NUMERICAL AND EXPERIMENTAL STUDY ON ROCKET STOVE COMBUSTION PROCESS FOR HEATING STIRLING ENGINE

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ABSTRACT

Indonesia has a problem on electricity supply, especially in remote areas. This is indicated by the electrification ratio in Indonesia which is only 88.3% with main shortage in remote areas. One of solutions to this problem of electricity in remote areas is small-scale power plants. One of the small-scale power plant is Stirling Engine, because it can use heat from various energy sources. One source of energy that can be utilized in Indonesia is biomass. With potential of 32 GWe. One of the biomass that is available and can be utilized in Indonesia is bamboo. However, the water content, heat value, and chemical composition of bamboo will greatly affect the combustion process in the furnace.

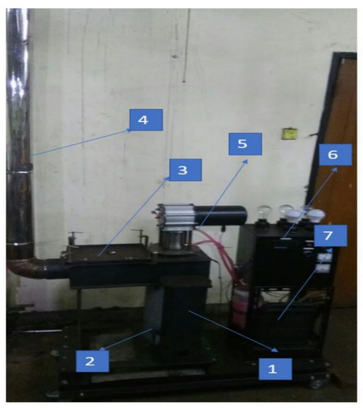
In this study, Rocket Stove type furnace, is used as the heat source of 200 W Stirling Engine. Rocket Stove is a stove that utilizes a stack effect as a combustion air provider. This research consists of simulation, experimental, and evaluation steps. The numerical simulation step was aimed to get predicted mass flow rate of fuel. The experimental step was aimed to obtain the Rocket Stove temperature distribution. Lastly, The evaluation step was aimed to analyze the characteristics of heat flue gas absorber and the efficiency of Rocket Stove.

The results obtained from this research are the fuel rate required to produce sufficient heat to meet the heat requirement of Stirling Engine is 3.28 kg / h in bamboo and 1.43 kg / hr in LPG. The average temperature distribution before the Heat Exchanger reached 788 ℃ and the standard deviation of 61 ℃ on the bamboo and the average temperature distribution before before the Heat Exchanger reached 725 ℃ and the standard deviation of 3 ℃ on LPG. The effectiveness of heat exchanger used is 68%. The conclusion obtained from this research is bamboo can be used as a heat source Stirling Engine capacity 200 W.

Keywords: Rocket Stove, Stirling Engine, bamboo, CFD, heat exchanger

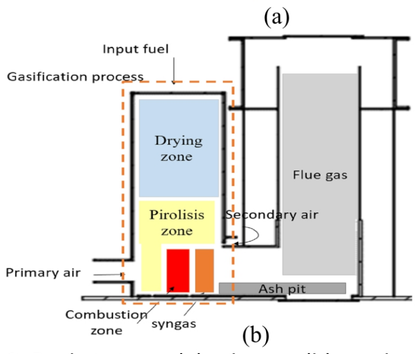
INTRODUCTION & BACKGROUND

In this study, combustion on Rocket Stove used as the heat source of 200 W Stirling Engine. Rocket stove include wood stove category, where the source of air combustion come from natural draft that exist because of stack effect



Component
1. Feeder
2. Furnace
3. Stove
4. Chimney
5. Stirling engine
6. Electrical load
7. Radiator & cooling water

(a)



(b)

Figure 1. Rocket stove: (a) scheme; (b) combustion process.

METHODOLOGY

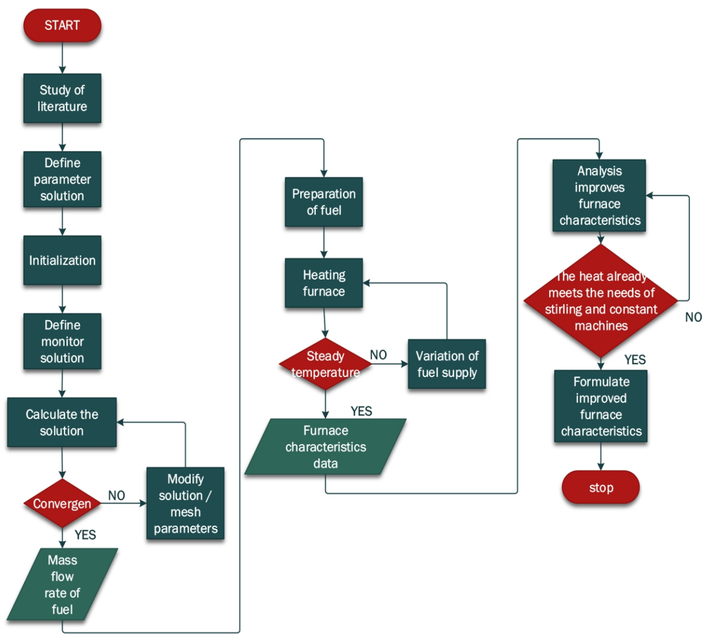


Figure 2.Methodology.

RESULT AND ANALYSIS

SIMULATION STEP
The simulation steps start with finding a device that function as a heat sink as a replacement of the stirling engine- rocket stove cogeneration that has a constant heat transfer, so in this research we used a heat exchanger. In this research The CFD model that use this research is shown on figure 4.a. By varying the fuel massflow than we can predict the contour temperature that happened on rocket stove, this is shown on figure 4.b. the figure shown that the increase of fuel massflow will resulting the increase of temperature.

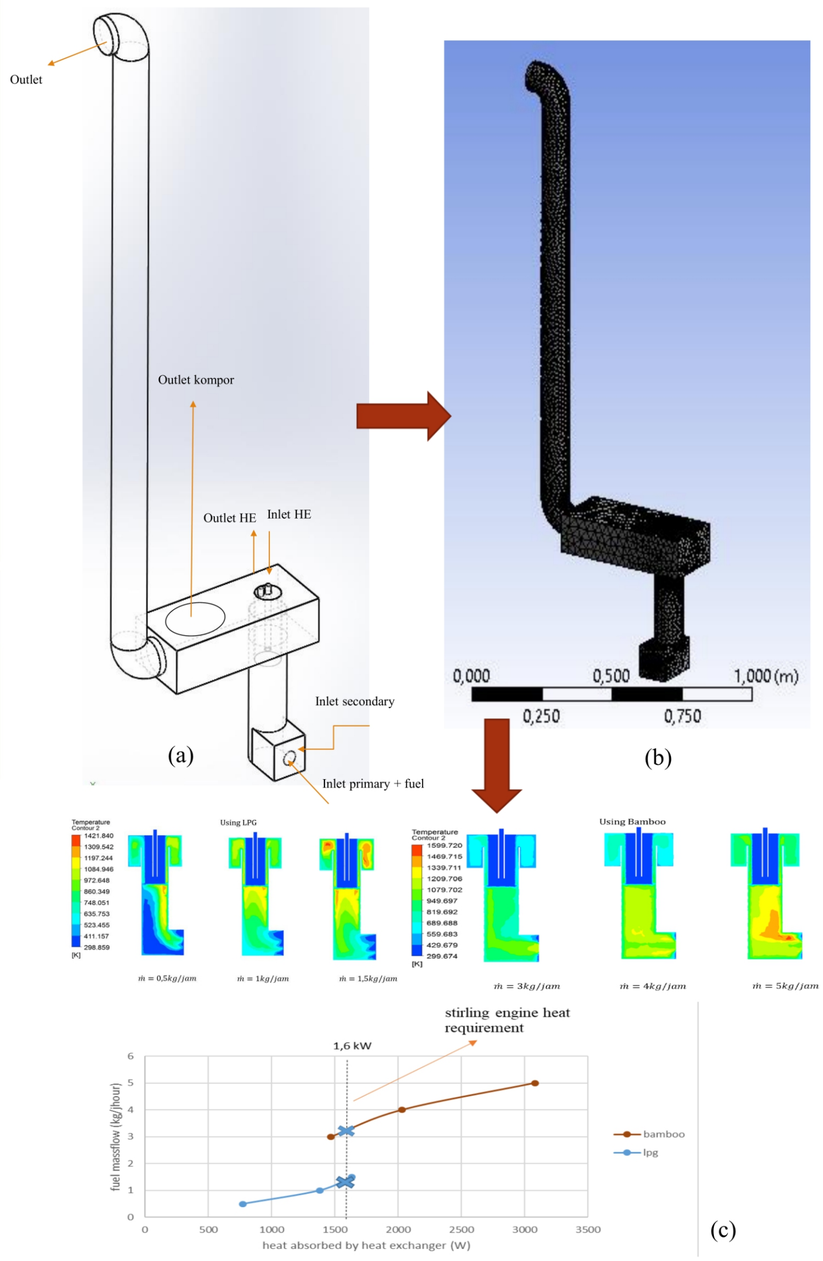


Figure 3.Simulation step: (a) rocket stove boundary condition; (b) meshing; (c) results.

EXPERIMENTAL STEP
The experimental step was done by doing the combustion process with the massflow amount as according to the simulation process. That was 1 kg/hour for LPG and 3 kg/ hour for Bamboo

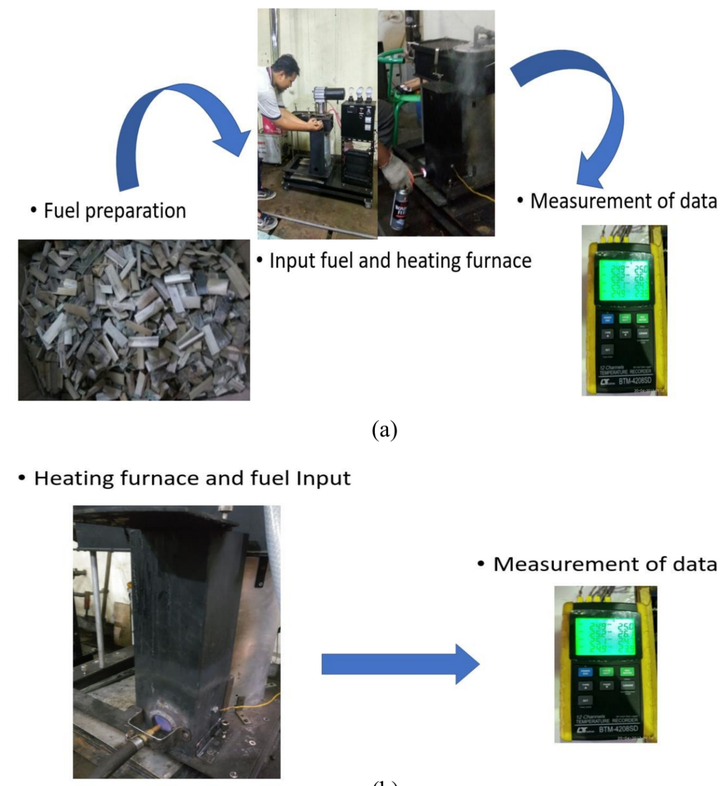


Figure 4 Experimental step: (a) bamboo; (b) LPG.

EVALUATION STEP
This step is containing about the comparison temperature distribution between the simulation process and experimental process. From this result we can see that the area that difference the most were area 2 that was the flame area, where in experiment this area was measure uniformly by thermocouple. On the other hand, on the simulation the temperature value was on specified point. Other less we can conclude that the simulation can be representative for the experimental process.

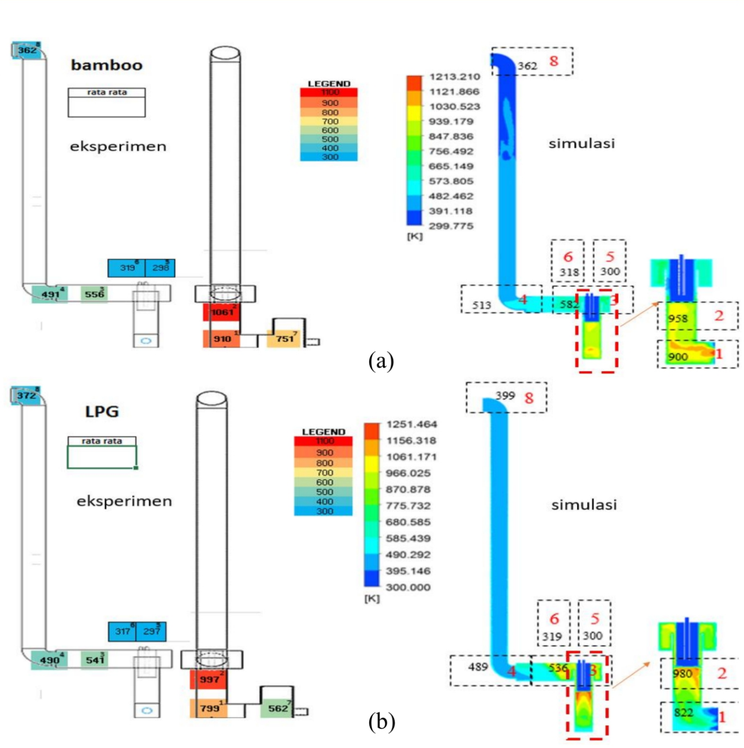


Figure 5. Temperature distribution between the simulation process and experimental process: (a) bamboo; (b) LPG.

The use of LPG produces heat constantly but still under the heat requirement of stirling engines. The use of bamboo produces unstable heat but in some conditions, it produces heat above the stirling engine heat requirement & by using interpolation required temperature of 840 Celsius to produce 1.6 kW.

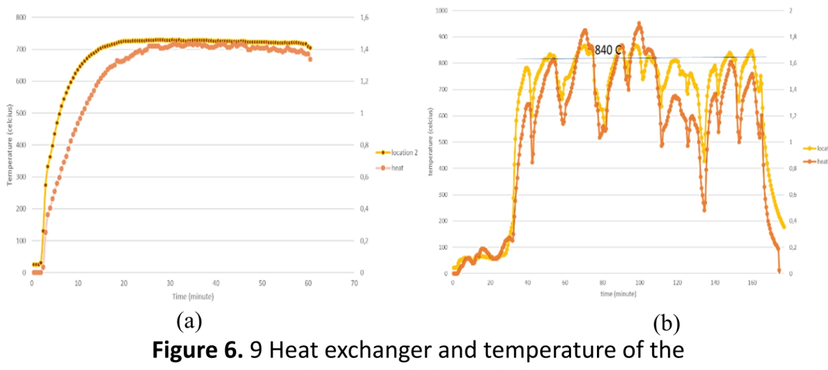


Figure 6. 9 Heat exchanger and temperature of the combustion room (a) LPG, (b) Bamboo

On this research, there were also compared between the temperature and efficiency using heat exchanger and stirling engine itself.

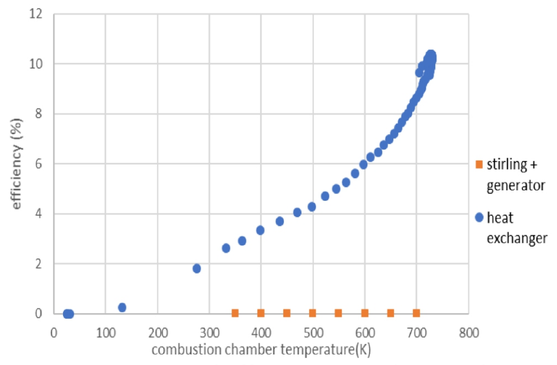


Figure 7. Temperature and efficiency using heat exchanger and stirling engine.

We can get that the more temperature that happened in this experiment the more efficiency that happened weather on using heat exchanger and stirling engine. The highest efficiency was 10,36 % for heat exchanger and 0,09% for stirling engine, both at 700 ℃.

CONCLUSION

- Based on the simulation results, the fuel rate required to generate 1.6 kW heat to meet the stirling engine heat requirement is 1.43 kg / hour in LPG and 3.28 kg / h in bamboo
- Based on the experimental results, temperature is required in the area before heat exchanger to produce sufficient heat to meet the stirling engine heat requirement of 1.6 kW was 840℃
- The deviation of the temperature distribution between the experimental results and the simulation ranges from 1 - 103℃
- The highest efficiency was 10,36 % for heat exchanger and 0,09% for stirling engine, both at 700 ℃.

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