RESEARCH REVIEW JOURNALS
Volume-04
Issue-02
February-2019

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com[UGC Listed Journal]

Design and Development of Heat Storage Device for Solar Cooker

Jannat Khattri

ARTICLE DETAILS

Article History
Published Online: 20February 2019

Keywords
solar collector; solar cooker; thermal energy storage (TES).

ABSTRACT

Solar cookers can be used to save fuel and make the cooking of food environmentally friendly. Only and intermittent solar energy is available during the day. Thus, for indoor solar cooking demands thermal energy storage is very important and guarantees continuity of use. The overall system is designed for 1 kg of rice to be cooked theoretically in 45 minutes, which takes 421 watts from the energy stored by the sun. In view of the many losses, the energy transfer to water has been somewhat reduced and the temperature has reached 355 K, as demonstrated by the experimental result. Even if it contains low energy, energy from the TES is reduced to the environment, when it is discharged in the isolated tank. The experiment and analytical calculation differ; however, because the model has not taken into account the basic losses and variations of sun radiation. After the solar collector is lifted the TES is discharged, but it is instantly placed on the isolated tank and loaded by the water pot. Thus, after 40 minutes, the maximum water temperature is 355 K.

1. Introduction

The world has great industrial growth and population growth has led to a significant increase in energy demand. In terms of wealth generation and economic development, energy is very important[1]. The population's main energy demand is mainly supported by fossil fuel sources. Scientific research and technological development have been pushed to find new energy solutions based on energy use and diversification efficiently by other elements such as global warming and environmental problems. Renewables are seen as the engine of new generation development in the coming decades[2] from the new resources. Cooking in every society of the world is one of the most important household work and necessary. Cooking is usually carried out in open fires, firewood-powered in most rural areas of the developing countries. In towns, the stoves are more prevalent and are supplied with wood, charcoal, kerosene and occasionally flue gas. Petroleum fuels are costly and wood-based fuel are becoming increasingly scarce in many developing world regions, including East Africa. In addition, fuel combustion and the release of wood carbon dioxide (CO2) as well as other greenhouse gasses and pollutants have contributed to environmental issues such as global warming, air and water pollution and other earth-like damage. Renewable energy technologies generate marketable energy through the transformation of natural phenomena to useful energy forms. Therefore, the Sun is a source of renewable energy and life on earth, but it is at the same time a "free" energy source forms any system using it to power the process[3]. The Sun is a source of energy. So solar energy is a major renewable energy component of the sun-based light and heat utilized by a range of technologies, such as solar thermal heating, solar solar photovoltaics, solar thermal energy, solar architecture and photosynthesis [4]. Solar energy is one of the most effective ways to reduce the use of non-resource resources[5]. Solar thermal power is a world-wide solar power source [6]. Solar energy is transformed from solar collectors into thermal energy. A solar cooker is an apparatus that heats and cooks direct sunlight (which is sun-heat). The simplest, safest, cleanest, environment-friendly and most comfortable way of cooking without consuming fuels and heating the kitchen is solar cooking, which saves a significant amount of traditional fuels [7,8]. But only during the daytime and intermittent, solar energy is provided. For solar energy applications, this is the main limit. Food is therefore needed throughout the day. Solar energy storage is therefore used to reduce the discrepancy between the supply of solar heat and energy for cooking. This paper conducts the design and testing of solar heat storage cookers.

2. Review of literature

Schwarzer K, et al. [10] conducted A flat plate type solar cooker performance analysis, as a TES material, with vegetable oil. The flat plate collector was designed, with TES heated leading up naturally. After several experiments, oil has been found to be a good material for heat storage.

In conjunction with thermal energy-storage units for higher cooking temperatures, Mussard M.[11] performed a low cost, concentrated solar collector. The system is manufactured using thermal oil and is free of pumping (self-circulation). He compared various types of heat storage materials and concluded that the heat-based latent system is important. He further concluded that thermal oil heat storage is more efficient, in particular, than aluminum crossed by thermal oil channels.

Senthil R. et al.[12] proposed that materials for sensitive heat transfer should be found to work effectively in heat storage and to help the heat transfer of conduct during the process of cooking. The nearly spherical solids can provide a better heat transfer conductivity. For heat storage, they compared rocks and sun flowers oil. The results show that the high efficiency of stone rocks is due to the higher specific heat, while the high density of sunflower oil and its high specific heat output compare with other oils are more effective.

In addition to the commercial-grade erythritol, Sharma SD. et al. [13] investigated a solar cooker based on an Evacuated tube solar collector. After charging the PCM to temperatures of 130oC, they performed boiling tests. The authors concluded, however, that the energy storage ratio is low and the system is considered costly for the people of low incomes.

Schwarzer K. et al. [10] conducted a range of sun cooker models, both heat and non-heat. The system uses thermal oil in copper pipes as a thermal storer and heat storeroom. The pipes are extended to a wall to cook indoors. The thermal efficiency was experimentally investigated by a water boiling test and found to be around 40%.

Saxena A. et al. [14] have investigated the suitability of various types of PCMs, using a solar box, to be used as heat storage for cooking purposes. Authors have investigated thermal storage solar cookers and not. Tests on stagnating temperatures and water boiling tests in the cooking process were used to perform both solar cookers. And it is concluded that the TES solar cooker was very successful.

Mussard M. et al.[15] The SK14 solar focal point and indirect cooker with a parabola trough solar concentrator system with a naturally circulated TES (oil) from the solar sel tester have been investigated in comparison. A water boiling test and a meat frying test were used for the thermal efficiency comparison. Diverse authors also studied different thermal energy storage solar cookers. This paper has now been used as a compound solar collector to cook oil and rock as heat storage. The main difference from the above literature is that the thermal energy absorber with thermal energy storages is placed in the cookery of the two plates until a sufficient thermal energy is stored by the absorber for cooking. Then an absorber is removed from the solar collector and placed in the cooking kitchen inside the isolating material. This is therefore used to remove the additional materials needed, such as a pump, engine and circular isolated tube that reduce the total system costs and heat energy losses in the tube and pump.

3. Materials and methods

Sizing and thermal analysis of parabolic solar concentrator

Solar cookers have a parabolic dish concentration compound and an absorber thermal energy (oil and rock) storage component to increase the time of effective temperature and store thermal energy at night without a tracking mechanism. The cooking mode is indoor; an absorber is placed at the core of both dishes as shown in Figure 1 until an absorber has stored enough thermal energy for cooking (from 9:00 a.m. to 3:00 p.m.). Then the absorber is removed from the solar collector and placed inside the cooking kitchen inside the isolating material.

Figure 1. 3D drawing of overall system

This research is conducted to demand the heat energy of cooker to cook 1 kg of rice at a time. In cooking process, the optimum ratio of rice to water by volume is 1 to 2 [16,17].

Heat transfer analysis between an absorber and thermal energy storages

The mode of heat transfers from the outer surface of an absorber to the thermal energy storage and to the cooking pot is conduction heat transfer.

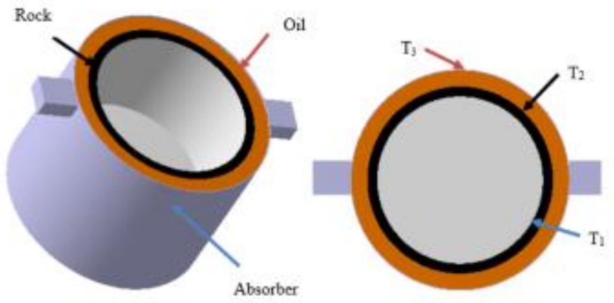

Figure 2. 3D drawing of absorber with TES

Thermal resistance circuit of the absorber presented in Figure 2 is; Basic Assumptions;

- The flow heat transfer is two dimensional
- Thermal properties of rock and Aluminium did not vary with temperature Based on the above resistance diagram, the calculated temperatures are presented in Table 1.

Table 1. Analytically calculated temperatures in the absorber

Parameters	Quantity
Temperature on the absorber surface (T_3)	617.37 K
Temperature between Oil and Rock (T_2)	374.57 K
Temperature between the Rock and pot (T_1)	366 K

Construction of parabolic solar collector and solar cooker with TES

Due to its lightness, lower cost, energy efficiency and the high quality and good reflectivity with its 85 percent reflectivity, aluminum has been selected with 0.5 mm thickness on steel for dish construction. The two plates with a diameter of 1 m and a depth of 12 cm are designed in this test. Also made of carbon steel, Absorber is easy to manufacture (sweat) and the energy (thermal conductivity) in material application. The 1.5 mm thickness carbon steel is used for the absorption, storage of oil and rock for this experimental examination.

Experimental setup of solar collector and solar cooker with TES

The absorber used for testing and the setup of the overall system used during the experimental work are presented in Figure 3 and 4.

Figure 3. Solar absorber (photograph)

Figure 4. Experimental setup (Photograph). a. Over all system; b. manual tracking of parabolic solar collector.

4. Results

This test is conducted to investigate the thermal performance of solar cookers with rock and used engine oil respectively indoors and outdoors. The reason that oil is utilized in the outside is that it is used as a fluid for heat transfer and also for the release period as an isolator (due to its low thermal conductivity).

Table 2. Daily solar radiation and ambient temperature

Days	Daily solar radiations (W/m^2)	Ambient temperatures (K)
Day 1	546	290
Day 2	543	291
Day 3	545	292
Day 4	544	290
Day 5	545	291

1. Charging temperature of TES

The charging temperature of absorber and thermal storage presented in Figure 6 are started after it is placed on the focal point of the solar collector.

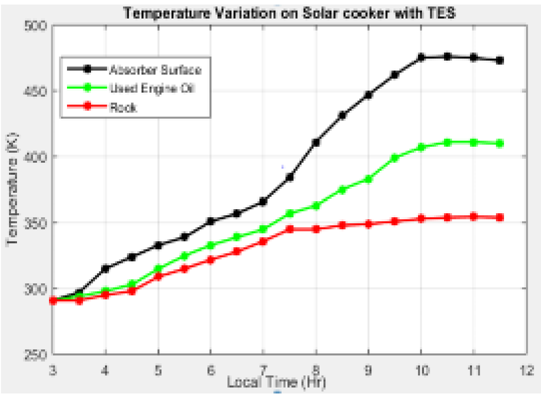

Figure 6. Temperature variation on the solar cooker with TES

2. Discharging temperature of TES

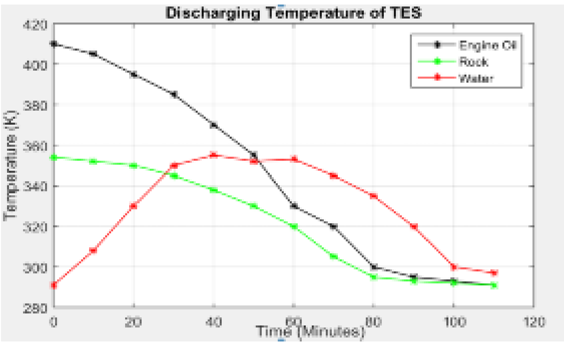

Figure 7. Discharging temperature of TES

5. Discussions

1. Charging temperatures

A surface absorber has an almost linear temperature loading temperature of 3:00 to 7:00 local time and reaches 366 K. Moreover, the sun is on the head and solar radiation in Addis Abeba is high at this moment as compared with the other hours. It is also increasing fast from 7:00 to 10:00 locally and it reaches 476 K. Thus the day goes to the night and the sun is set, therefore an absorber surface temperature slowly decreases from 10:00 to 11:30 local time, reaches 473 km at the start of discharge at 11:30 local time. But all this heat energy cannot be transferred from the surface of the absorber to oil because of convection loss, radiation loss and loss of driving. The temperature on the used motor oil increases linearly up to 7:00 local time, such as the absorber surface, to 345 K. The temperature increases gradually after 7:00 local time to 10:00 local time and as shown in Figure 6 reaches 411 K. The oil stores all this heat energy and acts as a medium for heat transfer, transferring it to the petroleum. This is because the oil's low thermal conductance and losses like radiation and conduction prevent the transfer of all heat energy to rocks. The oil's temperature is almost constant and decreases from 10:00 to 11:30 local time to 410 K by a small number. The reason for the use of engine oil is therefore that the temperature can not be lost easily over a short period of time and is freely available. In addition, in comparison to the thermal oil B, thermal conductivity and stores are low. Even so, the TES can store energy that is almost sufficient for water to boil. Thus it could be concluded that if Thermia oil B is used for practical testing such as theoretical study, the system can be more effective. Engine oil is used as the insulation material for heat storage and insulation (due to its low thermal conductivity). The rock temperature increases linearly between 3:00 and 7:30 local time and reaches 345 K, but increases slowly for the last hours at 11:00 local time and reaches 354.5 K. An absorber is lifted and placed inside the insulated tank and charged with water by the pot after 10:30 local time.

2. Discharging temperatures

By discharging (loosing) its heating energy to the pot and the environment, TES' temperature is gradually decreasing. Therefore, the water temperature increases dramatically up to 40 minutes from its environment and as shown in Figure 7, reaches 355 K. Since an absorber is not effectively isolated, the temperature from TES is further lost. Water is used as TES, however, which is why the water temperature is almost constant between 40 minutes and 60 minutes and gradually drops in 60 minutes.

6. Conclusion

It is only available in daytime that the most important limitation of solar energy is. This paper was therefore examined with the addition of the motor oil and rock for thermal energy storage on the night cooking absorber where no sunlight existed. For this reason, because of its important characteristics, this study has conducted TES; the time it takes for energy to be stored with accepted losses. The whole system is developed in this study and the experimental tests are performed. In the experiment the energy reached by the cooker (pot) is lower and its surface temperature is on average 380 K because of the many losses that are highlighted in the above. Even if it has low power, the energy loss of TES to the environment can be reduced by inside the isolated tank. The TES discharge will start when the compound parabola solar collectors are lifted from the focal areas. The maximum water temperature, which is almost boiling point, is 355 K and reaches 40 minutes later. The reason for the study was that rice can be cooked immediately upon the boiling of the water for practical testing. However, the cooker is expected to be effective when the experiment is carried out in a hot area and sunny season than the results. Therefore in Ethiopia, this test is advisable to take with effective isolation of the cooker's absorber in the hottest region such as: Samara, Dire Dawa, Gambella, etc.

References

1. Kalogirou SA (2004) Solar thermal collectors and applications. Prog energ combust 30: 231–295.
2. Bensenouci A, Medjelled A (2016) Thermodynamic and efficiency analysis of solar steam power plant cycle. Int J Renew Energy Res 6: 1556–1564.
3. Kalogirou SA, Karellas S, Badescu V, et al. (2016) Exergy analysis on solar thermal systems: a better understanding of their sustainability. Renew Energy 85: 1328–1333.
4. Singh B, Mishra AK (2015) Utilization of solar energy for driving a water pumping system. Int Res J Eng Technol 2: 1284 1288.
5. Thakkar V (2013) Status of parabolic dish solar concentrators. Int J Enhanc Res Sci Technol Eng 2: 42–50.
6. Yahuza I, Rufai Y, Tanimu L (2016) Design, construction and testing of parabolic solar oven. J Appl Mech Eng 5.
7. Liu YM, Chung KM, Chang KC, et al. (2012) Performance of thermosyphon solar water heaters in series. Energies 5: 3266–3278.
8. Sheth MG, Shah PK (2013) Design and development of compound parabolic concentrating solar collector with flat plate absorber. Int J Innovative Res Sci Eng Technol 2: 3384–3389.
9. Saxena A, Goel V (2013) Solar air heaters with thermal heat storages. Chin J Eng 2013: 1–11.
10. Schwarzer K, Da Silva MEV (2003) Solar cooking system with or without heat storage for families and institutions. Solar Energy 75: 35–41.
11. Mussard M. A solar concentrator with heat storage and self-circulating liquid. Norwegian University of Science and Technology, Norway, 2013.
12. Senthil R, Cheralathan M (2016) Thermal performance of solid and liquid energy storage materials in a parabolic dish solar cooker. Int J Chem Sci 14: 1977–1983.
13. Sharma SD, Iwata T, Kitano H, et al. (2005) Thermal performance of a solar cooker based on an evacuated tube solar collector with a PCM storage unit. Sol Energ 78: 416–426.
14. Saxena A, Lath S, Tirth V (2013) Solar cooking by using PCM as a thermal heat storage. MIT Int J Mech Eng 3: 91–95.

15. Mussard M, Gueno A, Nydal OJ (2013) Experimental study of solar cooking using heat storage in comparison with direct heating. Sol Energ 98: 375–383.
16. Veremachi A, Zia A, Cuamba BC, et al. (2017) Parabolic dish concentrating collector for indirect solar cooking. Glob J Sci Front Res 17: 23–34.
17. Ronge H, Niture V, Ghodake MD (2016) A review paper on utilization of solar energy for cooking. Imperial Int J Eco-friendly Technolo 1: 121–124.
18. Cuce E, Cuce PM (2013) A comprehensive review on solar cookers. Appl Energ 102: 1399–1421.
19. Indora S, Kandpal TC (2018) Institutional cooking with solar energy: A review. Renew Sust Energ Rev 84: 131–154.
20. Kuhnke K, Reuber M, Schwefel D (1990) Solar cookers in the third world, Germany.
21. Rathore MM, Warkhedkar RM (2015) A review of solar cookers. Int Mod Trends Eng Res 2: 1997–2004.