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Evaluation of the Thermal Performance of Thermosyphon Heat Pipe Solar Collector with Copper oxide as Nanofluid

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Abstract- In this research the effect of copper oxide nanofluid (pure water mixed with copper nanoparticle with 30-50nm diameter) on the thermal efficiency enhancement of a heat pipe at different operating state was investigated . The heat pipe made of straight copper tube of outer diameter 12 mm and inner diameter 10 mm. The tested concentration level of nanofluid are 0.3, 0.6, 0.9wt%. This study presents the discussion on the effect of coolant rate, inclination angle of solar collector and effect of nanomaterial concentration on the performance of solar collector. Result shows that by charging the nanofluid to the heat pipe the thermal performance is enhanced. Performance of solar collector was increases with increase in inclination of solar collector and concentration of nanofluid up to certain level and then again decreases. Increase in coolant rate also increases the thermal performance up to certain level.

Index Terms- Solar collector, Heat pipe, nanofluid,

I. Introduction

Solar water heaters are the most developed renewable energy technologies used in the world. For the past several years, conventional flat plate collectors have been well studied and developed. Their relatively low cost, lower maintenance and easy of construction have made these systems very competitive and are widely used all over the world especially for low temperature thermal systems. Conventional flat plate solar collectors use water pipes attached to the collecting where water circulates either naturally or forced inside the pipes and so transfers the heat collected by the plate to the storage tank. The following are some of the limitations of conventional flat plate solar collectors for water heating

• Low heat transported by the fluid which leads to low thermal efficiency
• Pipe corrosion due to the use of water
• Freezing of water used in cold nights
• The night-cooling effect due to the transverse flow of cooled water
• The extra space required for natural circulation due to the position limitation required
• And the heavy total system weight

A design improvement of conventional flat plate collectors increases the solar energy share for hot water production. Due to the low energy density and transient nature of solar energy, designing appropriate heat transport system is important in increasing the solar fraction for stand-alone or simulated hot water production systems. Employing heat pipes for solar water heating application is at its young stage and extensive studies are required to integrate heat pipe in solar collector systems so as to improve the heat transport. Since the advent of heat pipes in 1960, their importance in solar application such as solar collectors for domestic water heating, space heating and cooling has received increasing attention (Dunn and Reay, 1994). As the demand of energy conservation increases, heat pipes become more and more attractive for an increasing number of various applications. Heat pips have low thermal resistance for heat transfer than any other metals have (Dunn and Reay, 1994). Most of the above limitations of conventional solar collectors can be overcome by using a compact heat pipe solar collector system. For solar system application, very high thermal conductance (phase change heat transfer), ability to act as a thermal flux transformer, and an isothermal surface of low thermal impedance are very important properties of heat pipe.

Several studies have been reported on the use of heat pipe for solar water heating systems. Mostafa Keshavarz Moraveji et.al [1] has study the effect of using aluminum oxide nanofluid on the thermal efficiency enhancement of a heat pipe on the different operating state was investigated. The heat pipe was made of a straight copper tube with an outer length of 8 and 190 mm and a 1 mm wick-thickness sintered circular heat pipe. In the heat pipe tube, there is a 90° curve between the evaporator and condenser sections. The concentration levels of nanofluid used are 0%, 1% and 3%wt. Results show that nanofluid charge heat pipe gives better thermal performance. The thermal efficiency of heat pipe charged with pure water is compared with nanofluid.

Tooraj Yousefia, et.al [3] has studied effect of Al2O3 water nanofluid , as working fluid, on the efficiency of a flat-plate solar collector .. The composition of nanoparticles used was 0.2% and 0.4%. The diameter of particles used was 15 nm. He has varied the mass flow rate of nanofluid from 1 to 3 Lit/min. The results show that, addition of nanopartical increase the efficiency in comparison with water as absorption medium.. For 0.2 wt% the increased efficiency was 28.3%. He also concluded that that the because of surfactant there is increase in heat transfer

Chougule et al. [5] has studied Performance the solar water heater by charging nanofluid. He used the two identical with same dimensions, experimental set up of flat plate solar collectors using -heat pipes. The set p consist of three identical wickless copper heat pipes having length 620 mm and outer diameter of 18 mm. Result shows that, both collectors gave maximum instantaneous efficiency at the 50° for with and without tracking. The collector gave the better performance in the all conditions by using nanofluid as working fluid

II. Experiment

2.1. Nanofluid preparation

In this experiment Spherical copper oxide nanoparticles having nominal diameter 30–50 nm, density 6.4 g/cc are utilized and pure water was used as the base fluid to prepare the nanofluid. The required amount of the nanoparticles required to attain a 0.9, 0.6 and 0.3% volume concentration solution is calculated. Then the nanoparticles are mixed in deionized water and the solution is vibrated in an ultrasound device for 90 min in order to obtain a uniformly dispersed solution. The mixture was created by using an ultrasonic homogenizer.

2.2 Experimental Set-up

Fig 1 shows the experimental setup. The heat pipe used in this experiment is made by bending copper tube having Outer Diameter 12mm and inner diameter 10mm The length of condenser evaporator, adiabatic section is 65mm, 480mm, 50mm and respectively. Water and cuo-water nanofluid is used as working fluid for filling heat pipe. Black painted 0.5mm thick is given to copper plate whose dimension is 480 mm * 560 mm. A condenser section used for water heating in this experiment is made rectangular cross-section having dimension 25mm*65mm. 30 mm thick glass wool insulation is used from Bottom and side wall of setup and top side is cover with transparent glass cover to reduce convention heat loss. The experimental solar collector was installed on tilted stand facing south at yeola nashik, India (latitude 20.0420° N, longitude 74. 4890° E) and tested at outdoor condition. By taking Coolant (Water) flow rate 8kg/hr 4kg/hr.,.and 5 different angle of inclination (20°, 31. 5°, 40°, 50°, 60°) of collector the experiment is carried throughout the day.

Fig. 1 Experimental setup

2.3 Experimental Procedure

In order to test the performance of solar collector a test is conducted with water and nanofluid with different concentration (0. 9, 0. 6, and 0.3 wt. %) as a working fluid. The continuous drain of test was conducted from 9 a. m. to 5 p. m. on sunny days. During the complete test outlet cooling water temperature (Two), inlet cooling water temperature (Twi), solar intensity (It), and ambient air temperature (Tamb) was measured with the interval of half hour. Water supplied to condenser was measured and control by using flow control valve. The temperature of ambient air and Inlet and outlet temperature of condenser water was measured by using K-type thermocouple having accuracy ± 0. 1°c. Solar intensity was measure by using pyranometer.

2.4 Solar Collector Efficiency

Performance evaluation of solar collector can be done by calculating efficiency, which can be calculated

ɳ = Useful Heat Gain (Qw) / Heat supplied (Qs)…………………….(1)

Amount of useful heat gain can be calculated by considering water temperature variation flowing though condenser, taking into account the water flow rate and its specific heat

$Qw = m \times Cp \times \Delta T$ ……………….. (2)

Total heat supplied to collector is depend on solar intensity (It) and collector area (Ac)

$Qs = It \times Ac$……………….………….. (3)

III. Result and Discussions

Results include effect of coolant rate, tilt angle, working fluid and nanomaterial concentration on performance of heat pipe solar collector. These results are broadly classified on the basis of working fluid i.e. water and nanofluid

3.1 Water as a Working Fluid

3.1.1 Effect of coolant rate

Figure 2 shows that variation of average efficiency with respect to coolant rate for collector tilt angle 31.5° and 50°. The graph shows that efficiency variation is same in nature for both angle of inclination. Efficiency of solar collector is minimum at coolant rate 2kg/hr. and it increase with increase in coolant rate and comes to steady at coolant rate 8kg/hr. Large enhancement was observed when coolant rate increase to 4 kg/hr. from 2 kg/hr. It happens because high coolant rate draws large heat from condenser section and avoids raising pressure inside the pipe which reduces its working temperature and then reduces loss which raises the efficiency of collector. From the above result it was conform that 4kg/hr. were lower limit and 8 kg/hr. were the higher limit of coolant rate. So these limits are used for further experimentation

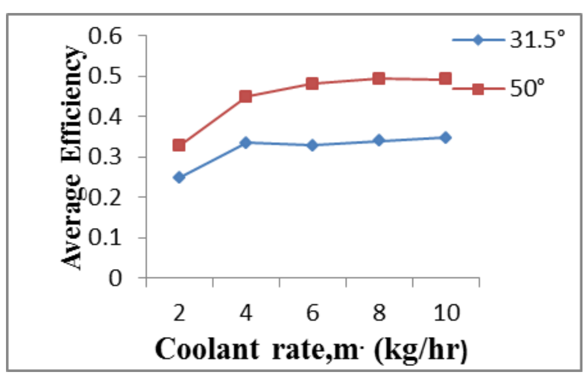

Fig 2 variation of average efficiency with respect to coolant rate

3.1.2 Effect of inclination angle

Figure 3 and Fig 4 shows the effect of inclination angle on collector efficiency. Fig 3 and Fig 4 shows the performance of collector with coolant rate 4kg/hr. and 8kg/hr. respectively for various tilt angle. The efficiency for both the coolant rates is low at lower tilt angle and it increases with increase in tilt angle. The maximum efficiency is found to be at 50° tilt angle. The maximum instantaneous efficiency obtained at 4 kg/hr. are 54% and at 8 kg/hr. is 63% at tilt angle 50° and further increase in tilt angle reduces efficiency. Increasing the tilt angle increases buoyancy force on up going vapors and gravity force on down coming liquid which gives rise to enhancement in performance with angle. But after 50° increase in angle (60°) reduces the performance of collector.

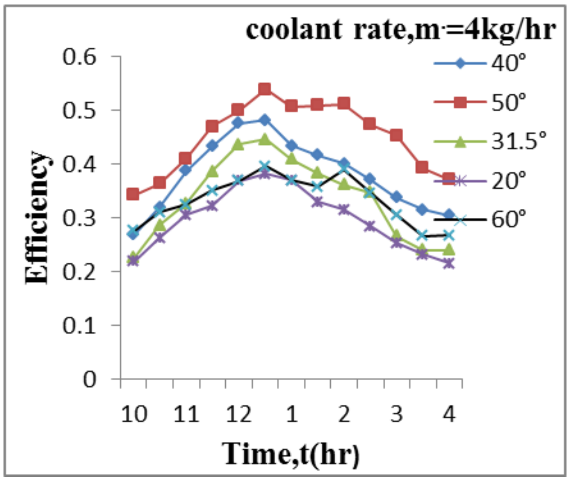

Fig.3 effect of inclination angle on collector efficiency

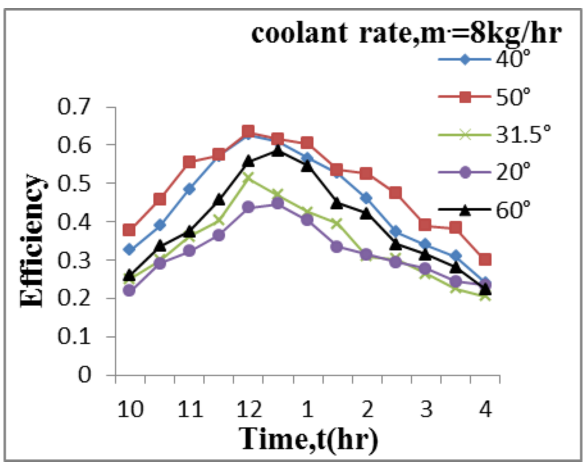

Fig 4 effect of inclination angle on collector efficiency

3.2 Water-CuO Nanofluid as a Working Fluid

3.2.1 Effect of coolant rate

Maximum Performance of heat pipe solar collector was observed at 50° tilt angle. So graph of effect of coolant rate at 50° tilt angle is drawn for nanomaterial concentration 0.3wt%, 0.6wt% and 0.9wt%. Figure 5, 6, 7 shows the comparison between the instantaneous efficiency of collector at different coolant rates at tilt angle 50°. These indicate that the maximum instantaneous efficiency of the collector is at the coolant rate 8kg/hr for all concentration of nanofluids because at high coolant rate condensation process of working fluid is better which enhance the performance. The maximum instantaneous efficiency for 0.3wt%,0.6wt%, 0.9wt% are 64%, 67% and 69% respectively for 8kg coolant rate and 56%, 61%, 62% for 4kg/hr coolant rate respectively.

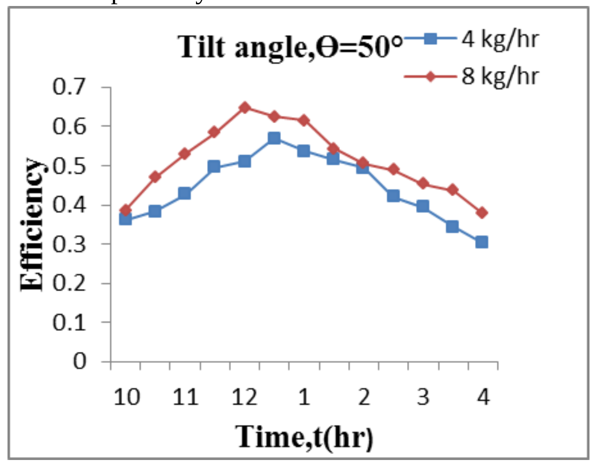

Fig 5 variation of efficiency with time for 0.3wt% Cuo nanofluid at 4 and 8kg/hr. coolant rate

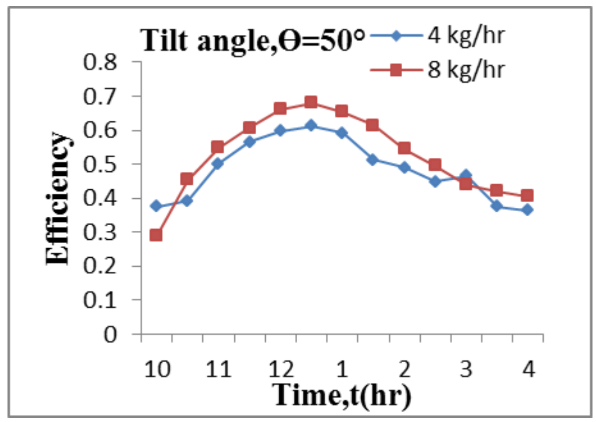

Fig 6 Variation of efficiency with time for 0.6wt% Cuo nanofluid at 4 and 8kg/hr. coolant rate

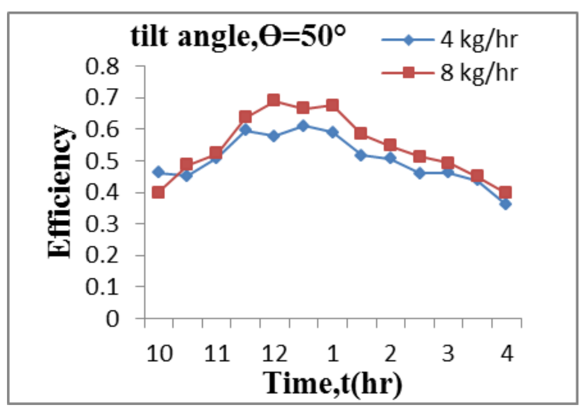

Fig 7 Variation of efficiency with time for 0.9wt% Cuo nanofluid at 4 and 8kg/hr. coolant rate

3.2.2 Effect of inclination angle

Figure 8,9,10 shows the effect of inclination angle on collector efficiency with Cuo nanofluid as a working fluid. All result is drawn at 50° inclination angle because it shows better performance. Fig 8, 9 and 10 shows the variation of instantaneous efficiency for 0.3wt%, 0.6wt%, 0.9wt% CuO nanofluid respectively for 8kg/hr. coolant rate. The Efficiency for both the coolant rates is low at lower tilt angle and it increases with increase in tilt angle. The average collector efficiency for 4kg/hr. coolant rate at 20°,31.5°, 40°, 50°and 60° tilt angle are 41%, 45%, 48%, 50% and 36% respectively. The average collector efficiency for 8kg/hr. coolant rate at 20°, 31.5°, 40°, 50°and 60° tilt angle are 44%, 48%, 50%, 54% and 41% respectively for 0.9wt% CuO nanofluid. Also maximum efficiency is found to be at 50° tilt angle. Increasing the tilt angle increases buoyancy force on up going vapour and gravity force on down coming liquid which gives rise to rise in vapour velocity which cause enhancement in performance with angle. But after 50° increase in angle (60°) reduces the performance of collector .

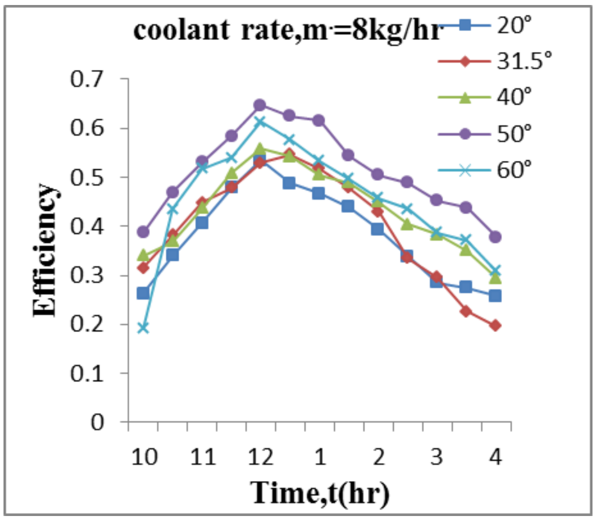

Fig 8 variation of efficiency with time for 0.3wt% CuO nanofluid

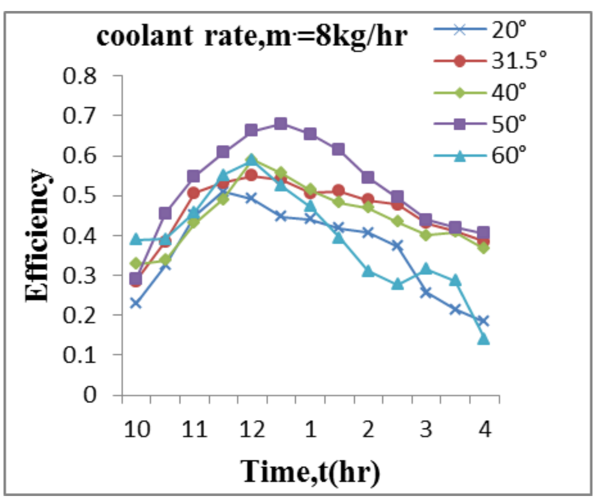

Fig 9 variation of efficiency with time for 0.6wt% CuO nanofluid

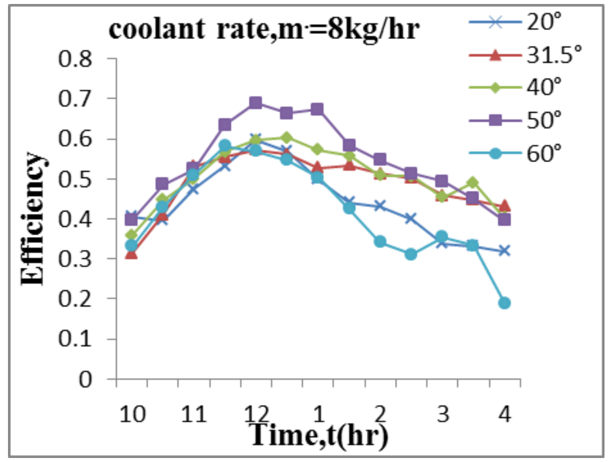

Fig 10 variation of efficiency with time for 0.9wt% CuO nanofluid

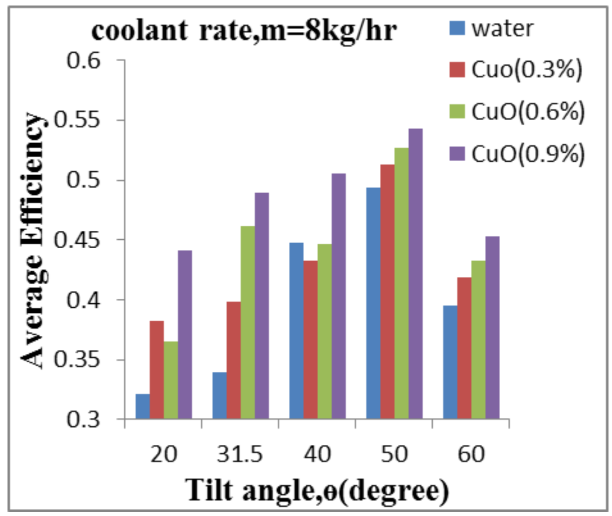

Fig.11 Effect of inclination angle and concentration of CuO on average efficiency

3.3.3 Effect of concentration

Figure 12 and Fig 13 shows the variation of instantaneous efficiency for water and different concentration of Cuo nanofluid with 4 and 8kg/hr coolant rate. Result shows that increase in concentration of nanomaterial in base fluid enhances the performance of solar collector. 8 kg/hr. coolant rate shows higher performance than 4kg/hr. water shows lower performance and 0.9 wt% nanofluid shows highest performance for both coolant rates. Fig 14 shows the variation of average efficiency for 50° tilt angle. It shows that increase in concentration increases the average efficiency of collector

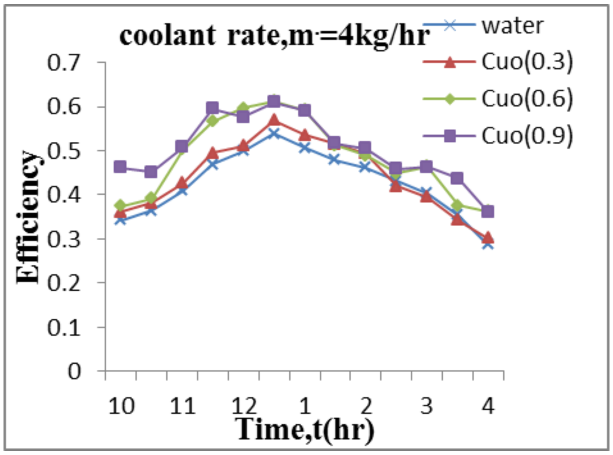

Fig 12 Variation of instantaneous efficiency for CuO nanofluid with 4kg/hr coolant rate

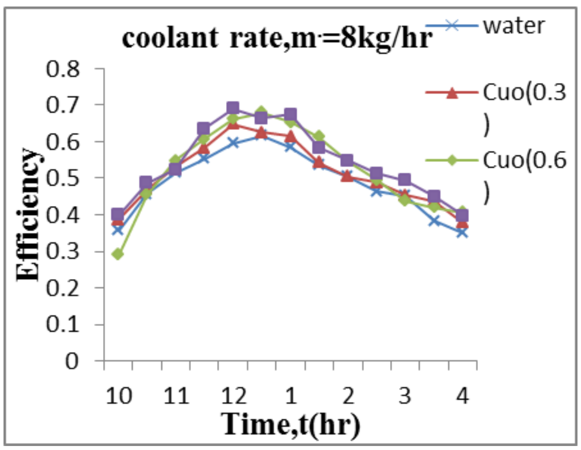

Fig 13 Variation of instantaneous efficiency for CuO nanofluid with 8kg/hr coolant rate

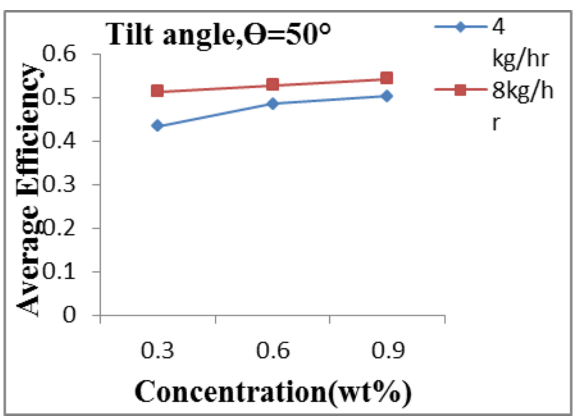

Fig 14 variation of average efficiency for different concentration of Cuo nanofluid at 50° tilt angle

IV. Conclusion

From the experimental analysis following conclusion are drawn for wickless heat pipes flat plate solar collector, it is concluded that,

1) The solar collector Performance depends on coolant flow rate, heat flux at evaporator, working fluid and inclination angle.

2) The thermal performance of heat pipe collector increases as the coolant rate increases up to certain level after that increase in coolant rate has no effect on performance.

3) As inclination angle increases from 20° to 50° the heat transfer rate through heat pipe collector with water as a working fluid is increases while further increase in angle reduces the heat transfer rate.

4) CuO nanofluid has greater potential to enhance the performance of heat pipe collector than that of water and it increase as concentration of nanomaterial increases up to certain level.

References

[1] M. K. Moraveji and S. Razvarz, “Experimental investigation of aluminum oxide nanofluid on heat pipe thermal performance”, International Communications in Heat and Mass Transfer, vol-39 (2012), 1444–1448

[2] Y.Chen, P.Wang and Z.Liu, “Application of water-based SiO2 functionalized nanofluid in a loop thermosyphon”, International Journal of Heat and Mass Transfer, vol-56 (2013),59–68

[3] T. Yousefi, F .Veysi, E. Shojaeizadeh and S.Zinadini, “An experimental investigation on the effect of Al2o3-H2O Nanofluid on efficiency of flat-plate solar collectors”, Renewable Energy,vol-39 (2012), 293-298

[4] R.R. Riehl and N.D.Santos, “Watercopper nanofluid application in an open loop pulsating heat pipe”, Applied Thermal Engineering,vol-42 (2012),6-10

[5] S. Chougule “Performance enhancement of two phase thermosyphon flat-plate solar collectors by using surfactant and nanofluid” Frontiers in Heat Pipes (FHP), 4, 013002 (2013)

[6] G.Huminic, A. Huminic, I. Morjan and F.Dumitrache, “Experimental study of the thermal performance of thermosyphon heat pipe using iron oxide nanoparticles”, International Journal of Heat and Mass Transfer,vol-54 (2011) ,656–661

[7] J. Qu, H.Wu and P.Cheng, “Thermal performance of an oscillating heat pipe with Al2O3–water nanofluids”, International Communications in Heat and Mass Transfer, vol-37 (2010),111–115

[8] J.S.kim, S.jung ha, S.lee and B.jeong, “The study of evacuated solar collector using pulsating heat pipe”, frontiers in heat pipes, vol- 3, (2012)

[9] S.H. Noie, S. Z.Heris, M. Kahani and S.M. Nowee, “Heat transfer enhancement using Al2O3-water nanofluid in a two-phase closed thermosyphon”, International Journal of Heat and Fluid Flow vol-3700–705

[10] S.A. Nada, H.H. El-Ghetany and H.M.S. Hussein, “Performance of a two-phase closed thermosyphon solar collector with a shell and tube heat exchanger”, Applied Thermal Engineering,vol-24 (2004) , 1959–1968

[11] G. Huminic and A.Huminic, “Heat transfer characteristics of a two-phase closed thermosyphons using nanofluids”, Experimental Thermal and Fluid Science,vol-35 (2011) ,550–557

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