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EXPERIMENTAL ANALYSIS OF PARABOLIC DISH WITH CONICAL COIL RECEIVER FOR SOLAR COOKING APPLICATIONS

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ABSTRACT

Solar cooking is the alternative method of cooking for reducing consumptions of fossil fuels. An affordable, energy efficient solar cooking technology is much needed due to the increasing cost of fossil fuels. It is the hottest research topic all over the world. This paper presents an experimental analysis of the heat transfer enhancement of solar parabolic dish cookers by conical coil receiver. The parabolic solar dish cooker assisted with conical coil receiver is experimentally tested to find the thermal characteristics and the instantaneous efficiency of the heat transfer fluids like water and Therminol 55.

***Keywords:* Conical coil receiver, Parabolic dish, Solar cooking, Therminol 55**

I. INTRODUCTION

The use of fossil fuels has produces large air pollution due to the release of harmful gases as combustion byproducts. Also, increasing levels of carbon dioxide in the atmosphere from fossil fuel combustion is believed by some to be the main source of global warming over the past 150 years. Additionally, power plants often release large amounts of waste heat to the environment. This can lead to thermal pollution in rivers and lakes causing harm to plant and animal life. Ever since the demand for fossil fuels has begun to rise, industries have been turning towards new, clean solutions to their energy needs. Solar energy has long been a potential solution to these needs. The power intercepted by the earth is estimated at about $1.8x\ 10^{11}$ MW. In fact, the sun provides enough energy in one hour to supply the earth with its energy needs for a whole year. The greatest volume of energy consumed worldwide comes from fossil fuels. Energy consumption in developed countries is growing at a rate of approximately 1% per year, and at the rate of 5% per year in developing countries [6]. The global energy demand is expected to increase, and fossil fuels are not projected to compensate that growing demand, mainly due to the decline in world oil production and environmental issues. Due to increasing cost of fossil-fuel cost, renewable energy technologies have received remarkable attention at the international level over the last few years. Renewable sources play important role in sustainable development and the environmentally friendly energy sources [6]. Among the renewable energy sources, solar energy is considered the most abundant and a viable option for thermal energy applications. As Thirugnanasambandam et al. [6] have highlighted, the total annual solar radiation falling on the earth is more than 7500 times of the world's total annual primary energy consumption. The annual solar radiation reaching the earth's surface, approximately $3.4*10^6$ EJ, is to the order of greater than all the estimated non-renewable energy resources, including fossil fuels and nuclear. When considering thermal applications of solar energy, solar cooking presents the best option and the most promising appliance for solar thermal energy [6]. Solar cookers provide many advantages, including fuel economy, reduction in green house gas emission, firewood utilization saving, lower cost and high durability, among others [6]. However, in many parts of the world, especially in developing countries, wood and fossil fuel based cooking energy resources still predominate with the highest share of global energy consumption in the residential sector. This situation creates serious ecological problems, such as deforestation [6]; economical and health problems are also the consequences of firewood use. On the other hand, the global demand for cooking energy is expected to increase with the increasing human population in the coming years. Currently, renewable energy sources supply about 14% of the total world energy demand, and their potential will play an important role in the future [6].

The development of solar cooking systems in the near future will also help to resolve the existing problems with technology like long duration cooking, uncontrolled temperatures, tracking strategies, and thermal storage techniques, etc. and thereby, overcome the barriers to the dissemination of the solar cookers. Many opportunities exist for their promotion of the potential for solar cookers. So more research attempts must be carried out to increase their efficiency and thus enhance current performance.

II. DESIGN CALCULATIONS

TABLE I. COOKING LOAD CALCULATIONS

S.NO	PARAMETERS	SYMBOLS	VALUE
1	Heat energy required to cook rice	Q_{rice}	378 kJ
2	Heat energy required to cook dhal	Q_{dhal}	564.3 kJ
3	Total heat energy required to cook(3 members)	Q_{total}	1000 kJ
4	Collector area	Ac	1 m^2
5	Efficiency of solar cooker	η	40%
6	Cooking time	t	2 hrs

III. EXPERIMENTAL SETUP

This system operates on the principle of focusing on the incident solar radiation into small enclosures via dish collectors. The solar receiver or the enclosure is located at the focal point or focal line of the dish collector. A Solar dish system consists of a dish with a reflective material and a receiver located at the focal point of the dish. The Solar dish type collector is supported by a stand. The solar radiation incidents on the dish are reflected toward the focal point of the dish where the receiver is located. Highly concentrated solar radiations enter the receiver and significantly increase the temperature of the receiver and the receiver fluid. The receiver is designed in the form of a helical tube structure. The helical tube consists of heat transfer fluid which circulate in the system with the help of a pump. The heat transfer fluid absorbs heat and transfers it to the cooker which is

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placed apart. The reflected rays from the dish collector focus on a small area, the focal point, where the receiver is located.

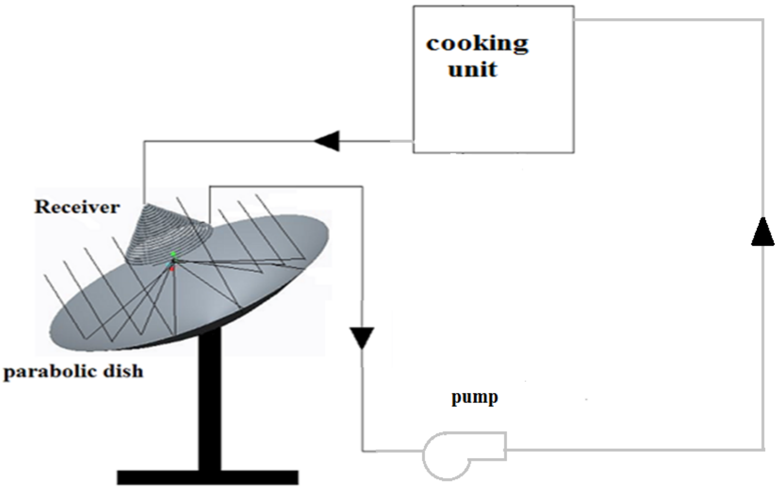

Fig.1 Schematic of Parabolic dish with conical coil receiver setup

Fig.2 Photographic view of Schematic of Parabolic dish with conical coil setup

TABLE II .Specification of Parabolic Dish collector

S.NO	PARAMETERS	SYMBOLS	VALUE
1	Aperture diameter	D_a	1.13 m
2	Half acceptance angle	φ	18.48°
3	Rim angle	ψ_{rim}	71.57°
4	Focal length	f	0.392 m
5	Receiver area	A_r	0.1 m^2
6	Radius of the cone base	R	0.178 m
7	Arc length	L	1.22 m
8	Height of the dish collector	h	0.204 m

In a forced mode, the HTF is circulated through the SPC by the pump with a flow rate of 0.004 kg/s. The flow rate is set by the jar filling method. In this mode, both water and therminol 55 are tested as heat transfer fluids. The various results obtained in this mode are discussed.

IV. RESULTS AND DISCUSSION

The results obtained from the experimental investigations of the performance analysis of Solar dish during the experimental process are discussed and presented in detail.

4.1 Outlet Temperature

The experiment is conducted using water with a mass flow rate of 0.004 kg/s and average wind velocity of 2.5 m/s.Fig.1 shows gradually increases and decreases in temperature with respect to radiation for a day. The maximum outlet temperature of 69ºC reaches at 12.30 p.m.

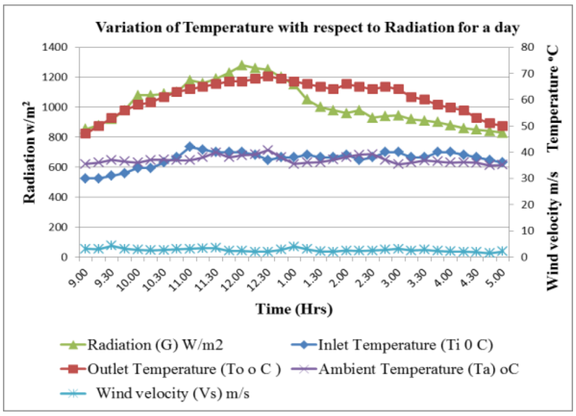

Fig.3 Outlet Temperature - Water as HTF

The experiment is conducted using water with a mass flow rate of 0.004 kg/s and average wind velocity of 4.6 m/s.Fig.4 shows gradual increases and decreases in temperature with respect to radiation for a day. The maximum outlet temperature of 86^{o} C is reached at 12.30 p.m.

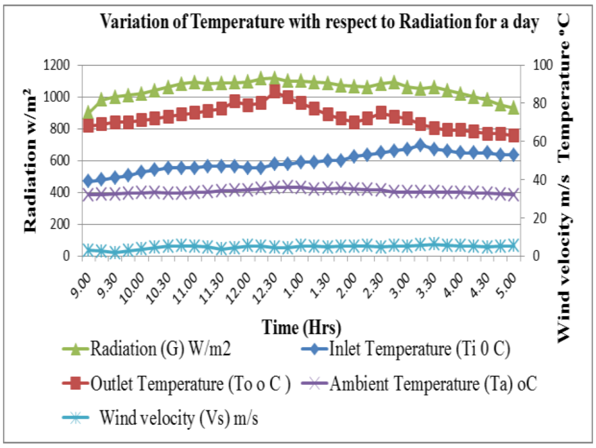

Fig.4 Outlet Temperature - Therminol 55 as HTF

4.2 Heat Gain

Radiation and heat gain gradually increase and decrease as shown in the figure 5. The maximum heat gain of 600 W attained at 12.30 p.m.

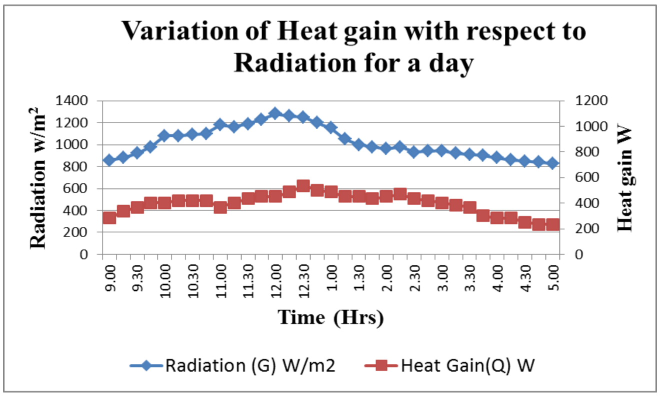

Fig.5 Heat gain - Water as HTF

Radiation and heat gain gradually increases and decreases are shown in the figure 6. The maximum heat gain of 380W attained at 12.30 p.m.

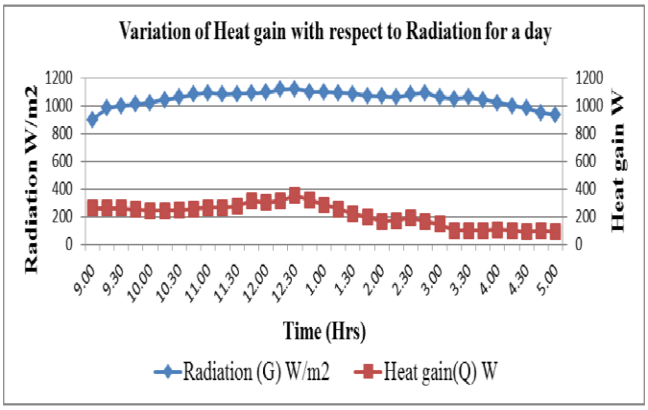

Fig.6 Heat gain - Therminol 55 as HTF

4.3 Efficiency

Efficiency varied over time and it reached high in between 1.00 to 3.30 p.m. is shown in the figure 7.The highest efficiency is 48% around 2.30 pm.

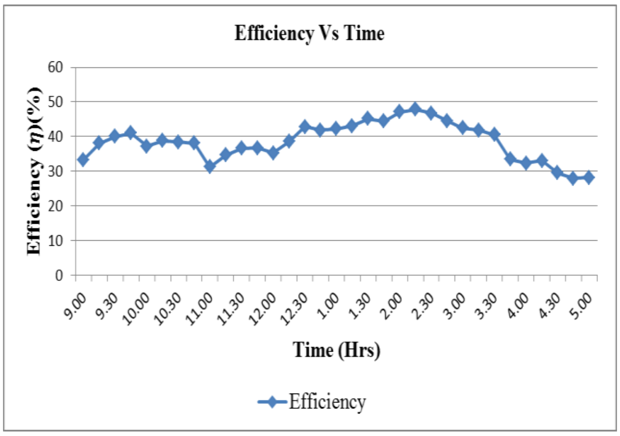

Fig.7 Efficiency – Water as HTF

Efficiency various over time and it reached high in between 12.00 to 1.00 p.m. is shown in the figure 7.The high efficiency is around33%.

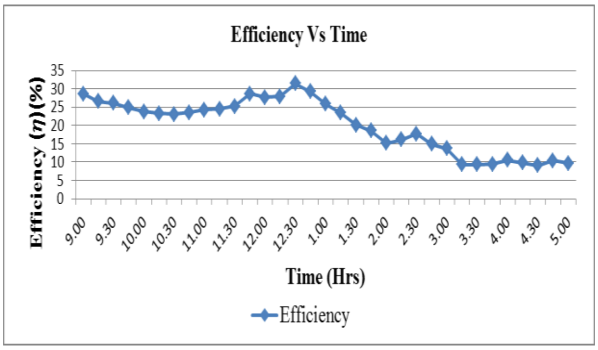

Fig.7 Efficiency –Therminol 55 as HTF

V. CONCLUSION

Over the decade, intensive research has been going in the field of solar energy for various household applications. Here, in this paper a special type of receiver i.e. conical coil receiver is used. The parabolic dish is designed in such a way as to focus the solar radiation into the receiver. The designed receiver is experimentally analyzed with various heat transfer fluids like water and Therminol 55.The results are more appreciable in the case of forced circulation mode than the normal mode.

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