

# Optimization Design and Performance of Small-Scale Downdraft Biomass Gasification: A Case Study For Air-Fresh Inlet

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**Abstract:** Biomass is the term for organic compounds, both animals and plants that can be reused as fuel or energy sources. Apart from that, gasification can be interpreted as a process of changing a solid fuel into a gas through thermochemical stages. The fuel used in the downdraft biomass gasification reactor is rice husks and coconut shells. The downdraft type biomass gasification reactor design used Autodesk Inventor professional software and for simulation using Ansys-R2 for 2021 student licensed. As the results after we create modified for inlet fresh-air showed the performance test of the hot start as flame temperature was increased to 21.7°C within the highest temperature reaches to 188.4°C. As a conclusion of modified performance test, we obtained the temperatures of pot-stove are slowly reaches from 6.38°C to 41.75°C of boiling water.

**Keywords:** Biomass, Gasification, Downdraft, Autodesk Inventor, Temperature Performance

## 1. Introduction

Biomass is the term for organic compounds, both animals and plants that can be reused as fuel or energy sources [3]. Biomass is an alternative fuel to replace coal and oil because it can be renewed. Gasification can be interpreted as a process of changing a solid fuel into a gas through thermochemical stages [7]. The place where the gasification process occurs is called a gasifier. In the gasifier, the biomass drying process occurs in the temperature range of 25° to 150°, pyrolysis occurs in the temperature range of 150° to 600°, combustion occurs in the temperature range of 600° to 800°, and gasification occurs in the temperature range of 800° to 1400°.

Biomass gasification is a thermal decomposition process of organic material or biomass by providing an oxygen

supply and continuous heating to produce synthesis gases (CO, H<sub>2</sub>, and CH<sub>4</sub>), small amounts of carbon char and ash. The gas resulting from gasification is called syngas [13]. Gasification stoves are one of the technologies for utilizing biomass cooking needs in the household sector, Biomass gasification is a process of thermal decomposition of organic materials through administration amount of heat with a limited oxygen supply to produce synthesis gases [4].

Coconut shells are the solid part of the coconut skin and are usually considered waste [10]. Rice husks are rice husk waste that has gone through a pounding process [15]. A gasification stove is a tool that implements a gasification working system and biomass as the main fuel for domestic cooking needs [1].

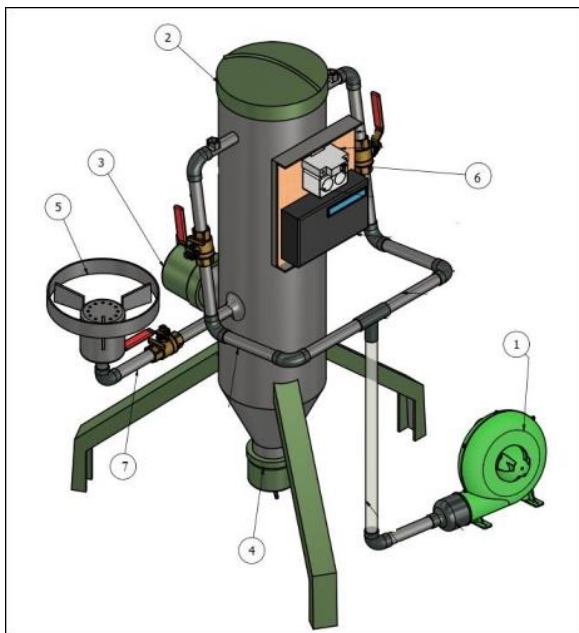
Computer Aided Design is a computer software for drawing a product or part of a product. The product you want to depict can be represented by lines or symbols that have a certain meaning [14]. Ansys is a finite element analysis software with the ability to analyze a wide range of problems. Ansys is able to solve differential equations by breaking them down into smaller elements [8].

FEA or Finite Element Analysis is part of a numerical method that uses matrix operations to solve physical problems. Another method is the analytical method, to do this requires a mathematical equation which is a model of physical behavior [2]. CFD or Computation Fluid Dynamic is a method of fluid mechanics that uses structured data and numerical analysis to analyze and solve problems that contain fluids. In its application, CFD uses algorithmic numbers and computer programs to carry out calculation analysis to obtain accurate data results [5].

Based on the background obtained this time, this research is intended to find out which parameters have a greater influence on the efficiency level of increasing the temperature of a downdraft type biomass gasification reactor.

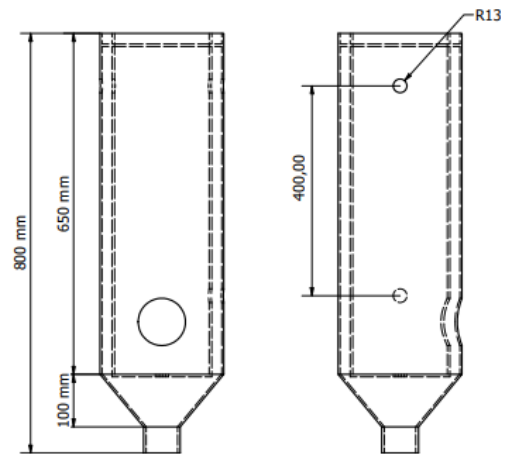
## 2. Method and Materials

Figure 1 shown that our previously designed reactor has two air input directions from one main source.



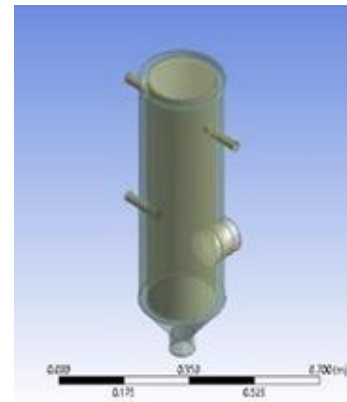
**Figure 1.** Initial reactor design [9]

After creating a 3D model, the next step is meshing, which is the process of dividing the model that has been created into small elements, then each element presents the reaction of the surrounding area. The modifying design was made using Autodesk Inventor 2021 software to create a 3D Reactor model as Figure 2.



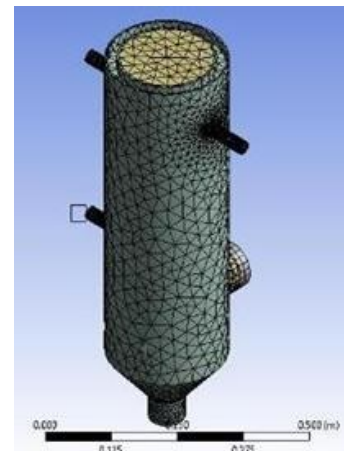
**Figure 2.** Reactor dimensional design.

Figure 3 shown the model design using 3D model, the next step is to import the file into the Ansys software.



**Figure 3.** Importing 3D model

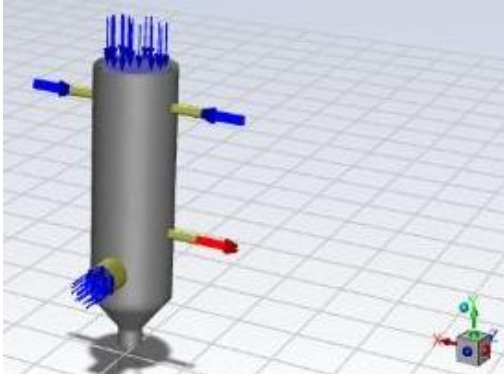
Figure 4 is the mesh model simulation of determining the fluent flow rate or output and input flow rate.



**Figure 4.** Mesh reactor results.

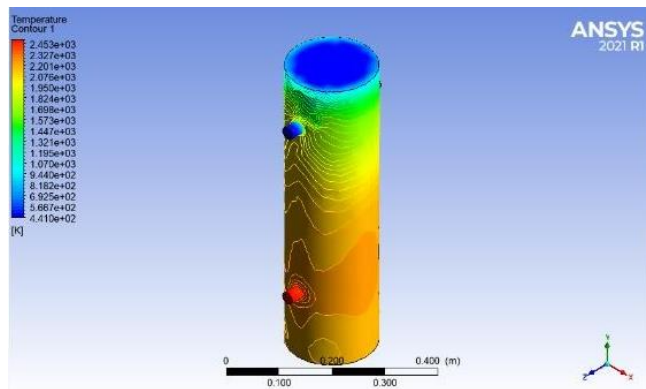
We created the 3D mesh design, the next process is to create a setup which is used to determine the flow rate of the fluent

flow or the output and input flow rate that occurs in the reactor. In Figure 5 is determining the flow rate that occurs in the reactor, the next process is to enter the composition of the components and elements contained in the flow.



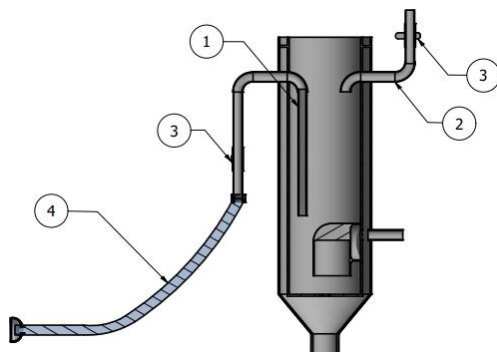
**Figure 5.** Flow air rate simulation

Figure 6 described that the 3D mesh design, the next process is to create a setup Displays the results of the simulation After the data calculation process is complete, the results of the simulation can be seen from the gradient graph by running Results.



**Figure 6.** Final stage simulation results

### 3. Result and Discussions



**Figure 7.** Completely design of reactor gasification for fresh-air inlet

Figure 7 is illustrated the unit design of gasification furnace, we used main configuration 1 to 4 presented as (1) Additional Pipe (2) Fresh Air Output, (3) valves gate control, (4) Fresh-air inlet. The gasification modeling design system that the

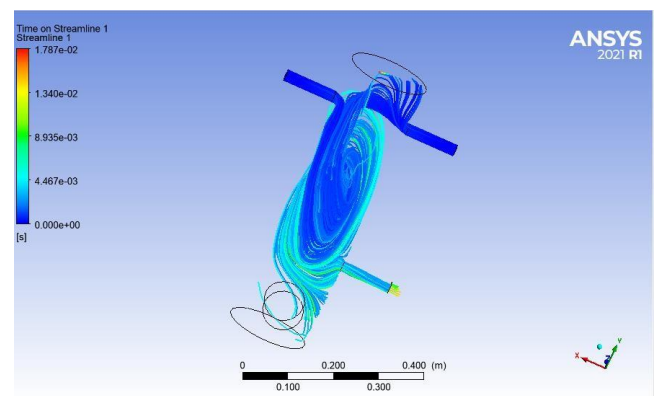
reactor works is by utilizing air input from a one-way blower without dividing the incoming air, for reduce the breakdown of air flow to the reactor and provide additional air channels in the reactor to increase combustion efficiency beginning.

#### 3.1. Optimization Simulation

The simulation process was carried out using a Lenovo V14 series laptop with an Intel Core IC3 Gen 10 processor with a speed of 3.5 GHz and Ansys Fluent 2021 R2 software. By entering the data, model and assumed values obtained, a simulation is then carried out to produce data that can be analyzed.

##### 3.1.1. Initial stage of combustion

The initial stage of this simulation shows the occurrence of the biomass drying process which occurs when the biomass experiences an initial temperature increase and begins to show charcoal formation occurring in the temperature range of 25°C – 150°C that shown on figure 8.

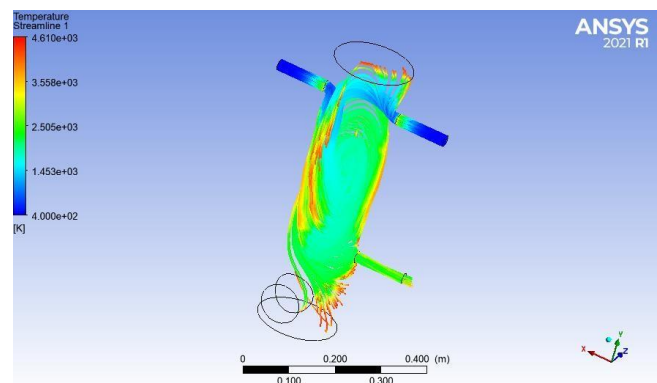


**Figure 8.** Startup temperature simulation

##### 3.1.2. Temperature rise stage

Next is the pyrolysis stage which is the process of forming CO and CO<sub>2</sub> from the reaction of charcoal and volatiles which produces heat which will be used next, occurring in the temperature range of 150°C – 600°C is illustrated to Figure 9.

**Figure 9.** Temperature rises for Pyrolysis model



##### 3.1.3. Formation of methane gas

The next stage is combustion and will occur when biomass charcoal reacts with  $\text{CO}_2$  and water vapor to produce CO and Methane gas, occurring in the temperature range of  $600^\circ\text{C}$ – $800^\circ\text{C}$  that temperature ranges are obtained on Figure 10.

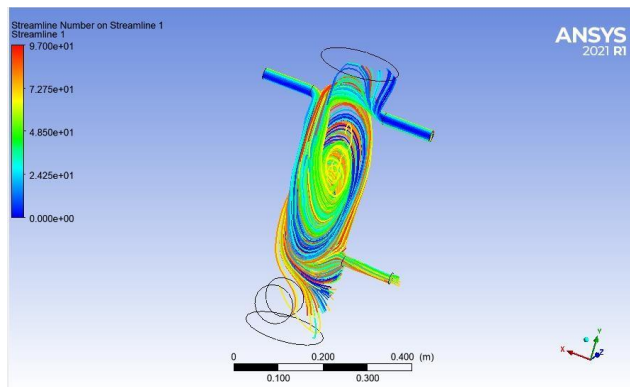


Figure 10. Temperature rises for methane gas model

### 3.1.4. Pressurized of methane gas

The final stage occurs when the thermo-chemical reaction in the gasification reactor reaches equilibrium. Some of the CO formed in the reactor reacts with water vapor and forms  $\text{CO}_2$  and  $\text{H}_2$ , occurring in the temperature range of  $800^\circ\text{C}$ – $1400^\circ\text{C}$  that illustrated to Figure 11.

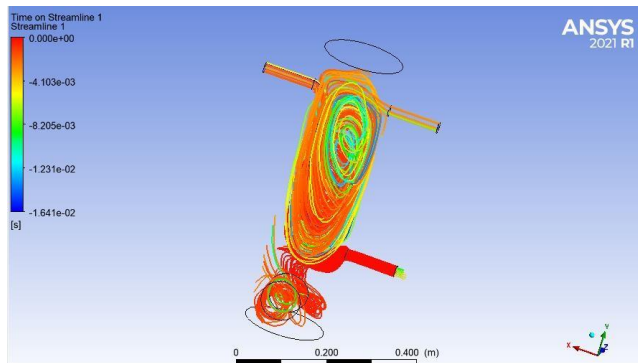


Figure 11. Pressure performance for methane gas reaches

### 3.2. Temperature Performance test

This modified results of fresh-air inlet we obtained for performance test shows that into Figure 12 and Figure 13.

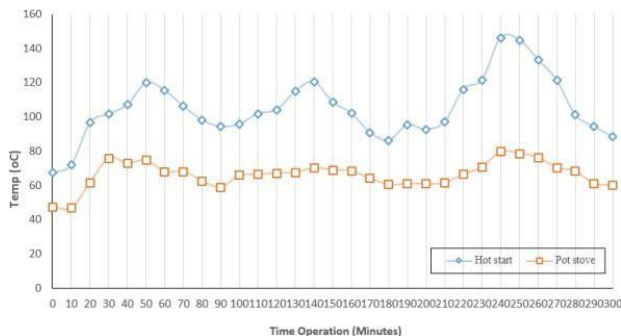


Figure 12. Initial reactor test of temperature rises [9]

Figure 12 illustrated are initial results of performance test that shows the pot stove temperature achieved within 300 minutes

reached an average of  $66^\circ\text{C}$  with the highest temperature value of  $79.5^\circ\text{C}$ . Also the average Hot Start as flame temperature reached  $104.9^\circ\text{C}$  with the highest temperature reaching  $149^\circ\text{C}$ .

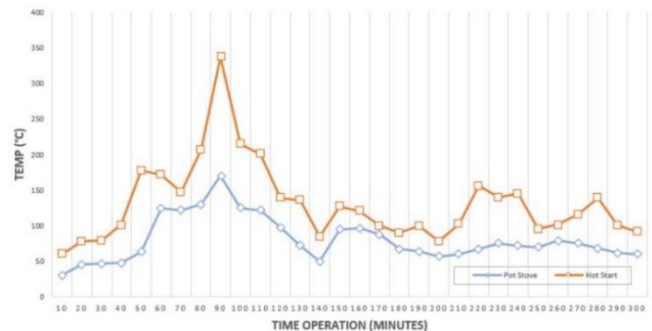


Figure 13. Modified reactor test of temperature rises

In this results study we obtained the performance temperature test after we modified the fresh-air inlet as illustrated on figure 13. The results shows that the stove temperature achieved within 300 minutes reached an average of  $72.38^\circ\text{C}$  with the highest temperature value of  $121.25^\circ\text{C}$ . Then, the average Hot Start as flame temperature reaches to  $126.6^\circ\text{C}$  with the highest temperature reaches to  $337.4^\circ\text{C}$ .

## 4. Conclusion

In this research, we have been modified, assembly and thermal performance test. Also, we used the estimated energy (5.314 kJ/hr) for cooking required for one family in Indonesia. As the results after we create modified as inlet fresh-air for the performance test illustrated that the hot start as flame temperatures were increased to  $21.7^\circ\text{C}$  with the highest temperature reaching to  $188.4^\circ\text{C}$ . As a conclusion of modified performance test, we obtained the temperatures of pot-stove are slowly reaches from  $6.38^\circ\text{C}$  to  $41.75^\circ\text{C}$  of boiling water.

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