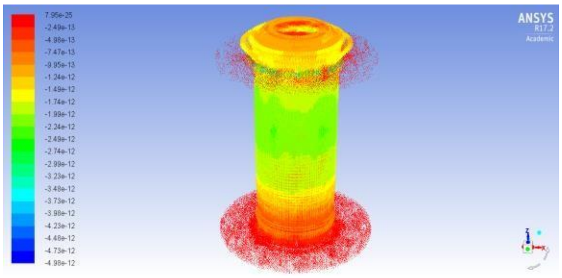

Figure 10. Vector of Velocity Color By Heat of Reaction

Figure 10 shows the vector velocity of the Heat Reaction which explains that the heat from the gasification process occurs evenly and the lowest position of the gasifier experiences the greatest heat distribution process so that most of the wood pellets from the solid phase turn into gas phase and are produced by producer gas, where most of the wood pellets from the solid phase turn into gas phase and are produced by producer gas. gas producers produced are CH_4, CO, CO_2, H_2, and N_2 (Gómez-Barea et al., 2013)(Naryanto et al., 2020).

CONCLUSION

The results of simulations that have been carried out in researchThis shows that the level of convergence is getting better as the process iteration time is getting longer. In addition, at the bottom of the gasifier, the pressure distribution process and temperature distribution will be greater, and if the pressure distribution and heat distribution occur uniformly, the gasification process will be better so that a better gas producer will be produced. From the simulation process, the results are close to 100% with the results of research in the laboratory on a real scale, this is very helpful in the research process because it can save time and effort.

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