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Design of A Portable Solid-Fuel Rocket Stove

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ABSTRACT

The depletion of fossil fuels is a hot topic of discussion these days. This is due to the increasing use of fossil fuels in human life. In terms of the increase in fuel and gas prices, we realise that the energy consumption that is increasing from year to year is not balanced with the availability of energy sources, which affects households that use fuel in the cooking process. So a design was carried out to make an ergonomic solid fuel stove with the aim of not using fuel anymore in the cooking process, in this design, the stove is designed to be more flexible and get a portable biomass rocket stove design by considering social aspects, performance, local resources, economy, environmentally friendly. Biomass fuels are solids, liquids or gases produced from organic matter.. Biomass fuels used in solid fuel stoves such as firewood, charcoal, briquettes and pellets. Each biomass fuel has different properties and characteristics. The designed portable rocket stove consists of several main parts namely combustion chamber, chimney, air duct, pan spot and cassing, using stainless steel material. The test results include combustion chamber and water temperature during the process, thermal efficiency, combustion rate and specific fuel consumption under cold start and hot start conditions. After hot start, it is found that the use of a chimney on a portable stove designed using coconut shell fuel is more effective than without a chimney. Shorter boiling time of 1 minute, greater combustion rate of 0.13 grams/minute, higher thermal efficiency of 2% and lower specific fuel consumption of 9.11 grams/litre of water when the stove uses a chimney.

Keywords: Biomass Fuel, Rocket Stove, Chimney.

Introduction

The increase in the price of fuel (especially kerosene) and gasoline (LPG) has made us realise that energy consumption, which is increasing from year to year, is not balanced by the availability of these energy sources. Scarcity and rising oil prices will also continue to occur due to its non-renewable nature. This must be immediately balanced with the provision of alternative energy sources that are renewable, abundant, and cheap so that they are affordable to the wider community. Apart from its scarcity, fossil fuels also have a very serious impact on the environment. The use of fossil fuels will cause global warming due to its combustion residue in the form of CO and CO_2 gases. Some examples of fossil fuels that are commonly used in household activities include Liquefied Petroleum Gas (LPG) and kerosene, This is why many people in rural areas have switched to using traditional stoves for cooking. Converting a conventional furnace to a biomass furnace model that has a higher efficiency level is required. Traditional stoves also have many problems that occur in operation including the first: It is not easy to stabilise the size of the furnace flame, especially at the start of ignition, so it takes

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several minutes to stabilise the flame. Secondly: The use of the furnace requires additional energy or kerosene as ignition to get the flame. Third: The difficulty of extinguishing the fire.

To overcome the three problems in the furnace, there are several researchers who have made a biomass rocket stove, which is one of the modern stove innovations that use biomass energy as the main energy source. The rocket stove is designed for improving fuel efficiency with thermal efficiency, a combination of improved combustion efficiency and heat transfer associated with solid fuel combustion, The working principle of the rocket stove is that when the stove is lit, the fire gets enough oxygen due to the air opening at the bottom of the tube. The heat will be channelled through a vertical tube and exit at the top end. So this stove will produce more efficient combustion because all the fuel will burn completely and will produce less smoke than conventional stove stoves.

The purpose of this design is to design a portable biomass rocket stove by considering social, performance, local resources, economic, and environmental aspects and to obtain rocket stove innovations in terms of form and function, with the height of the combustion chamber to the adjustable pan spot.

Improved cook stove (ICS) is a system that burns biomass fuel to generate heat from combustion and is used in domestic cooking. ICS can also be utilised in other ways depending on the design and purpose of the user. Such a stove is called an Improve Stove (IS) which can be used for many applications such as cooking, food preservation, drying, space heating, as well as for social and cultural activities, In addition to using the principle of combustion, stove design also requires the field of heat transfer science so that the heat generated by the fuel can be used optimally. Heat transfer is the process by which heat generated by combustion is transferred to surfaces that absorb heat. The science of heat transfer is used to reduce the heat losses that occur when the stove is operating. The biomass rocket stove is one of the modern stove innovations that uses biomass energy as the main energy source.

Rocket stoves are designed to improve fuel efficiency by thermal efficiency, a combination of improved combustion efficiency and heat transfer associated with burning briquetted fuel. The working principle of the rocket stove is that it is made of two horizontal tubes for placing wood fuel and an air opening at the bottom, which is connected to a vertical tube as a heat sink so that the stove will be shaped like the letter "L" or "J" When the stove lights up, The fire gets enough oxygen because of the air opening at the bottom of the tube. The heat will be channelled through a vertical tube and exit at the top end, so that this stove will produce more efficient combustion because all the wood will burn completely and will produce less smoke than conventional stoves, stove testing generally uses the Water Boiling Test (WBT) method. WBT is a test of furnace performance by boiling water in a pot, which aims to determine the amount of energy produced from fuel that is transferred to a pot containing water at the WBT method, data can be obtained in the form of thermal efficiency on the stove and can be found using the following equations:

$$\eta_t = \frac{C_p \times m_w \times (T_{w1} - T_{w0}) \times h_{fg} \times m_s}{m_f \times LHV} \quad [1]$$

In the stove manufacturing process Sheet metal working includes cutting and forming operations performed on relatively thin sheets of metal. Common sheet metal thicknesses are between 0.4 mm (1/64 in) and 6 mm (1/4 in) for thicknesses exceeding about 6 mm, stock is usually referred to as plate rather than sheet, while for bending and drawing it is used to form parts. sheet metal into the desired shape.

While for determining the stretch in the bending process the stretch length is used:

(L) = a + b + c [2]

c = S/360 x (π x (R+t/2)2) [3]

Methods

The manufacturing process of this biomass-fueled portable rocket stove is as follows:

a. Design the shape of the tool by drawing using Computer Aided Drawing (CAD) in accordance with the desired achievements.

b. Selecting suitable materials that are suitable for the manufacture of portable rocket stoves (in this case, the material must be lightweight, resistant to high temperatures and easy to perform machining).

c. Measurement and drawing stages on the materials to be used in accordance with the predetermined dimensions.

d. Next, cut the material according to the size and drawing.

e. Bending the cut plate according to the shape that has been designed.

f. Connection process using rivets.

g. Assembly process steps on all molded components.

Table 1. Materials required in the manufacture of a portable rocket stove.

No	Name	Type	Size
1	*Aluminium Plat*	5083 *Shipbuilding*	1 m x 1 m x 2 mm
2	*Stainless Plat*	316	0.5 m x 0.5 x 0.8 mm
3	Rivets	Aluminum rivets	Ø 3 mm
4	Insulan	*Rockwall*	200 gr
5	Coconut shell	-	2 kg
6	Water	-	2 kg

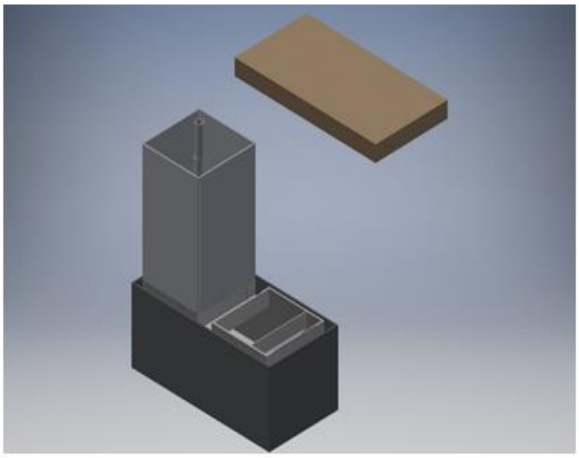

Figure 1. Portable rocket stove design

Table. 2 Size of portable rocket stove

Components	Parameters	Size (mm)
Combustion chamber	High	69
	Width	83
	Length	114
Chimney	High	170
	Width	100
	Length	100
Primary air duct	Width	60
	Length	10
Secondary air duct	Width	11
	Length	100
Casing	High	124
	Width	135
	Length	235
Pan spot	High	20
	Length	60

For the working scheme of the portable rocket stove, it is shown in the following figure

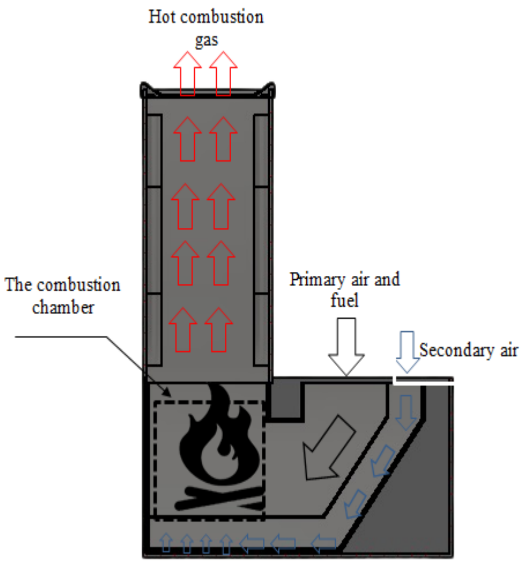

Figure. 2. Schematic of the rocket stove

In the design of the combustion chamber, the material used is taken into consideration. This consideration is to avoid damage to the stove, because the combustion chamber is the part that is at the highest temperature. The material used in the combustion chamber must have a melting point above or equal to 800°C, so the

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designed biomass stove combustion chamber uses stainless steel material which has a melting point of 1390^0C – 1440^0C.

In this study, the Water boiling test method was carried out using a hot start in the form of a condition where the test starts with the condition of the furnace or stove in a hot state (the stove is used directly after completing the cold start test). The hot start procedure is as follows:

a. Filling a pot with water weigh 1000 gr.

b. Prepare the fuel (coconut shell & charcoal) to be used weighing 1 kg.

c. Perform fire starting and calculate the time required during the fire starting process.

d. Measure the temperature of the combustion chamber, flame tongue, outer furnace outer pot and water at the time of boiling.

e. Calculating the time taken to boil water.

f. Switch off the flame when the water has reached boiling point.

g. Weigh the remaining fuel.

h. Weigh the ash content.

i. Weigh the burnt charcoal.

j. Weigh the remaining water in the pot.

Results and Discussions

a. Temperature rate

The test results include the temperature rate of the combustion chamber and water during the process, thermal efficiency, combustion rate and specific fuel consumption under cold start and hot start conditions.

From the graph above, it can be explained if the contour graph generated from the hot start temperature test in the combustion chamber tends to increase faster than cold start, this is , chamber in the combustion chamber from the start of operation is higher than that at hot start.

From the results of the tests carried out there was an increase in the hardness of the stove combustion chamber wall using aluminium material. This is due to the combustion chamber temperature approaching or touching the melting temperature of aluminium, thus changing the characteristics of the material used, but no serious damage to the stove such as melted material occurred.
The results of the temperature rate test on the portable rocket stove, where data is taken at every minute can be seen in Figure, 3 for the temperature rate in the combustion chamber.

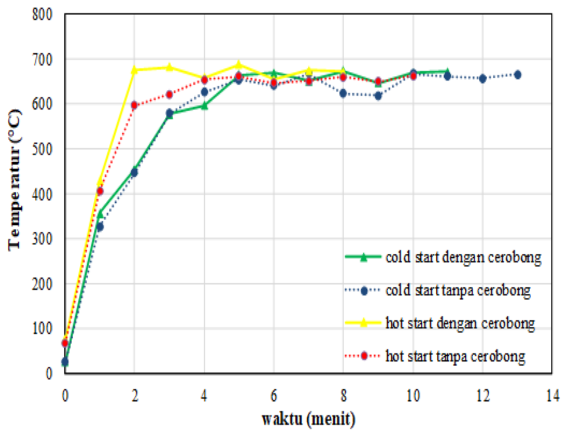

Figure 3. Temperature rate in combustion chamber

b. Temperature rate of water

The results of tests carried out on portable rocket stoves can be explained for stoves that use chimneys and do not use chimneys, It is clear that the time taken to reach the boilling point is shorter in the stove with the chimney with 8 minutes for hot start operation and 11 minutes for cold start operation.

Next a portable stove that does not use a chimney only takes 10 minutes during hot start operation and 14 minutes for cold start operation, this is because the stove does not use a chimney, so the fire does not provide a rocket effect resulting in a lot of heat wasted from the fire on the side of the pan. Furthermore, for stoves using a chimney, it gives the effect of a concentrated flame (rocket) from the bottom of the pot, resulting in less heat being wasted over the sides of the pot.

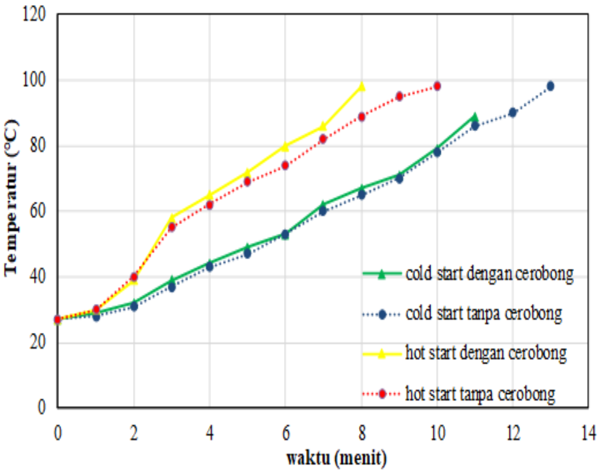

Figure 4. Temperature rate using chimney & without chimney

As for the comparison of the fire generated from the fuel used by portable stoves using a chimney and not using a chimney.
As follows: For stoves that do not use a chimney, it is better to use charcoal fuel because charcoal has a short flame tongue, for portable stoves designed using chimneys it is better to use shell fuel because the fire produced is better compared to charcoal fuel in a stove without a chimney, This is because the fire produced by the shell is more centralised and does not spread according to the size of the designed chimney.

In the cold start test, we can see that the use of a chimney on a portable stove designed using coconut shell fuel is much more effective than a stove without a chimney using charcoal fuel, where the water boiling time is 1 minute shorter, while the combustion rate is 0.2 grams/minute greater, while the thermal efficiency is 1.16% higher and the specific fuel consumption is 5.13 grams/litre of water lower when the stove uses a chimney, and more efficient use of fuel and higher efficiency.

It can be concluded that the use of coconut shell fuel is more suitable to use a chimney in the operating company. The results of the cold start testing process using the chimney can be seen in the table. 3

Table. 4 Cold start test results

High Power Test (Cold Start)	Units	With a Chimney	No Chimney	*Average*	*St Dev*
Time to boil Pot	min	12	13	12.5	1.0
Burning rate	g/min	29.27	28.82	29.05	0.32
Thermal efficiency	%	24.12%	22.48%	23.3%	1.16%
Specific fuel consumption	g/liter	111.59	118.85	115.22	5.13
Firepower	watts	8,626	8,491	855.88	95.3

Hot start test results as described in table 5 above, for portable stoves using a chimney designed using coconut shell fuel more effective than portable stoves that do not use a chimney.

Table 5. Hot start test results

High Power Test (Hot Start)	Unit	With a Chimney	No Chimney	*Average*	St Dev
Time to boil Pot	min	8	9	8.5	1.0
Burning rate	g/min	37.73	37.92	37.82	0.13
Thermal efficiency	%	25.25	22.93	24.09	0.02
Specific fuel consumption	g/liter	94.44	107.32	100.88	9.11
Firepower	watts	11,118	11,174	11146	39.6

The test results obtained from boiling more time achieved a short 1 minute, where the resulting combustion rate is greater than 0.13 grams/minute, From the more efficient use of fuel and higher efficiency, it can be stated that the use of coconut shell fuel is more suitable to use a chimney on the stove.

c. Analysis of Production Cost

Table .6. material price specifications for making portable rocket stoves

No	Description	Phisik	Price (Rp)	
			Unit	Amount
1	*Alumunium Plat*	0.8 kg	30.000/kg	24.000
2	*Stainless Plat*	0.25 kg	69.000/kg	17.250
4	*Rock Woll*	0.1 kg	74.000/kg	7.400
5	Hinges	8 buah	5.000/buah	40.000
6	River Plate	88 buah	115/buah	10.120
7	Manufacturing Cost	-	200.000	200.000
	Amount			**298.770**

From the material costs and manufacturing costs for one unit of this portable rocket stove for marketing it can be sold at a price; 300,000,- IDR per unit, This is very affordable for the middle to lower class people as well as for community groups who like Camping and hilling.

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Conclusions

1. The rocket stove that has been designed has good mobility (portable) because the chimney used on the stove can be dismantled, with the dimensions of the stove when it is in the casing of 124 mm x 135 mm x 235 mm.
2. The manufacturing process of the stove was carried out using the following methods: cutting, bending and drilling, for joining plates using a hand riveter with rivets of 3 mm diameter and making rivet holes of 4 mm. while the bending process is used with a curved side length of 3.14 mm.
3. For efficiency and specific fuel consumption viz: 9.11 grams/litre of water when the stove uses a chimney. From the use of fuel that is more efficient and higher efficiency, compared to the stove not using a chimney with charcoal fuel.

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Author Contributions

The concepts, research method as well as the manufacture of the stove were carried out by: Aljufri and Riki Mardian. While for Validation and completeness of the research was carried out by: Reza Putra and Abdul Rahman

Conflicts of Interest

The authors declare no conflict of interest

References

[1] Almuzakir dan Setiawan, A. (2021). Performance Test of a Household Rocket Stoves Fired with Coconut Frond, Coconut Shell and Bamboo. *International Journal of Research and Review*, *8*(1), 59–64. https://doi.org/10.52403/ijrr.20210107

[2] Barnes, D. F., Openshaw, K., Smith, K. R., and Van der Plas, R. (1994). What makes people cook with improved biomass stoves. *World Bank Technical Paper, 242*, 2004.

[3] B.Sutar, K., Kohli, S., Ravi, M., & Ray, A. (2015). Biomass Cookstoves A reviem of technical aspects. Renewable and Sustainnable Energy Reviews 41, 1128-1166.

[4] Bryden, M., Still, D., Scott, P., Hoffa, G., Ogle, D., Bailis, R., and Goyer, K. (2005). *Design principals for wood burning cook stoves*. Aprovecho Research Center.

[5] E. Widawati, S. O. (2019). Kompor Rocket Berbahan Bakar Briket Indonesia. Seminar Nasional AVoER XI 2019

[6] Febriansyah, H., Setiawan, A., dan Suryopratomo, K. (2013). Optimasi Desain Kompor Cangkang Kelapa Sawit. *Jurnal Teknofisika*, *2*(3), 69–74.

[7] Ferguson, C. R., & Kirkpatrick, A. T. (2016). *Internal combustion engines: applied thermosciences. Third*. John Wiley and Sons.

[8] Khan, S., Hossain, T., dan Rahman, M. (2016). Development of Portable Rocket Stove and Performance Evaluation. *International Research Journal of Engineering and Technology*, *3*(12), 36–44. www.irjet.net

[9] Khurmi, R. S., and Gupta, J. K. (2005). Machine Design. In *Garden* (Issue I).

[10] Mikell, P. (2010). Groover Fundamentals of Modern Manufacturing. *Materials, Processes and Systems, 4th Ed.; John*

Wiley and Sons: Hoboken, NJ, USA, 395–403.

[11] Nayan, A., Setiawan, A., Asnawi, A., Siska, D., Ridara, R., & Pertiwi, I. A. (2021). Pemanfaatan Teknologi Kompor Roket Biomassa untuk Mengurangi Ketergantungan Terhadap Bahan Bakar Fosil di Desa Keude Krueng Kecamatan Kuta Makmur Aceh Utara. Jurnal Solusi Masyarakat Dikara, 1(1), 21-26.https://doi.org/10.1234/jsmd.v1i1.5

[12] Sheasby, P. G., Pinner, R., and Wernick, S. (2001). *The surface treatment and finishing of aluminium and its alloys* (Vol. 1). ASM international Materials Park, OH.

[13] Wahyono, Y., Sutanto, H., dan Hidayanto, E. (2017). Produksi gas hydrogen menggunakan metode elektrolisis dari elektrolit air dan air laut dengan penambahan katalis NaOH. *Youngster Physics Journal*, *6*(4), 353–359.

[14] Widawati, E., Octaviani, S., Lauwrence, L., dan Sudharma, L. R. P. (2019). Kompor Roket Berbahan Bakar Briket Biomassa. *Prosiding Applicable Innovation of Engineering and Science Research*, *2019*, 1053–1060.

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