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Experimental study of the effect of plate curves on solar stove

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ABSTRACT

In the midst of various other energy needs, cooking has received special attention in energy consumption due to the scarcity of fuel for cooking which is currently commonly used by the community. The scarcity is directly proportional to the increase in fuel prices. Currently, many alternative energies are being developed, one of which is cooking using solar power. In this study, an experimental study of the effect of the number of plate bends on the solar cooker carried out. This study aims to determine the effect of the number of curvatures of the plate on the performance of a solar cooker. The number of curved aluminum plates in the solar cooker was expected to be able to expand the area of absorption of solar heat, thereby increasing the temperature of the air inside the solar cooker. The solar cooker also adds an absorbent plate in the shape of a flower-like arc. Variations in the number of arches to be studied are 6, 8, and 12 arches. The method used in this study is an experiment in actual conditions. Research result show solar stoves with 12 curved walls have a higher temperature increase and heat absorption compared to 6 and 8 arches. This is because 12 arches have a wider solar heat absorption area.

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INTRODUCTION

Human life is inseparable from the cooking process that produces food intake. This intake is needed so that humans have energy to carry out activities. Amidst various other energy needs, cooking receives special attention in energy consumption due to the scarcity of cooking fuel that is currently commonly used by the community. The scarcity is directly proportional to the increasing price of fuel. Currently, many alternative energies are developed, one of which is cooking using solar power. In addition, conventional energy sources for the cooking process commonly used in most communities cause respiratory diseases. This is because it produces pollutants in the form of combustion of fuels such as firewood (Chaudhary & Yadav, 2020). The World Health Organization estimates that three billion people cook with biomass and coal causing 4 million deaths per year from inhaling these emissions. In addition to the dangers of indoor air pollution, cooking over an open fire also results in CO emissions. The negative effects of current cooking methods can be reduced with the use of solar cookers (Watkins et.al., 2017). In Indonesia, cooking activities are not only for household activities but most of the business sector is in the form of cooking activities. This is shown by the number of culinary industries in Indonesia and the business in this field continues to increase. Developing the utilization of solar power is a challenge for the people of Indonesia. This is very likely to be realized considering that Indonesia has sufficient solar potential with several regions. Currently, many alternative energies are developed, one of which is cooking using solar power known as solar cookers. Solar cooker technology converts sunlight energy into heat energy, energy that does not consume fossil fuels and does not produce pollution, and most importantly is durable with very little maintenance. In addition, solar cookers are an attractive alternative to solar energy that can save time, energy and fuel and are environmentally friendly (Abu-Hamdeh & Alnefaie, 2019). Many studies on solar cookers have been conducted using experimental methods, including experiments on two twin vessels conducted in India (Magendran et.al., 2019) and the addition of solar cookers using funnels or concentrators (Kaiyan et.al., 2009). In addition, simulation methods are also carried out to complement the results of experimental testing. One of them, research that has been done is a solar air heater that has the same character as a solar cooker using fluid computing software has the advantage of being able to know the air temperature distribution so that positions that are less than optimal or have low temperatures can be known (Diana et.al., 2019). Previous research related to increasing the efficiency of solar cookers is used as a reference for research references, among others: Heat Transfer in Solar Stoves Research on solar ovens was conducted using a box type. Other simulation to evaluated the performance of a solar cabinet dryer equipped with evacuated tube solar collector and thermal storage system (Iranmanesh et.al., 2020).

Experimental testing under the sun was carried out to determine the performance of the oven heat transfer calculations were carried out including calculating useful heat and heat loss. One of the results showed an increase in air temperature inside the solar oven against the intensity of the sun. The heat transfer scheme in the oven studied and the graph of temperature changes in the oven (Neto et.al., 2021). Thermal resistance calculation research on solar cookers was conducted. The stove functions as an oven with a box type made of aluminum and glass cover. After the thermal resistance is made, it is continued with a numerical method to determine the buoyancy force which is a natural convection heat transfer phenomenon that occurs in the box (Zafar et.al., 2019). Research on solar cookers was conducted using two types of stoves, namely cylinder type and box type. Both types of stoves are supplied with heat by solar water heater collectors. The supply aims to make the stove get additional heat. So that the heat is not lost quickly, both the cylindrical stove and the box-shaped stove are given a pass at the bottom. The route is made of plates arranged alternately. The zigzag route has the aim that the hot fluid flow becomes turbulent and has a long enough time to heat the stove (Chaudhary & Yadav, 2020). PCM (Phase Change Material) is a material that can store heat in the form of latent heat and release energy depending on the temperature difference. During temperature decreases and temperature increases or sudden climate changes, these materials are able to change their phase from solid to liquid or liquid to solid to store heat or release heat. PCMs are categorized into two different types known as organic PCMs and inorganic PCMs. Inorganic PCMs such as salt hydrates, or also known as Glauber salts. They are also well known for some of their attractive characteristics such as high thermal conductivity, increased latent heat value, non-flammability and lower cost compared to other organic compounds. Organic PCMs are widely used in a number of applications, and are relatively effective than inorganic PCMs due to their outstanding qualities such as non-corrosive, reusable, low initial cost (Magendran et.al., 2019). Solar energy is considered a promising renewable energy for the sustainable development of society, especially Indonesian society. Among the various uses of solar energy is the existence of solar photovoltaic (PV) (Hu et.al., 2020).

METHOD

The solar cooker consists of several components including: a pot as a stove, an aluminum plate as a heat absorber, a heater element, a 50 Watt solar photovoltaic (PV) as a source to power the heater, and a battery. The schematic design of the solar cooker tested and the curvature of the plate in this study are shown in Figure 1. Data collection was carried out transiently to determine changes in water and wall temperature against time (Incropera, 2011).

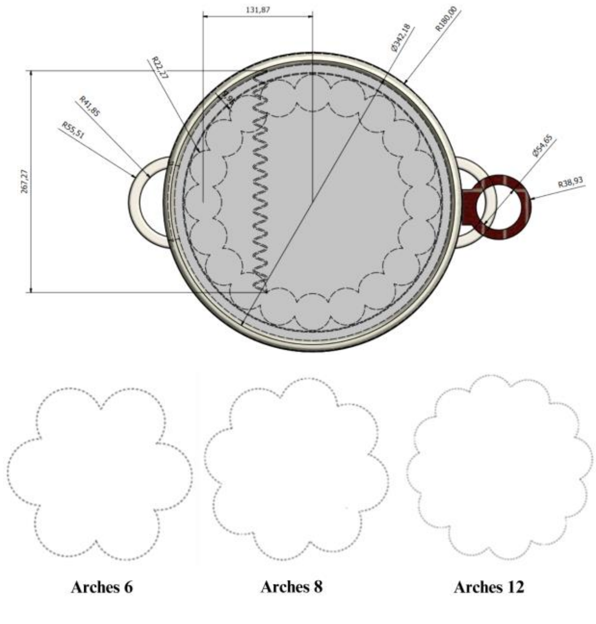

Figure 1. Schematic of the solar cooker and variations in the curvature of the absorber plate

The measuring instruments used in this study have the following specifications:

Pyranometer

Measuring area : 0 to 2000 W/m2

Sensitivity : 100 V/W/m2

Working temperature : -30ºC to 70ºC

Response time : <1 second

Stability : 0.15%

Direction error : <10 %

Spectral range : 0.4-1.1 micron

Temperature measuring instrument

Temperature range : -10 ºC~60 ºC

Humidity range : 20%~95%

Condensation temperature : -29 ºC~59 ºC

Figure 2. Solar cooker testing

The test method in this study was carried out experimentally. Tool experiments were carried out under actual conditions at the Surabaya State Electronics Polytechnic with coordinate positions located at -7.275738, 112.7932219. The test steps are as follows:

1. Ensure clear weather conditions with sufficient sunlight
2. Place the solar cooker in a location that has optimum sunlight
3. The test begins by putting 2.5 liters of water into the solar cooker
4. Turning on the PV as an energy source to turn on the heater starting at 07:00
5. Data collection is carried out until the maximum cooking process, namely until the water is warm with a temperature of 50ºC
6. Taking data in the form of solar intensity, wall temperature, water temperature, and calculation of absorbed heat
7. After testing the first variation is complete, cooling down to room temperature is carried out

8. Turning off and tidying up all equipment
9. If the weather conditions are not favorable, repeat the data collection

RESULTS AND DISCUSSION

Experimental testing was conducted in an open room. Figure 3 shows the measurement of solar intensity for 3 days starting from 07:00 to 15:00 WIB.

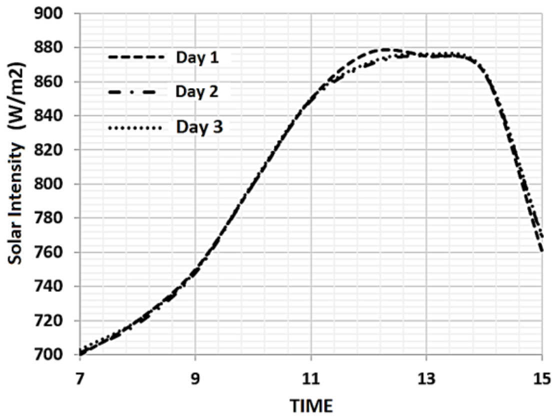

Figure 3. Graph of changes in solar intensity over time

Based on Figure 3, the solar intensity has a parabolic shape, which continues to increase until 12:00 and decreases at 15:00. Tests were conducted on 3 adjacent days with weather conditions not too different. This resulted in the intensity value not experiencing much difference.

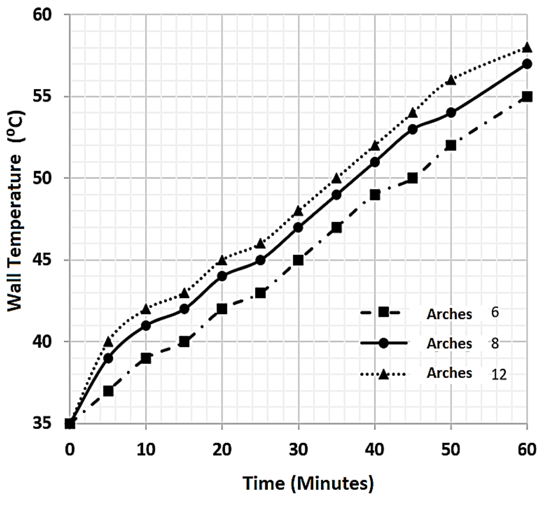

Figure 4. Graph of temperature change of the inner wall of the stove over time

Figure 4 shows the wall temperature inside the solar cooker for 60 minutes. Wall temperature increased in all variations of aluminum arches. However, the number of arches 12 in the solar cooker has the highest temperature increase of 58°C compared to the other variations. This is because the number of arches 12 has the largest area of solar heat absorption when compared to the other 2 variations.

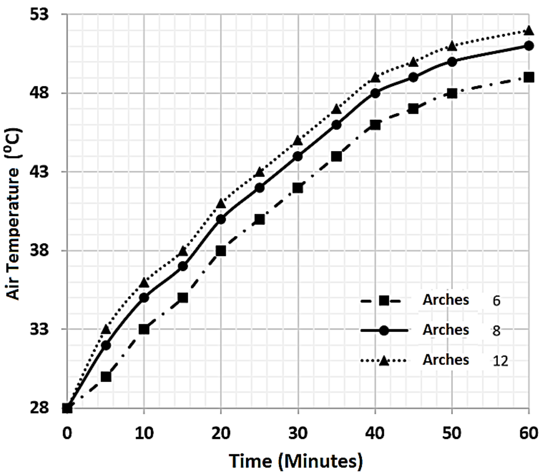

Figure 5. Graph of water temperature change over time

Figure 5 shows the change in water temperature inside the solar cooker for 60 minutes. Based on the graph, the change in water temperature in the three variations does not show a significant difference in results. This can be due to the heat lost from the stove to the environment. However, the highest water temperature occurs in arch 12 at 52°C. Based on the results that have been obtained, further research is needed by providing insulation on the surface of the solar cooker so that the heat on the inside does not escape into the environment.

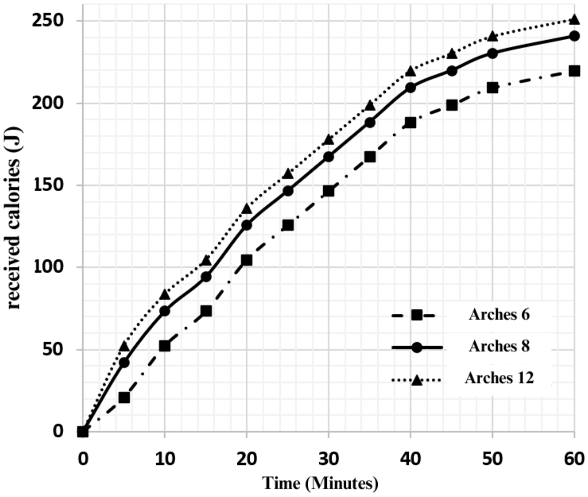

Figure 6. Graph of change in heat received by water over time

Figure 6 shows the heat received by the water against changes in time. Based on Figure 6, the heat received continues to increase with changes in time. This is because the heating process continues so that the increase in water temperature continues to increase. Based on Figure 6, the stove with arch 12 has the highest heat absorption when compared to the other two variations.

CONCLUSION

The solar cooker with the number of arch walls 12 has a higher temperature increase and heat absorption when compared to arches with 6 and 8, which is 58 ° C for 60 minutes. This is because arch 12 has a wider solar heat absorption area.

REFERENCES

Abu-Hamdeh, N. H. & Alnefaie, K. A. (2019). Assessment of thermal performance of pcm in latent heat storage system for different applications. *Solar Energy*, *177*, 317-323. https://doi.org/10.1016/j.solener.2018.11.035.

Chaudhary, R. & Yadav, A. (2020). Twin vessel solar cook stove for the simultaneous cooking of two different cooking articles. *Solar Energy*, 208, 688-696. https://doi.org/10.1016/j.solener.2020.08.032.

Diana, L., Safitra, A.G., Ichsani, D., Nugroho, S. (2020). CFD analysis of airflow through prism obstacles inside solar air heater channel. *Journal of Physics: Conference Series 2020*, *1577*(1), 012038. https://iopscience.iop.org/article/10.1088/1742-6596/1577/1/012038/meta.

Hu, M., Zhao, B., Ao, X., Ren, X., Cao, J., Wang, Q., Su, Y., & Pei, G. (2020). Performance assessment of a trifunctional system integrating solar pv, solar thermal, and radiative sky cooling. *Applied Energy*, *260*, 114167.

Incropera, F. P. (2011). *Fundamental of Heat and Mass Transfer* (7th ed.). John Wiley & Sons, Inc.

Iranmanesh Masoud dan Jahromi Mohammad Saleh Barghi, (2020). Cfd modelling and evaluation the performance of a solar cabinet dryer equipped with evacuated tube solar collector and thermal storage system. *Renewable Energy*, *145*. https://doi:10.1016/j.renene.20196.038.

Kaiyan, H., Hongfei, Z., Tao, T., & Xiaodi, X. (2009). Experimental investigation of high temperature congregating energy solar stove with sun light funnel. *Energy Conversion and Management*, *50*, 3051-3055. https://doi.org/10.1016/j.enconman.2009.08.009.

Magendran, S. S., Khan, F. S. A., Mubarak, N.M., Vaka, M., Walvekar, R., Khalid, M., Abdullah E.C., Nizamuddin, S., & dan Karri, R. R. (2019). Synthesis of organic phase change materials (pcm) for energy storage applications: a review. *Nano-Structures & Nano-Objects*, *20,* 100399. https://doi.org/10.1016/j.nanoso.2019.100399.

Neto, R. V. P., Souza, L. G. M. D., Lima, J. C. D., Souza, L. G. V. M. D., & Mendes, E. V. (2021). Theoretical-experimental study of a box-type solar oven made from disused recyclable elements. *Solar Energy*, *230*, 732-746.

Watkins, T., Arroyo, P., Perry, R., Wang, R., Arriaga, O., Fleming, M., O'Day, C., Stone, I., Sekerak, J., Mast, D., Hayes, N., Keller, P., & Schwartz, P. (2017). Insulated solar electric cooking-tomorrow's healthy affordable stoves. *Development Engineering*, *2,* 47-52. https://doi.org/10.1016/j.deveng.2017.01.001.

Zafar, H. A., Badar, A. W., Butt, F. S., Khan, M. Y., & Siddiqui, M. S. (2019). Numerical modeling and parametric study of an innovative solar oven. *Solar Energy*, *187*, 411-426.