Thermal Analysis of Parabolic Dish Snow Melting Device

Kailash Karunakaran[1] Hyacinth J Kennady[2]
[1]M.Tech Thermal Engineering, [2]Professor, Mechanical Engineering
[1,2]HINDUSTAN University, Padur, Chennai, India
[1]kailashkarunakaran@gmail.com, [2]hyacinthjk@hindustanuniv.ac.in

Abstract—*Solar energy can be utilized in different ways to meet the various energy requirements. A parabolic dish collector is a device designed to collect energyfrom sunlight. The aim of the project is achieved by concentrating the solar energy using a parabolic dish collector to a receiver arrangement. The dish surface is made highly reflective which ensures the effective concentration of energy to the receiver. The receiver is the part where snow is melted. A storage tank with suitable insulation is proposed to ensure the effective future utilization of water produced. The thermal analysis of the snow melting process is carried out and the various losses and heat transfer coefficients calculated.*

Keywords–parabolic dish collector, receiver, solar energy, thermal analysis.

I. INTRODUCTION

In today's climate of growing energy needs and increasing environmental concern, the utilization of non-renewable and polluting fossil fuels have to be minimized. Solar energy is one of the alternative sources of energy for meeting the energy demands. This form of energy can be harnessed at comparatively low cost. Only a very small fraction of the total radiation produced by the sun reaches the Earth. Solar energy is a diffuse form of energy which demands the use of special devices to capture the energy. The devices that are used consist of a collector surface, a receiver arrangement and a storage unit. The function of the collector is to simply collect the radiation that falls on it and this can be converted to other forms of energy (either electricity and heat or heat alone).

A parabolicdish, similar in shape to satellite television dish focuses all the sunlight that strikes the dish up onto a single point above the dish, referred to as focal point. A receiver which captures the heat is placed at the focal point of dish and this energy is transformed into a useful form. The dish arrangement ensures higher temperatures by concentrating energy from the sun. The parabolic dish is aligned in such a way that its axis is pointing towards the sun. This allows almost all incoming radiation to be reflected towards the focal point of the dish. Optical losses are reduced with perfection in the collector surface design.

In literature there exist a number of papers concerning the thermal performance of solar collectors and its use in water heating. For instance, Ari Rabl [1] presented a comparison of solar concentrators.James A. Harris et al. [2] evaluated the thermal performance of solar concentrator and cavity receiver systems. H.E. Imadojemu [3] evaluated the concentrating parabolic collectors.S.K. Tyagi et al. [4] presented an exergy analysis and parametric study of concentrating type solar collectors.N. Sendhil Kumar et al. [5] presented a comparison of receivers for solar dish collector system.VandanaArora et al. [6] presented on development and performance characteristics of a low-cost parabolic solar collector. Ibrahim Ladan Mohammed [7] presented on design and development of a parabolic dish solar water heater.

In this work the focus is given to the design of the parabolic dish surface with a receiver arrangement which concentrates maximum possible energy. This energy is utilized in the process of melting snow. The work aims at producing water in an effective manner and aids in avoiding the need for carrying water to hilly areas where snowfall is present.

II. DESIGN OF THE PARABOLIC DISH COLLECTOR

The parabolic dish collector surface is made of aluminium having a diameter of 1.668 m. The diameter and the height of the receiver is 0.2335 m. The receiver is placed at the focal point which is at 0.578 m with respect to the dish surface. Aluminium is considered for the receiver being light weight. A protective coating is applied on the receiver surface to reduce the adverse effects of weather. The coating is selected taking into consideration the absorptivity of the concentrated radiation.The height of the parabolic dish surface is 0.3 m.The rim angle is 75.565^0.Fig.1 shows the designed parabolic dish collector with the dimensions as mentioned above.

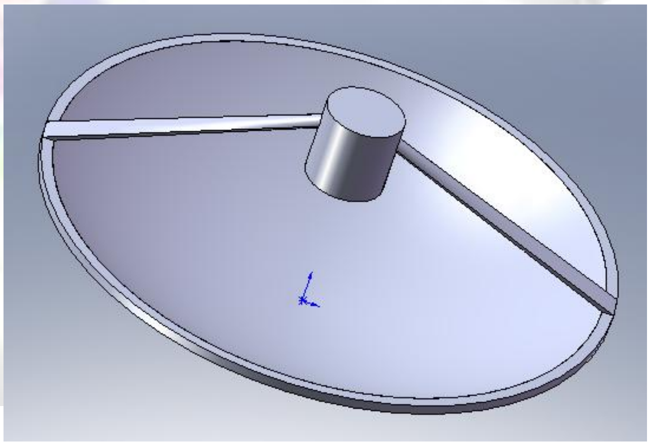

Fig. 1: The parabolic dish collector

III. THERMAL ANALYSIS

The incident energy on the concentrator aperture [8] is the product of beam solar radiation (I_b) and the concentrator aperture area (A_a) given by:

$$Q_I = I_b A_a \quad (1)$$

The radiation falling on the receiveris a function of the optical efficiency (η_0) which is defined as the ratio of the energy falling on the receiver to the energy incident on the concentrator's aperture. The power on receiver [8] can be written as:

$Q_R = \eta_0 Q_I$ (2)

Under steady state conditions, the useful heat energy delivered by a solar collector system is equal to the energy absorbed by the heat transfer fluid, which is determined by the difference between radiant solar energy falling on the receiver (Q_R) and the direct or indirect heat losses (Q_L) from the receiver to the surroundings [8]. That is,

$Q_U = Q_R - Q_L$ (3)

The heat loss from the receiver surface is due convection and radiation modes of heat transfer to the surroundings and is given by the relation,

$Q_L = U_L A_r (T_r - T_a)$ (4)

where the overall heat loss coefficient is U_L, A_r is the receiver or the absorber surface area, T_r is the receiver surface temperature, T_a is the ambient temperature.

The collector thermal efficiency (η_{th}) is defined [7] as the ratio of the useful energy delivered (Q_U) to the energy incident (Q_I) on the concentrator aperture and is given as:

$\eta_{th} = Q_U/Q_I$ (5)

The optical efficiency is the parameter which determines the amount of energy intercepted by the receiver. The parabolic dish surface is made of a reflective surface and the efficiency is taken to be 0.74. The optical efficiency also contributes to the maximum achievable temperature on the receiver surface. Aluminum is selected as the dish material which has a reflectivity of 0.85.

IV. RESULTS

The parabolic dish collector has to track the sun for absorbing the maximum energy from the sun. The variation of the incident power, power on receiver and the useful power is as shown for two days in Table I.

Time of the day (hrs.)	Q_I (W)		Q_R (W)		Q_U (W)	
	June 15	Dec. 15	June 15	Dec. 15	June 15	Dec.15
8	1923	572	1423	423	1147	339
9	2089	1278	1546	946	1249	751
10	2182	1591	1615	1178	1306	937
11	2230	1732	1650	1281	1335	1020
12	2245	1772	1661	1312	1344	1044
13	2230	1732.	1650	1281	1335	1020
14	2182	1591	1615	1178	1306	937
15	2089	1278	1546	946	1249	751
16	1923	572	1423	423	1147	339

Table 1: Performance Of Parabolic Dish Collector

Thermal losses vary with different parameters like the wind velocity, the area of the receiver, temperature of the receiver, the emissivity of the receiver. The variation of the thermal losses for various months is as shown in the Fig.2.

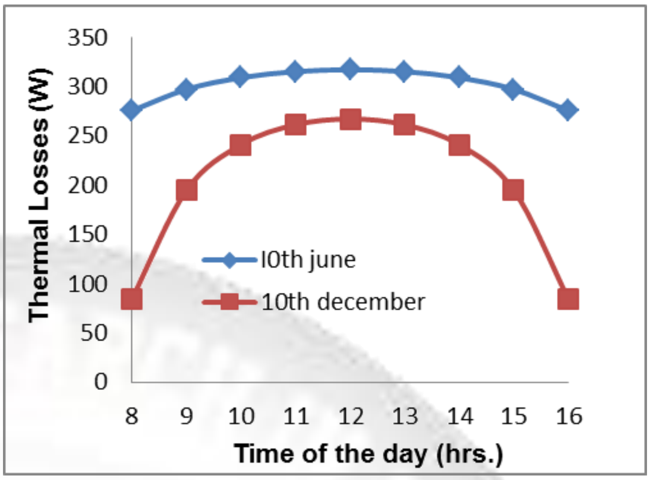

Fig. 2: The graph shows variation of thermal losses for two days.

Thermal efficiency is calculated for various months in year and is plotted in Fig. 3, the thermal efficiency is found to vary from 59% to 60% for the two days. The amount of energy absorbed in the receiver has a great impact on the efficiency, it is the thermal losses which contribute to a reduction in the absorbed power.

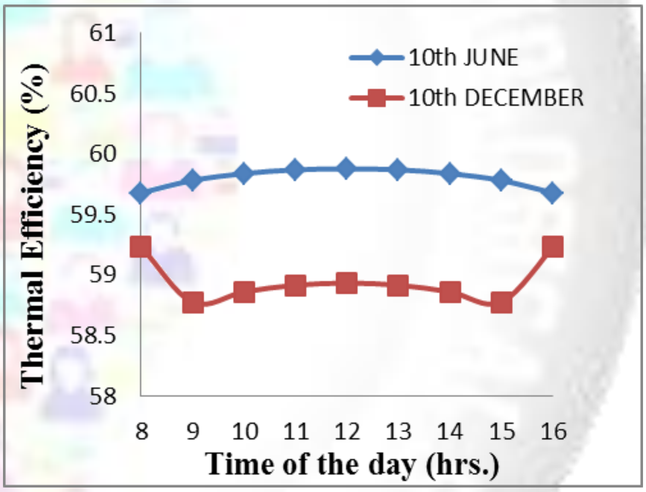

Fig. 3: The graph shows variation of thermal efficiency for two days.

The variation of performance is calculated for two days in a year and clearly depicts the performance of the device.

V. CONCLUSION

The device produces about 50 to 60 liters of water on an average in a day. The storage system ensures the efficient storage of water for effective utilization. The work can be considered as a helping hand for people in high altitude areas where it snows almost all days.

REFERENCES

[1] Ari Rabl, Comparison of Solar concentrators, Solar energy, Volume 18, Issue 2, 1976.

[2] James A. Harris, Terry G. Lenz, Thermal performance of solar concentrator/ cavity receiver systems, Solar Energy, Volume 34, Issue 2, 1985.

[3] H.E. Imadojemu, Concentrating parabolic collectors,

Energy Conversion and Management, Volume 36, Issue 4, April 1995.
[4] S.K. Tyagi, Shengwei Wang, M.K. Singhal, S.C. Kaushik, S.R. Park, Exergy analysis and parametric study of concentrating type solar collectors, International Journal of Thermal Sciences, Volume 46, Issue 12, December 2007.
[5] N. Sendhil Kumar K.S. Reddy, Comparison of receivers for solar dish collector system, Energy Conversion and Management, Volume 49, Issue 4, April 2008.
[6] VandanaArora, TanujaSheorey, Development and performance characteristics of a low-cost parabolic solar collector, IPCSIT, Volume 56, 2012.
[7] Ibrahim Ladan Mohammed, Design and development of a parabolic dish solar water heater, International Journal of Engineering Research and Applications, Volume 2, Issue 1, January-February 2012.
[8] Lloyd C. Ngo, Exergetic Analysis and Optimisation of a Parabolic Dish Collector for LowPower Application, Centre for Renewable and Sustainable Energy Studies, University of Pretoria.
[9] G.N.Tiwari, Solar energy, Narosa publishing house pvt. Ltd., 2012.
[10] Fareed. M. Mohamed, Auatf.S.Jassim, Yaseen. H. Mahmood, MohamadA.K.Ahmed, Design and study of portable solar dish concentrator, International Journal of Recent Research and Review, Volume 3, 2012.
[11] Gavisiddesha, Dr.Revankar P.P., Gorawar M.B., Evaluation of thermal performance of paraboloid concentrator solar cooker, International Journal of Innovative Research in Technology & Science, Volume 1, 2013.
[12] Shiva Gorjian, Barat Ghobadian, TeymourTavakkolHashjin, Ahmad Banakar, Thermal performance of a Point-focus Solar Steam Generating System, ISME, 2013.