Journal of Advances in Science and Technology
Vol. 12, Issue No. 25, (Special Issue) December-2016, ISSN 2230-9659

Solar Energy for Cooking using Thermic Fluid

M. P. Marajakke[1*], K. M. Akkoli[2], R. K. Chitgopkar[3]

[1]PG Scholar VTU, Belagavi, Department of Mechanical Engineering, Hirasugar Institute of Technology, Nidasoshi, India

[2]Department of Mechanical Engineering, Hirasugar Institute of Technology, Nidasoshi, India

[3]Department of Mechanical Engineering, Hirasugar Institute of Technology, Nidasoshi, India

Abstract – The cooking is an integral part of an every human being and food is the basic need for the living. Firewood, crop residue, cow dung cake, kerosene, electricity, biogas and LPG are commonly used as energy sources for cooking. This work is an attempt to develop a solar cooker to use in the kitchen and solar heat energy is transferred by servothermic (thermic) fluid. The details of the design and experimentation of the solar cooker using thermic fluid was discussed. The performance evaluation of cooker was also carried out and compared with the performance of the other types of the solar cookers. It has been observed that the energy conversion efficiency of developed solar cooker is somewhat lower about 48% but the inconvenience of using outdoor solar cookers and indoor air pollution by using other fuels cooking systems can be avoided.

Keywords: Solar Energy, Thermic Fluid, Solar Cooker

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1. INTRODUCTION

The solar energy is the resource for the most of the energy sources on the earth. The most convenient renewable energy is the solar energy, either in its active or passive form and also use of solar energy does not emit the greenhouse gases (GHG) [1]. The solar energy reaching to the earth surface in the form of sunrays is about 180x106 GW, which is many times the world total energy requirement [2]. The available solar energy is in the form of heat, which can be directly used for thermal applications or can be converted into electricity by photovoltaic (PV) cells [3].The solar energy can be used for different applications such as air heating, water heating, food cooking, grain drying and thermal energy converted to electricity by low temperature steam or gas turbines through solar ponds and solar chimneys [4]. The tropical country India has the much importance for the solar energy as compared to other renewable energy sources [5]. The immediate aim of the JNNSM Mission is to focus on setting up an enabling environment for solar technology development in the country both at a centralized and decentralized level. This is set a mission target of 20 GJ of power generation from solar energy by the year 2020.

The cooking of the food is an essential part of human beings since from the invention of fire. The cooking of food is required to eliminate harmful bacteria's and make food hygienic [6]. There are different heat sources being used for the food cooking such as firewood, crop residue, cow dung cake, kerosene, electricity, biogas and LPG [7]. The devices which are used for cooking the food are called cooking stoves and are designed based on the type of fuel, type of food and quantity of dishes to be cooked [8]. The most of the stoves are installed in the kitchen except solar cookers. The use of cooking stoves in the kitchen causes the indoor air pollution during the cooking and this will affects the human health. Recent conservative estimates show that between 1.5 and 2 million deaths every year could be attributed to indoor air pollution [9]. The use of solar cookers does not cause any pollution and also less health hazardous. The presently using solar cookers classification is given in the figure 1.

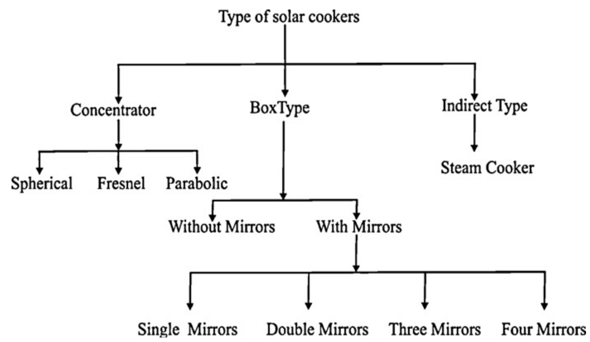

Figure 1 Types of solar cookers

The different types of solar cookers presently being using are inconvenient and have the difficulty to place the cooking pot in the cooker at outdoors and to bring back after cooking. There are continuous efforts by the researchers to develop convenient and better solar cooker. The solar cookers using phase change materials, thermic fluids to store and transfer the energy and using reflectors to focus sunrays are the recent developments. The some other methods use the sensible heat, latent heat and chemical reaction heat to store the solar energy. There are noticeable difference between the analytical estimation and the experimental analysis of solar cookers [10].

2. MATERIALS AND METHODOLOGY

2.1 Working

The evacuated solar heater is used to heat the thermic fluid. The flow rate and heater capacity are selected according to the cooking temperature requirement. The experimental setup and the details of the parts are given in the figure 2. The photograph of the experimental setup is given in the figure 3. During the day the experimental setup is kept at outdoors, when the sunrays falls on the heater the fluid inside the heater starts receiving the heat. The circulating pump and valve is off until the required temperature for the cooking is reaches. When the required temperature is reached the inlet valve of cooker is opened and circulating pump is put on, which is running by the power from the solar photovoltaic panel to make flow of thermic fluid. In the cooker the arrangement is made to transfer the heat from the fluid to the cooking utensils. The thermic fluid is recirculated till the food cooks and later the valve and the pump are again put off. During late evening again the temperature is reaches to sufficient for cooking, then we can use the stored heat for cooking and the pump runs on battery during this period.

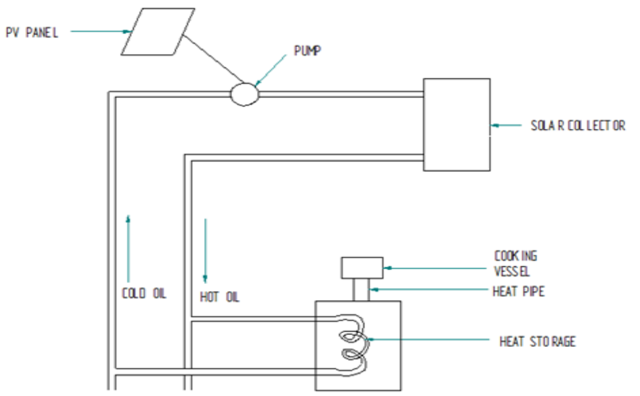

Figure 2 Schematic of solar energy cooker using thermic fluid

Figure 3 Photograph of experimental setup

3. RESULTS AND DISCUSSIONS

Initially for two hours from morning 8.00 AM to 10.00 AM the setup is kept for heating the thermic fluid by solar radiation. After 10 AM the system can be run by opening circulating valve and starting the pump. The ambient, inlet and outlet temperatures are recorded for every one hour time period. The temperatures variations on 16th May 2016 from morning 8.00 AM to 5.00 PM are tabulated in table1.The experiment may be repeated on different clear days.

Table 1 Temperature Variations

Time	Ambient temperature (°C)	Inlet temperature (°C)	Outlet temperature (°C)
8 AM	26		
9 AM	30		
10 AM	33	63	52
11 AM	35	66	51
12 PM	38	69	52
1 PM	37	70	52
2 PM	36	69	53
3 PM	35	67	50
4 PM	34	66	50
5 PM	33	65	52

From the table 1 it has been observed that the maximum temperature reaches around afternoon 12 PM to 1 PM.

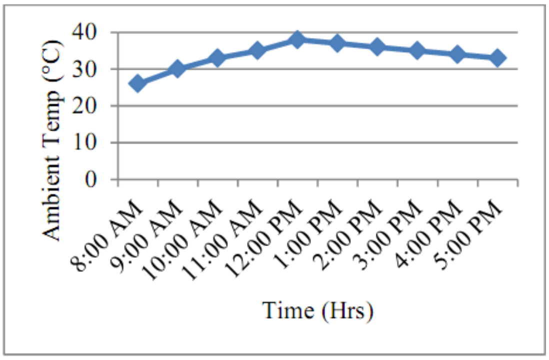

Figure 4 Ambient temperature variations

The ambient temperature variations for one day are plotted in figure 4 which shows that the peak temperature will be around 1 PM and temperature increases slowly in the morning but it will not fall early in the evening. After the afternoon cooking the cooker is shut off, then the heat will store in the fluid and again reaches the required cooking temperature at late evening.

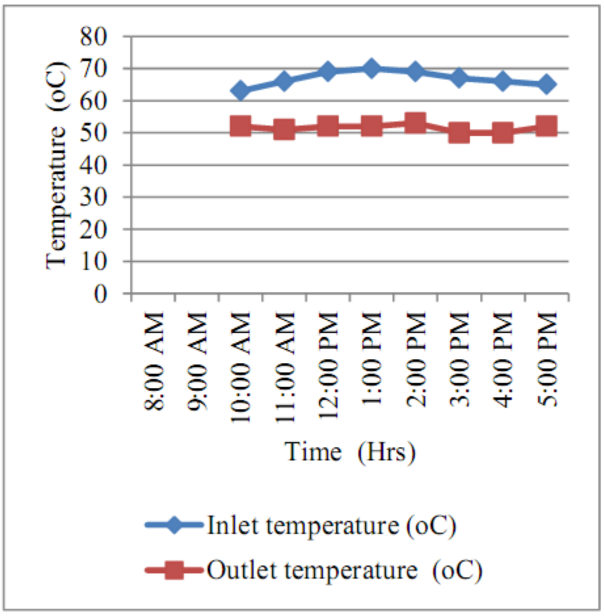

Figure 5 Comparison of inlet and outlet temperatures of cooker

The inlet and outlet temperatures of the cooker are given in the table 1 and plotted in the figure 5 which shows that the peak inlet temperature will be nearer to the maximum ambient temperature. The peak temperature is about 70 oC. The outlet temperature is varying according to the inlet temperature and maximum temperature difference achieved is that of 18oC at 1 PM. The temperature requirement for cooking is varies for different dishes and is about 65 oC for rice cooking and the temperature achieved is sufficient for cooking.

Table 2 Heat supplied and absorbed

Time	Heat supplied (KW)	Heat absorbed (KW)
10 AM	1.632	0.598
11 AM	1.680	0.816
12 PM	1.687	0.870
1 PM	1.796	0.979
2 PM	1.796	0.870
3 PM	1.741	0.925
4 PM	1.741	0.870
5 PM	1.686	0.707

The amount of heat energy supplied to the cooker and the amount of heat energy absorbed during the cooking of food is calculated. The values are given in the table 2 and variation is plotted in figure 6. The rate of heat absorption will be gradually increases up to 1 PM and remains nearly constant at afternoon and again decreases at late evening.

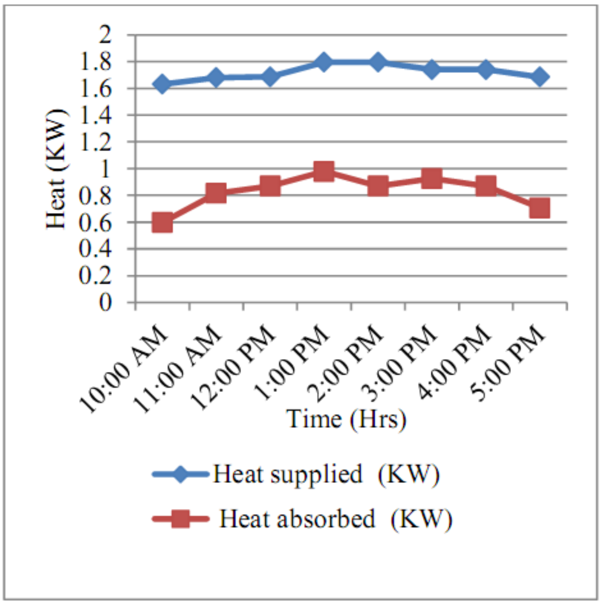

Figure 6 Comparison of heat supplied and absorbed

Table 3 Comparison of different solar cookers and the present work

Type of cooker	Advantages	Limitations	Reference
Solar box cooker (solar oven) T = 150 ^{o}C	Uses both direct & diffuse radiation. Requires little intervention by the user. Very easy & safe to use. (2-6kg/day) Easy to construct. High acceptance angle. High tolerance for tracking error.	Slow even cooking *i.e.* 1.5 to 2 hours Not use for frying/chapatti making.	[11]
Panel cooker T=200-250 ^{o}C	Better performance than box cooker.	Poor performance on cloudy conditions. Relies more on reflected radiation.	[11]
Collector Cooker	Uses both direct and diffuse radiation. Simple, safe and Convenient to use.	Complicated to build. Expensive.	[11]
Concentrating (reflector) cooker $\eta = 50\%$	Quite efficient. Can achieve extremely high temperatures 300 - 350^{o}C. Cooking is quicker. (1/2 to 1 hour)	Complex design Strong reliance on direct beam. Relatively high cost. Safety problems (burns or eye damage)	[11]
Thermic fluid solar cooker	Cooker can be placed in kitchen Convenient and safe Night cooking also possible Improved efficiency about 48%	System is complex and expensive Requires thermic fluid	Present experimental work

The table 3 shows the comparison of the different solar cookers and present solar cooker using thermic fluid. This shows that the box type solar cooker is better over all other solar cookers followed by concentrating type solar cooker. The new solar cooker developed is convenient, safe and moderate efficient. The developed solar cooker using the thermic fluid can be modified, so that this can be used in the rural and urban buildings conveniently.

4. CONCLUSIONS

The solar cooker using the thermic fluid is convenient for cooking the dishes in the kitchen without any pollution. It is observed that the maximum temperature of the thermic fluid in the heater will reaches maximum around 1.00 PM of 70 oC, which is inlet temperature to the cooker and sufficient for cooking. The temperature drop during afternoon is less, thus the cooking rate is faster at afternoon. If the circulating pump is off during the day then the heat can be stored in the thermic fluid for cooking at the night by running the pump with power stored in the battery by solar panel. The maximum temperature difference achieved is of 18oC and the maximum heat utilised for cooking is about 0.9 kW. The conversion efficiency of the solar cooker using thermic fluid is about 48%.

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Corresponding Author

M. P. Marajakke*

PG Scholar VTU, Belagavi, Department of Mechanical Engineering, Hirasugar Institute of Technology, Nidasoshi, India

E-Mail – mallikarjunme034@gmail.com