

Research on Impact of Nanofluids in Heat Pipes

A. Premkumar, S. Senthilkumar, B. Suryakumar, M. Manikandan



Abstract: The basic aim of this study is to study the impact of nanofluids such as (Al₂O₃+Distilled water) in complete liquid form by dispensing aluminium oxide (fluid form) in base fluid and also to investigate the thermal performance of heat pipe solar collector using nanofluids under real operating conditions by theoretically and experimentally. The experimental setup is made with heat pipes and real time temperatures are measured for experimental efficiency. The theoretical investigation is to be done by using Computational Fluid Dynamics (CFD). The main innovation done in this experiment is the nanofluid prepared in complete fluid form without particles suspension to avoid the settling of nanoparticles in thermo syphon setup. For long term applications, we opted this method of preparing the fluid. The operating parameters to be considered are solar intensity, effect of tilt angle and effect of working fluid. Finally, the experimental output is to be compared with the theoretical one (CFD). The efficiency of theoretical was higher than experimental because of assumptions considered in CFD. The nanofluid filled with 25% of total capacity of heat pipe i.e. 25ml/pipe. Heat pipes are best energy conserving technology for solar energy conversion.

Keywords: heat pipes, nanofluids, temperatures, nanofluids, aluminium oxide, complete dispersion, efficiency.

I. INTRODUCTION

Solar energy is considered as renewable energy with minimum environmental effects. Solar energy is a natural result of electromagnetic radiation released from the sun by the thermonuclear reactions occurring inside its core. In spite of this huge amount of available solar energy, approximately 80% of energy used worldwide still significantly comes from fossil fuels. Recently, one of the future projections is to reduce CO₂ emissions by 2050 to 75% of its 1985 level if we can improve and use the solar energy equipment such as solar collectors.

The combination of heat pipe with nanofluid filled will result high temperature in cold region and it is also incorporated in energy conservation system.

II. OVERVIEW

All the heat pipes available in market are glass evacuated with condenser part at the top. That structure itself will multiply the heat inside evacuated part with incident solar irradiation. To enhance the heat propagation, Nano fluids are used which will increase surface area inside the heat pipe and also increases the thermal conductivity of flat plate collector. There arises a problem of imparting particles such that for experiment purpose the Nano sized particles can be used that too for only certain period of time say 3 months even after adding some surfactants in it and then the particles starts to settle at the bottom. Then appropriate results will not be obtained.

The real problem we identified is the settling of particles inside heat pipes and we came up with a solution of adding nanoparticle in water dispensable form like dissolving aluminum in suitable chemical acids and mixing with appropriate base fluid say ethylene glycol or distilled water. This concept suited for best solar heating applications for long period of term without any flaw in heat transfer. Also vacuum helps the inside pressure to decrease which will decrease the boiling point of nanofluid for better evaporation.

III. WORKING PRINCIPLE AND EXPERIMENT DETAILS

PRINCIPLE: The heat pipe works on the thermo syphon principle. Thermo syphon means natural convection occurs due to temperature gradient and circulates the fluid without any use of pumps. It is a kind of passive heat exchanger.

EXPERIMENT SETUP: The experimental setup is fabricated in the manner to obtain individual temperatures of heat pipes and overall inlet and outlet temperatures with help of Thermocouple unit. The panel is a sheet metal with length and breadth with thickness. The heat pipes of are filled with Nano fluid (Distilled water + Aluminium oxide in wax form) and inserted to the holes provided in panel and connected with thermocouple unit. Also the panel and the pipes are painted in black for absorption and insulated with foam plate to avoid dissipation of heat. At various environmental conditions, readings are taken correspondingly and calculated for thermal efficiency.

Manuscript published on 30 September 2019.

* Correspondence Author (s)

A.Premkumar, Author, RMK College of Engineering and Technology Rsm Nagar, Gummidipoondi Taluk, Puduvoyal, Thiruvallur, Tamil nadu, India. (Email: jollyboyprem@gmail.com)

S.Senthilkumar, Author, RMK College of Engineering and Technology Rsm Nagar, Gummidipoondi Taluk, Puduvoyal, Thiruvallur, Tamil nadu, India. (Email: sskrb55@gmail.com)

B.Suryakumar, Co –Author, Rmk College of Engineering and Technology Rsm Nagar, Gummidipoondi Taluk, Puduvoyal, Thiruvallur, Tamil Nadu, India. (Email: suryakarnan98@gmail.com)

M.Manikandan, Co –Author, Rmk College of Engineering and Technology Rsm Nagar, Gummidipoondi Taluk, Puduvoyal, Thiruvallur, Tamil Nadu, India. (Email: manikandanm@rmkcet.ac.in).

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](https://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

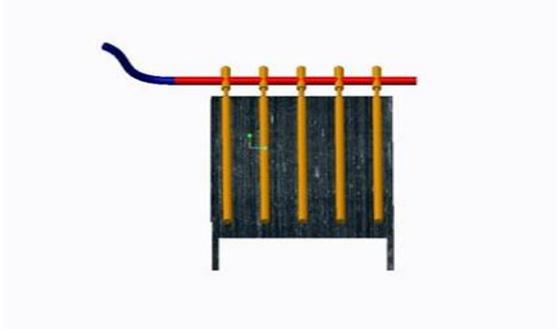


Fig.1Theoretical investigation

As the experimental readings are used for calculating thermal efficiency, we need comparison with standardized result for theoretical one. The simulation tool called CFD (COMPUTATIONAL FLUID DYNAMICS) is used for temperature variation, peak temperature at outlet etc. The operating parameters to be considered are variation of solar intensity, effect of coolant rate, effect of tilt angle and effect of working fluid. The performance parameters to be calculated are thermal efficiency of the collector and heat transfer rate. Finally, the experimental output is to be compared with the theoretical one (CFD).

Block Diagram

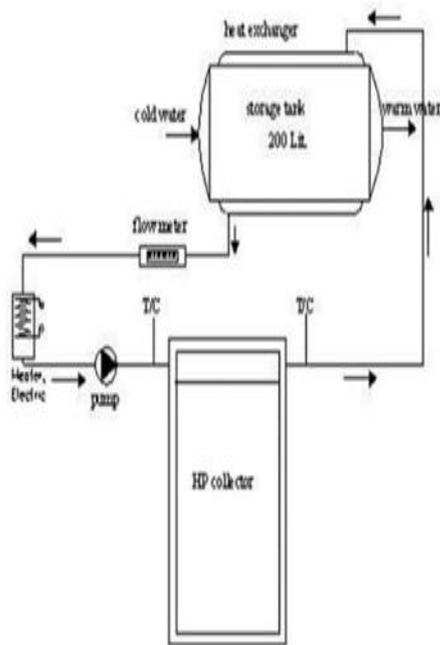


Fig.2

IV. COMPONENTS AND DESCRIPTION & RESULTS

4.1 Panel Board

The panel board is the functional area for heat absorption and transfer it to the copper pipes clamped on it. It accommodates five heat pipes at equal distance. The panel is made up of layers with acrylic plated with aluminium. It has three layers, the bottom layer is acrylic while the top layer is aluminium. Most of the solar intensity is radiated on this flat plate are where the heat conduction is higher than the heat pipes. The upper layer is painted in black colour since the black body absorbs nearly 96% of solar radiation than other

colours. This kind of layered plates are used in industrial furnace boilers to withstand high temperatures.

Table.1

PANEL AREA	1200mmx800mm
STAND	600mmx100mm
TRANSFER PIPE DIAMETER	12.7mm
CONDENSER DIAMETER	30mm
COPPER PIPE LENGTH	1000mm
ANGLE	30°
THICKNESS OF STAND RODS	20mm
PANEL THICKNESS	3mm
COPPER PIPE DIAMETER	12.7mm



Fig.3

4.2 Heat Pipes

A heat pipe is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to effectively transfer heat between two solid interfaces. In a heat pipe, the vacuum is used to alter the behaviour of the Nano fluid inside heat pipe. At sea level water boils at 100°C / 212°F, but if you climb to the top of a mountain the boiling temperature will be lower. This is due to the difference in air pressure, and a vacuum is a state of very low pressure. Based on this principle of water boiling at a lower temperature with decreased air pressure, by evacuating the heat pipe we can achieve the same result.



Fig.4

4.3 Transfer Pipes

The water passage is done transfer hose pipes. This pipe connects the thermal storage tank at the lower position and passes through the condenser area. The water through inlet first reaches the first heat pipe condenser and when the condenser is filled it passes to next condenser and so on. By this the heat gets adding on it.



Fig.5

4.4 Nanofluid

The Nano fluid used here is (Al₂O₃+Distilled Water).Here the aluminium oxide is used as metallic particles in wax form and distilled water as base fluid. The volume concentration used here is 0.2% (i.e.) 25 ml of Al₂O₃ liquid dissolved in sodium hydroxide and 100ml of distilled water for 5 heat pipes. Hence total quantity of Nano fluid is 125ml.The While filling 25 ml of prepared Nano fluid

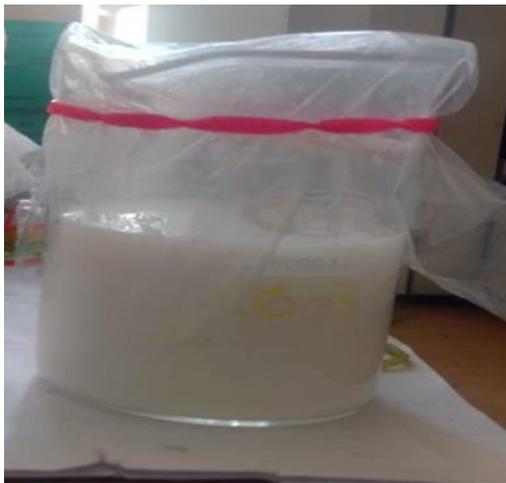


Fig.6

inside each heat pipe, there will be more space for vacuum in adiabatic section.This 25ml quantity was fixed with reference work of E.Azad in literaturepart. The Nano fluid is prepared in one step method for stability of liquid.In this one-step method, it involves the homogeneous mixingthrough magnetic stirrer and dispersion of the nanoparticles in the base fluid. Thus the stability of fluids is highly increased and remains stable for very long period.

4.5 Digital Thermometer

A thermometer is a device that measures temperature or a temperature gradient. A thermometer has two important elements namely, a temperature sensor in which some change occurs with a change in temperature and some means of converting this change into a numerical.

Thermometers are widely used in technology and industry to monitor processes, in meteorology, in medicine, and in scientific research.



Fig.7

4.6 Charging Pin Valve

The charging pin valve is a one-way service valve with valve inside .Pin valve is a two port valve where it allows fluid through it and can be taken out with vacuum pump since it has ball spring action which opens the valve due to pressure.Pin valves are often used with sometypes of pumps and refrigeration systems. The heat pipe is evacuated through one port while the other port is closed. Then this port is locked and other port is used for filling the Nano

SPECIFICATIONS	
Pressure	7 bar
Unit	10 ⁻⁴ Torr
SPEED	3400 rpm
Voltage	12V

Table.2

fluid of required quantity. Each pin valve is fixed at the top end of heat pipe and welded at around circumference to avoid fluid leakage. When vacuum is created, it is maintained until removed intentionally as the valve gets closed due to decreased pressure.

4.7 vacuum pump

Vacuum pump is for evacuating the adiabatic section of the heat pipe. This is done through pin valve. Small size vacuum pressure is enough for evacuating small copper pipes. Achieving high vacuum is difficult because all of the materials exposed to the vacuum must be carefully evaluated for their vacuuming and vapour pressure properties.



Fig.8



Fig. 9

4.8 Tilt Bar

The purpose of tilt bar is to tilt the panel in two stages. With help of metal studs welded in the base stand, the board is supported on the top portion and the angle can be increased or decreased. For fixing optimum angles for different region this kind of facility is in need. The optimum angle for chennai region is 30.12 degree south facing.



Fig.10

V. RESULTS & CONCLUSION

The experiment conducted at the outdoor condition with tilt angle 30.12°. Nearly 6 readings were taken at 30 minutes intervals from 9.00 am to 2.00 pm. The surface temperature on the panel reached up to 90°C . All the experiment readings were used in formula and experimental efficiency was found:

$$\eta_{thermal} = \frac{\dot{m}c_p (T_o - T_i)}{AI}$$

η - Efficiency of Flat plate collector
 \dot{m} - Mass flow rate of water

T_o - Outlet Temperature of water (K)

T_i - Inlet Temperature of water (K)

C_p - Specific Heat Capacity of water $\frac{J}{Kg.K}$

A - Area Of collector

I - Insolation W/m^2

The final conclusion of this study is that the impact of Nano fluids in fluid form gave better results than the particles suspension and also reliability period is much more than the conventional Nano fluids. The average efficiency obtained from experimental result is 60.4% while the theoretical heat accumulation reached up to 72% .There obtained an absolute difference of 11.6% .This due to the fact that the simulation in CFD considers certain assumption which favours the result perspective.

The following assumptions were made regarding the design model

- The heat loss coefficient between the collector and the surroundings is constant.

- In the solar collector, the temperature gradient according to the longitudinal direction can be neglected.
- No heat loss in the manifold part.

5.2 Applications Of Heat Pipes

- Spacecraft thermal control
- Transportation systems, automotive industry
- Stabilization, bio-related applications, solar systems
- Manufacturing.

REFERENCES

1. E. Azad , Iranian Research Organization for Science and Technology, 71 Forsat Avenue Ferdousi sq., Tehran, Iran Experimental Thermal and Fluid Science 32 (2008) 1666–1672
2. Ramesh R 1, Dr. P. Arulmozhi2, Department of Mechanical Engineering, International Journal of Engineering Research & Technology (IJERT) , Experimental Analysis of Flat Plate Solar Water Heater using Cerium Oxide / Water Nano Fluid Under Forced Convection ISSN: 2278-0181
3. M. Jamil Ahmad & G. N. Tiwari , Hauz Khas, Indian Institute of Technology , New Delhi.(Volume 30) Published online: 30 Mar 2011.
4. Y. Tong, “Theoretical investigation of the thermal performance of evacuated heat pipe solar collector with optimum tilt angle under various operating conditions” Journal of Mechanical Science and Technology 30 (2) (2016) 903~913
5. Maryam Shafahi, “An investigation of the thermal performance of cylindrical heat pipes using Nano fluids” International Journal of Heat and Mass Transfer 53 (2010) 376–383
6. Naseema, Assistant Professor, Mechanical Engineering Department, M.J.C.E.T, “Heat Enhancement Of Heat Exchanger Using Aluminium Oxide (Al₂O₃), Copper Oxide(Cu) Nano Fluids With Different Concentrations”.

