

## Performance analysis of elliptical heat pipe solar collector

K. Sivakumar, N. Krishna Mohan and B. Sivaraman

Department of Mechanical Engineering, Annamalai University, Chidambaram-608001, TN, India  
 vksivakumar\_75@yahoo.co.in

### Abstract

Elliptical heat pipe flat plate solar collector was designed, constructed and tested with a collector tilt angle of  $11^\circ$  to the horizontal. Experimental analysis of the effect of condenser length/evaporator length ( $L_c/L_e$ ) ratio of the heat pipe, different cooling water mass flow rates and different inlet cooling water temperature were analysed. Five numbers of elliptical heat pipes with stainless steel wick has been fabricated and used as transport tubes in the collector. Copper tube has been used as container material with methanol as working fluid of the heat pipe. These heat pipes were fixed to the absorber plate of the solar collector and the performance of elliptical heat pipe solar collector has been studied and results were compared. It has been found from the experimental trials that the elliptical heat pipe solar collector having  $L_c/L_e$  ratio of 0.1764 achieved higher instantaneous efficiency.

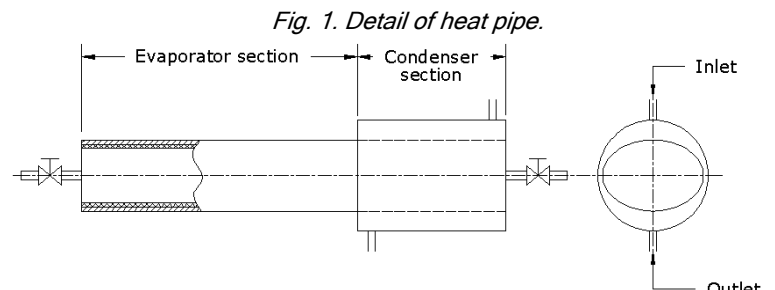
**Keywords:** Heat pipe, flat plate solar collector.

### Introduction

Heat pipe is a device for transferring heat from a source to a sink by means of evaporation and condensation of a fluid in a sealed system. The main components of heat pipe are evaporator and condenser. This sealed pipe has a working fluid which absorbs the heat energy from the evaporator and gets vaporised and move towards the condenser where it get condensed. The condensate returns to the evaporator through the wick by capillary action. Heat pipes can be used to provide a uniform temperature. They can be used for temperature control in the electronic applications to cool processors and as thermal diodes. They have the advantage of being silent, operating independently of gravity, does not need servicing and having no moving parts.

Ismail and Abogderah (1998) studied the performance of a heat pipe solar collector and found its efficiency to be compared with the conventional solar collector. Akyurt (1982) developed heat pipes for solar water heaters and found that they exhibit isothermal behaviour and is considered to possess potential for solar applications. Hussein *et al.* (2006) studied the performance of wickless heat pipe flat plate solar collector having different cross section geometries and filling ratios. They investigated the water filling ratio corresponding to the flooding limit of the elliptical cross section and referred that it is very close to 35% for circular section so that an elliptical cross section significantly improves the performance of wickless heat pipe flat plate solar collectors at low water filling ratios. Theoretical model of a thin membrane heat pipe solar collector was discussed by Riffat *et al.* (2004). Abdul-Jabbar & Khalifa (1999)

studied the performance of locally made flat plate collectors used as part of a domestic hot water system. They found the temperature distribution along the flow direction and the thermos phonic mass flow rate. Kulkarni *et al.* (2007) observed that there exists a minimum as well as a maximum storage volume for a given solar fraction and collector area. Nada *et al.* (2004) studied the performance for different cooling water temperature. Also the effect of the number of the collector was investigated. The effect of the condenser inclination on the system efficiency was remarkable for natural circulation water flow but no significant effect for forced circulation



(Radwan *et al.*, 1990). In this work, an attempt has been made to fabricate the elliptical flat plate heat pipe solar collector. The performance of the collector was studied at different  $L_c/L_e$  ratios and mass flow rates.

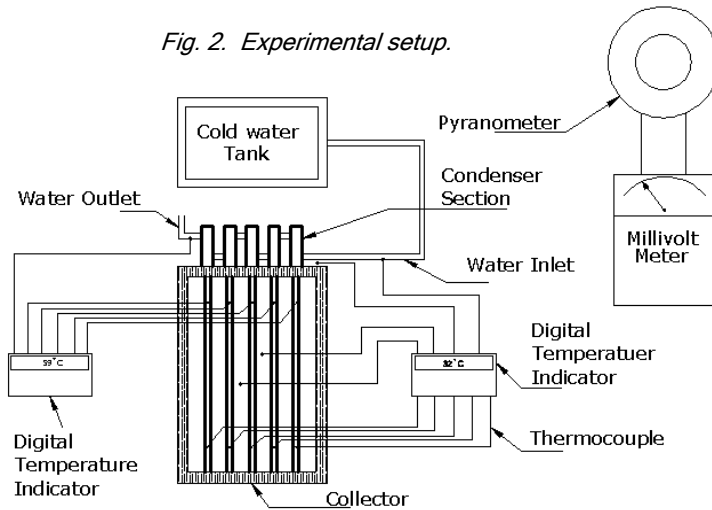
### Working principle

In the heat pipe solar collector, the sun rays passes through the glass cover to heat a copper heat pipe. Inside the heat pipe, a non-toxic liquid carries the heat to another end of the heat pipe, then to the collector unit in which it is transferred through the water heating system. Solar radiation is absorbed by the absorber plate and converted in to heat. Heat

Table 1. Heat pipe specifications.

Heat pipe material	Copper
Working fluid	Methanol CH <sub>3</sub> OH
Total length of pipe ( $L_t$ )	1.00 m
Evaporator length ( $L_e$ )	0.65 m, 0.75 m, 0.85 m
Condenser length ( $L_c$ )	0.35 m, 0.25 m, 0.15 m
Major axis of elliptical pipe (a)	$26 \times 10^{-3}$ m
Minor axis of elliptical pipe (b)	$16.7 \times 10^{-3}$ m
Thickness of pipe (t)	$2.0 \times 10^{-3}$ m

Fig. 2. Experimental setup.



pipes then conduct the heat from evaporator section to condenser section where water is circulated through the condenser section and the water gets heated there.

#### Design & construction details

Five numbers of heat pipes have been used in solar collector and placed over the absorber plate. The schematic diagram of a heat pipe is shown in Fig.1. Copper has been used as container material and stainless steel as wick material. Wrapped screen wick structure with 2 layers of wick has been used in the heat pipe. Methanol has been used as a working fluid of the heat pipe. The specification of the heat pipe is given in Table 1. The solar collector is a flat plate collector having dimension of length 0.83 m and breath 0.81 m. Aluminium sheet of 2 mm thick has been used as absorber material and is painted with black paint thickness of glass plate is 3.2 mm.

#### Experimental trial

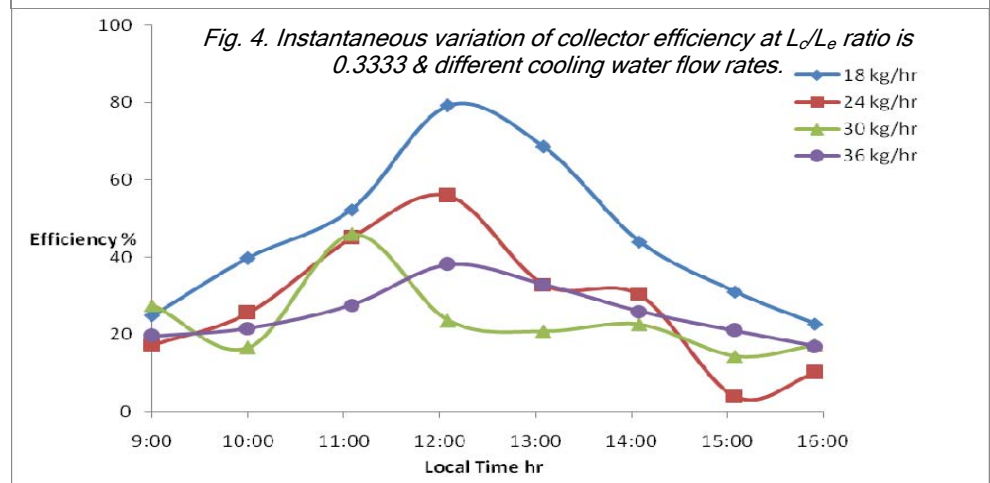
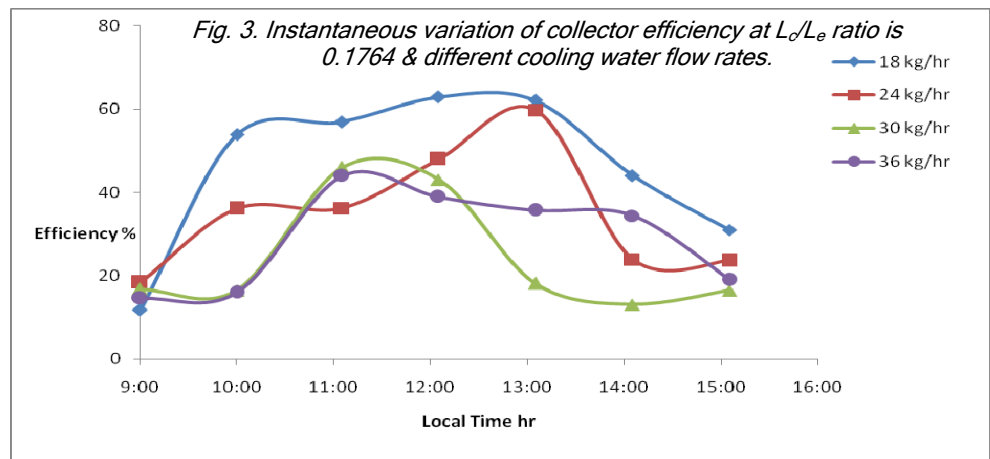
Experiments were conducted on the designed elliptical heat pipe solar collector with different mass flow rate of 18 kg/h, 24 kg/h, 30 kg/h and 36 kg/h on various days. The condenser and evaporator length ratio were varied (ie.,  $L_c/L_e$  ratio as 0.1764, 0.3333 and 0.5384) in the experimental study. Experiments were conducted first with  $L_c/L_e$  ratio 0.1764 with constant mass flow rate for various days and then mass flow rate was changed. Similarly the trials were conducted for  $L_c/L_e$  ratio of 0.3333 and 0.5384. The observation of various

parameters were measured and recorded from 9 a.m to 4 p.m. The collector has been placed facing due south with a tilt angle of  $11^\circ$  to the horizontal. The elliptical heat pipes have been brazed to the absorber sheet in such a way that the evaporator section of the heat pipe is in the collector and condenser section is protruding outside the collector. The water circulated through the condenser section. Water temperature at inlet and outlet were measured by K-type thermocouple. Solar intensity at the test site was measured using EPPLY pyranometer. The heat pipe surface temperature, absorber plate temperatures and glass plate temperatures were measured using thermocouples (Fig. 2).

#### Results and discussion

The efficiency of elliptical heat pipe flat plate solar collector are calculated and graphically represented in order to compare different mass flow rate at various days. Fig. 3 gives the efficiency curve for trials made with a  $L_c/L_e$  ratio of 0.1764 and for different cooling water mass flow rate on various days. A maximum efficiency of 80% was achieved during the trial for  $L_c/L_e$  ratio of 0.3333.

Fig. 3, 4 and 5 show the performance of the collector for the different mass flow rates (18 kg/h, 24 kg/h, 30kg/h & 36kg/h) of the cooling water. The efficiencies were



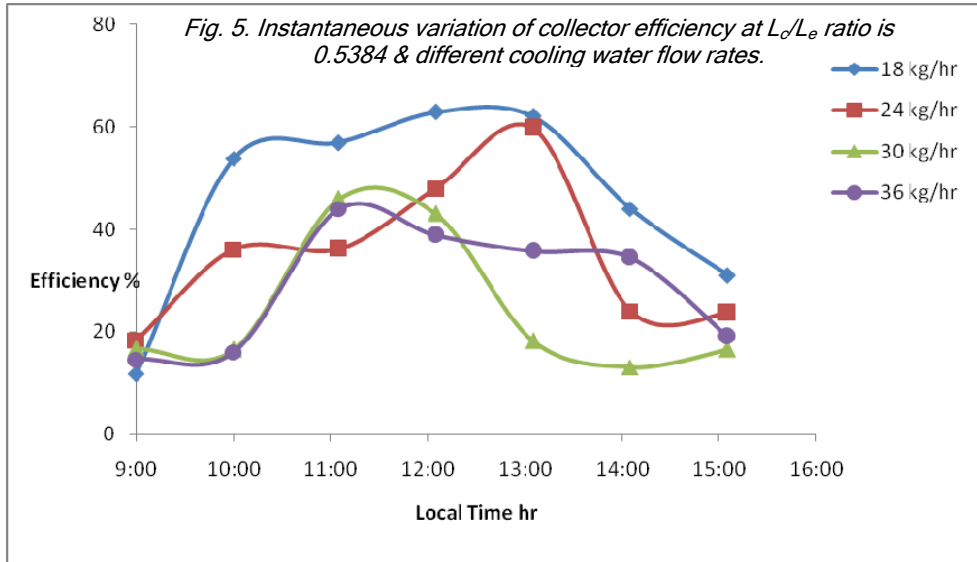


Fig. 6. Instantaneous variation of collector efficiency and  $(T_{wi}-T_a)/I_t$  at  $L_c/L_e$  ratio is 0.1764 & different cooling water flow rates.

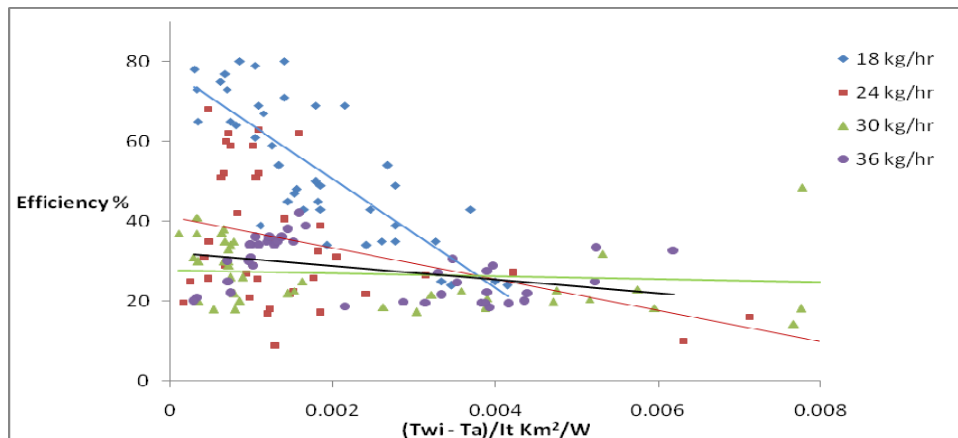
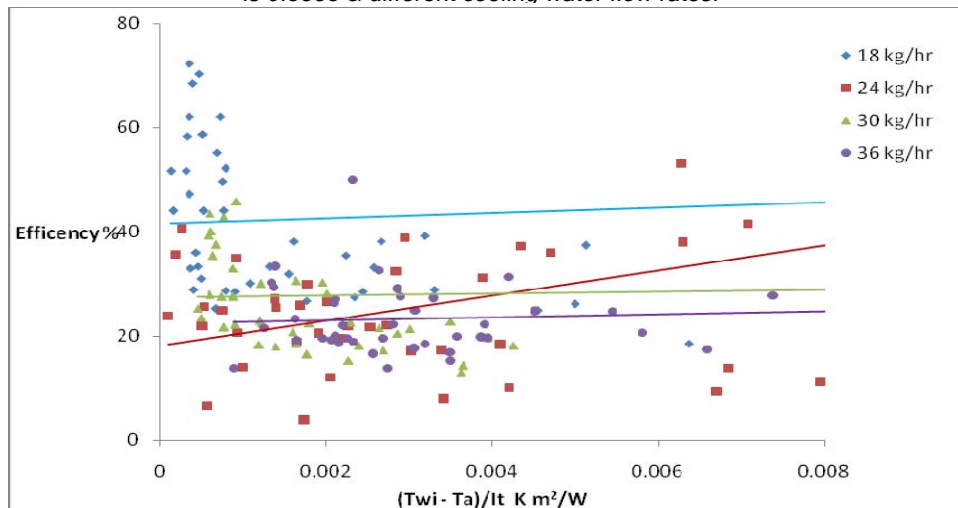


Fig. 7. Instantaneous variation of collector efficiency &  $(T_{wi}-T_a)/I_t$  at  $L_c/L_e$  ratio is 0.3333 & different cooling water flow rates.



found to be lower during forenoon at the mid-day it reaches maximum and then decreases in the afternoon. The efficiency is low during forenoon and relatively high

at the end of the afternoon, because of the heat storage in the system. Fig. 6, 7 and 8 show the results of the efficiency of the heat pipe solar collector versus  $(T_{in}-T_a)/I_t$  indicating standard one for the 4 flow rates used in the experiments. Fig. 9 gives the surface temperature of the heat pipes and absorber plate temperature on a day it clearly shows that the curve has the same trend as that of the solar intensity. Maximum temperature of absorber plate was achieved around 110°C. Fig. 10 gives the plot of solar intensity against time. It has

been found from the experimental trials that the elliptical heat pipe solar collector having  $L_c/L_e$  ratio of 0.1764 achieved higher instantaneous efficiency.

**Conclusion**

The elliptical heat pipe solar collector was designed, fabricated and tested for different mass flow rates and  $L_c/L_e$  ratio. The efficiency of the elliptical heat pipe solar collector was calculated. The performance analysis of the above test results shows that when the water flow rate was 18 kg/h it is performing better than the others (i.e. 24 kg/h, 30 kg/h & 36 kg/h). It has been found that when the  $L_c/L_e$  ratio was 0.5384, its performance was better than the others (i.e. 0.1764, 0.3333).

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Fig. 8. Instantaneous variation of collector efficiency &  $(T_{wi}-T_a)/I_t$  at  $L_c/L_e$  ratio is 0.5384 & different cooling water flow rates.

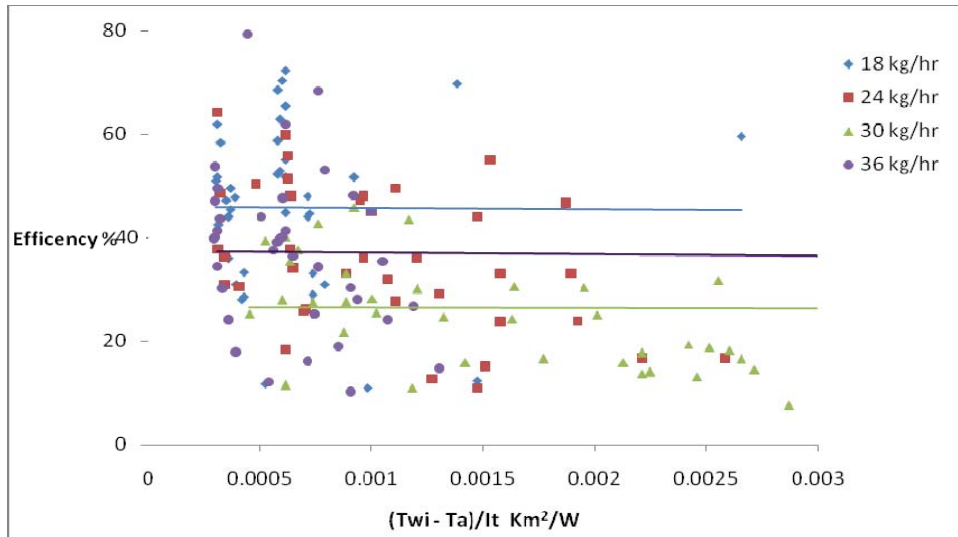


Fig. 9. Variation of heat pipes surface temperature & absorber plate temp.

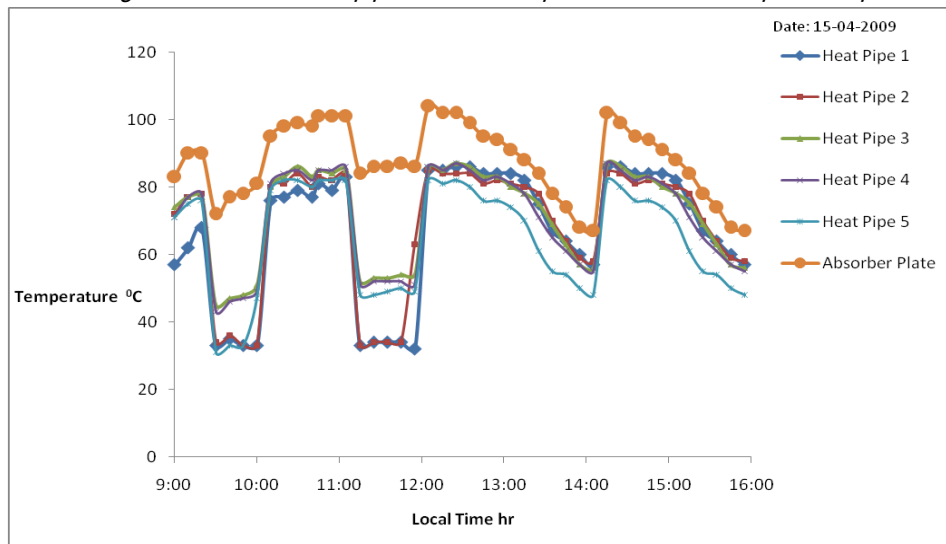
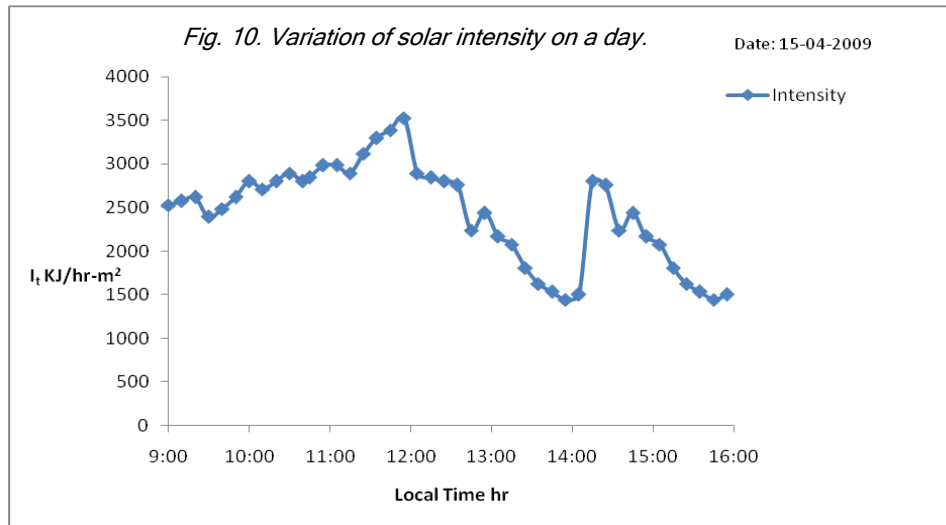


Fig. 10. Variation of solar intensity on a day.



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