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Performance of TiO_2 Nanofluid and DI Water Filled Flat Type Heat Pipe (FTHP) Internally Grooved at Various Fill Ratios and Inclinations

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Abstract: Heat pipe operates, with a metallic wick (or grooved) installed inside the pipe, containing fluid under a pressure which permits evaporated vapour at the hot side to fill the core of the pipe and travel to the cooled side. The vapour condenses at cold side, transporting heat by this method. This study focuses on the heat transfer performance of flat type internally grooved heat pipe with two different working fluids DI water and TiO_2 nano fluid, used with various heat input (50, 60, 70 and 80W) and at two different orientation 45deg and 90deg of the pipe. The fill ratio used was 50% and 70%, concentration and the size of the nano particle were 80 mg/lit and 30 nm respectively. In this setup, the condenser section of the Flat Type Heat Pipe (FTHP) was cooled by rectangular aluminum fins. The result shows that the decisive factors of FTHP are the working fluids, internal grooves and inclination angle. The relatively high rate of heat transfer was achieved while using TiO_2 nano fluid at 90deg orientation with a fill ratio of 50% compared to FTHP with DI water.

Keywords: FTHP, Internally Grooved, Rectangular Aluminum Fins, Fill Ratio

1. Introduction

Heat pipes are very effective heat transfer devices employed to transmit large quantities of heat through a small cross-sectional area over a considerable distance with no additional power input to the system. They are also capable of controlling and transporting large quantities of heat at various temperature levels. They were first conceptualized in 1836 by Jocob perkins and was called the perkins tube. Heat pipes have been used in space crafts, computers, solar systems, heat and ventilating air – conditioning systems and many other applications [1].

The majority of research presented in the heat pipe are addresses a cylindrical shaped geometry [2, 3, 4-13]. However, it has been clearly demonstrated that the flat-shaped heat pipes [13-18] have an advantage in terms of heat removal capability and geometrical adaption for many applications such as electronic cooling, space craft thermal control and commercial thermal applications.

Nanofluids possess unique properties, which motivate scientific community and industry to keep on intensive research of their fundamental aspects and practical applications. The most important properties of nanofluids are high thermal conductivity and low susceptibility of sedimentation, erosion and clogging as compared to ordinary fluids with micro particles. This inspired many promising applications of nanofluids, like those in nuclear energy, thermal management of systems with high dissipation rates of energy, cooling systems of electronic and optical devices. Heat pipes and thermosyphons, as well as nano materials and complex fluids [19-22]. Trijo et al [23] analyzed the miniature loop heat pipe with water and two concentrations of grapheme-water nanofluid (0.0003 vol% and 0.0006 vol%). The analysis shows that the model is in good agreement with experiments with a maximum variation of 6% in evaporator wall temperature and found that the heat transfer is the dominant factor for the entropy generation in mLHP. Naresh et al [24] experimentally investigated the heat transfer for internally finned thermosyphon charged with either water or acetone. Results show that a fill ratio of 50%

gives better heat transfer performance. Providing the internal fins at the condenser produces additional condensation which improves the thermal performance by 17%. Baskar et al [25] studied the enhancement of convective heat transfer of secondary refrigerant. The study indentified that CNT nano fluid enhances the convective heat transfer of secondary refrigerant and also improves the efficiency of the experimental setup.

Not much work was found in the literature using FTHP with rectangular fins. From the literature review it could be concluded that the performance of a heat pipe depended upon types of fill liquid, fill ratio and power input. This is due to the very complex nature of the boiling process in the heat pipe. As a result, the thermal resistance and efficiency of the heat pipe would be affected. The objective of this paper is to determine the effect of thermal resistance and the fin efficiency of DI water and TiO_2 nature fluid at two fill ratios and two different orientations of FTHP.

2. Experimental Setup

The schematic diagram of the experimental setup is shown in Figure 1. The first priority goes to the material selection of FTHP. The material has to be selected in such a way that it can permit a wide range of temperature and it should have better heat transfer characteristics. The copper pipes are more effective. For a heat pipe operating below 200°C. The cut-section of FTHP internally grooved show in Figure 2. All the other parameters are given in Table 1.

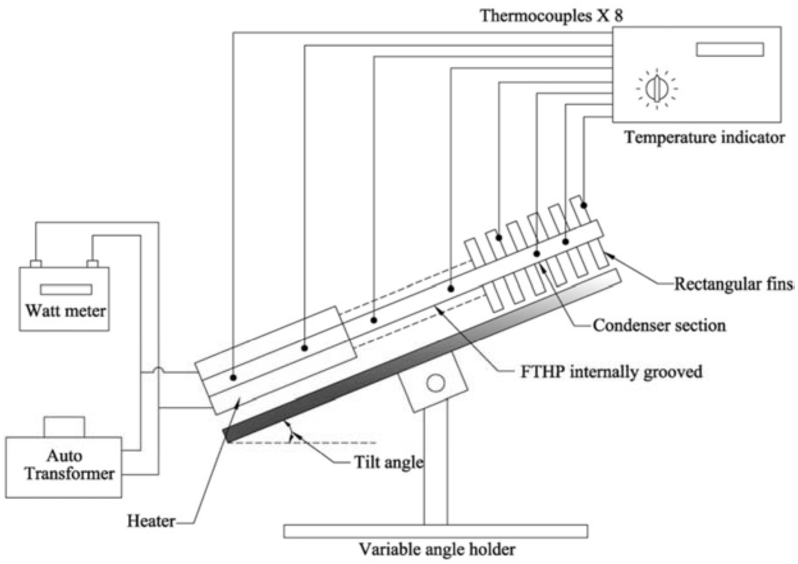

Figure 1. *Experimental setup.*

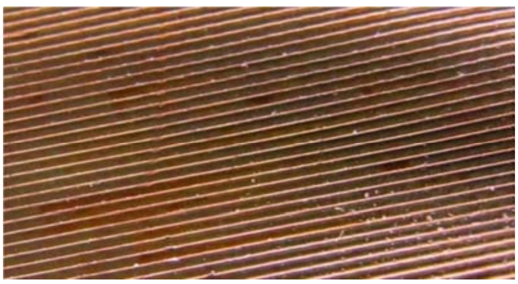

Figure 2. *Cut-Section of Flat Type Heat Pipe Internally Grooved.*

Table 1. *FTHP experimental configuration.*

Total Length of FTHP	600 mm
Evaporator length	200 mm
Adiabatic length	200 mm
Condenser length	200 mm
Fins material	ALUMINUM
No. of rectangular fins	34
Breadth of the pipe	12
Thickness of the pipe	10 mm
Fill ratio	50% & 70%
Inclination angle	45° & 90°
FTHP	Internally grooved

The temperature distribution of flat heat pipe at wall was measured with K-type thermocouple. In total eight thermocouples on the heat pipe wall ie., two at evaporator, two at adiabatic and four at condensation section. The uncertainty in temperature measured was ± 0.1°C all these thermocouples were connected to the temperature indicator.

Plate type heater (max. 200 W) was used as a heat source in the evaporator section. The heat input was measured by using watt meter. The power is varied with the help of an auto transformer, the condenser section was surrounded by rectangular aluminium fins and it was cooled by atmospheric air (free convection).

Spherical TiO_2 nanoparticles with 30 nm diameter are utilized and DI water was used as the base fluid to prepare the nanofluid and the concentration of 80 mg/lit nanoparticles are dispersed in the deionized water and the solution is vibrated in an ultrasonic device for 9 hrs in order to obtained a uniformly dispersed solution. The mixture was created by using an ultrasonic homogenizer. Figure 3 shows a SEM image of TiO_2 nano particles. The experimental samples have to be statically placed for 30 days until a good suspension effect is achieved.

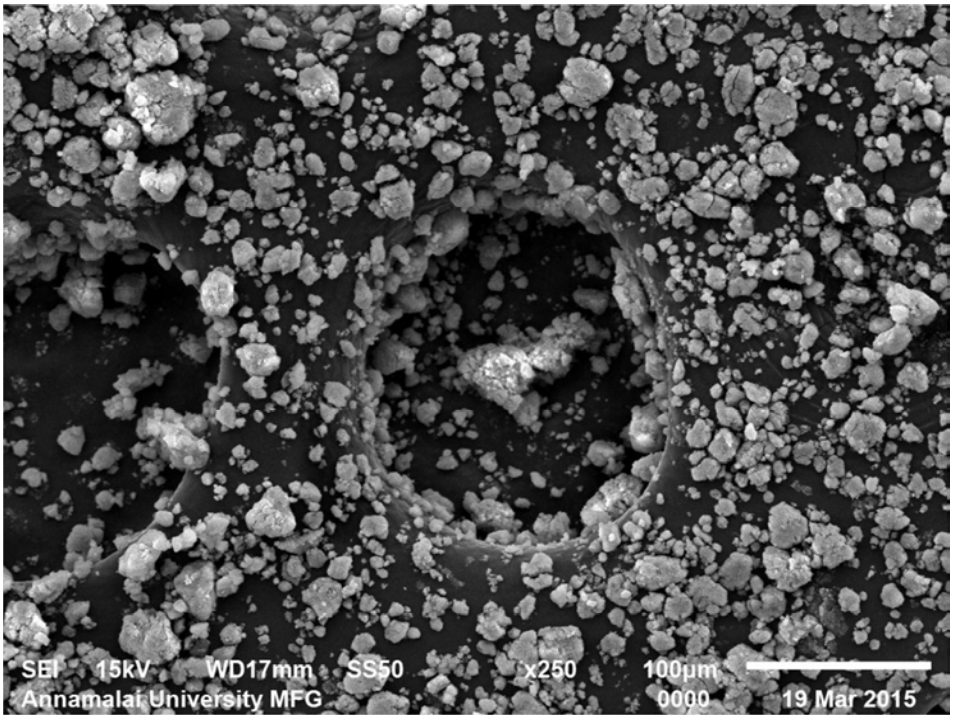

Figure 3. *A SEM Photograph of TiO_2 nanoparticles.*

Thermal resistance is expressed as the ratio of temperature difference to input heat provided at the evaporator as given by equation (1),

$$R_{th} = \frac{T_{avg}(\text{evap}) - T_{avg}(\text{condenser})}{Q_{in}}$$

$$R_{th} = \frac{\Delta T}{Q_{in}} \quad (1)$$

The amount of heat transfer to the thermosyphon is calculated from the formula given below,

$$Q_{in} = VI \quad (2)$$

Fin Efficiency (Steady state analysis) are calculated from the formula given below,

$$T_{mt} = \frac{T_{fin\ avg} + T_{atm}}{2}$$

$$Gr = \frac{g\beta\Delta T L^3}{v^2} \quad (3)$$

$$h = \frac{NuK}{L} \quad (4)$$

For rectangular fin $L_c = L + \frac{t}{2}$

$$A_m = tL_c$$

$$L_c = L$$

From HMT data book the efficiency of the rectangular fin is calculated.

3. Results and Discussions

3.1. Effect of Fill Ratio

Figure 4-7 represents the fill ratio profile related to tilt angle, working fluid, heat input and thermal resistance. Conveniently, influence of percentage charged value of working fluid on the thermal performance of FTHP internally grooved. The high range [300 to 7000 Btu/hr-ft^2°F] of heat transfer was achieved in the evaporator section by using internally grooved heat pipe was reported by Carnavos [26]. In order to study the effect of% charged value of working fluid on thermal resistance of FTHP, in a different heat input, here heat pipe was charged with two different working fluids were DI water and TiO_2 nano fluid in two different quantities 50% and 70% of fill ratio. From graph, that thermal resistance decreases when charged value is 50% for TiO_2 nanofluid in all heat inputs. The best value of thermal resistance is 0.79°C/W achieved at 80 W, when FTHP oriented with 90°. Two factors were the reason for that, first FTHP at inclination angle of 90° absorbing more heat which means capacity of working fluid in absorbing the heat and the second factor is needed space for moving the vapour of working fluid due to phase-change and pressure drop along the FTHP. However other case to 70% fill ratio, the thermal resistance was little bit high when compare to 50% fill ratio. This is because of the working fluid not having enough space for moving the generated vapour. Thus it effectively affects the flow and heat transport capacity of the FTHP.

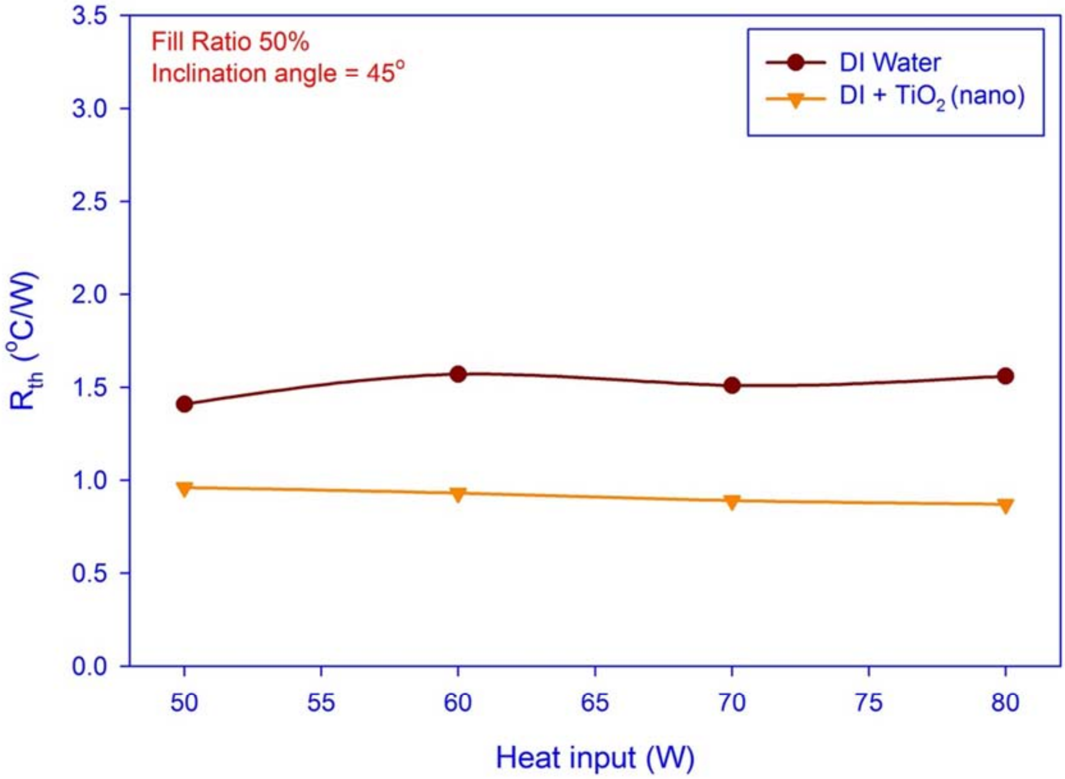

Figure 4. *Rth Vs heat input fill ratio 50% inclination angle 45°.*

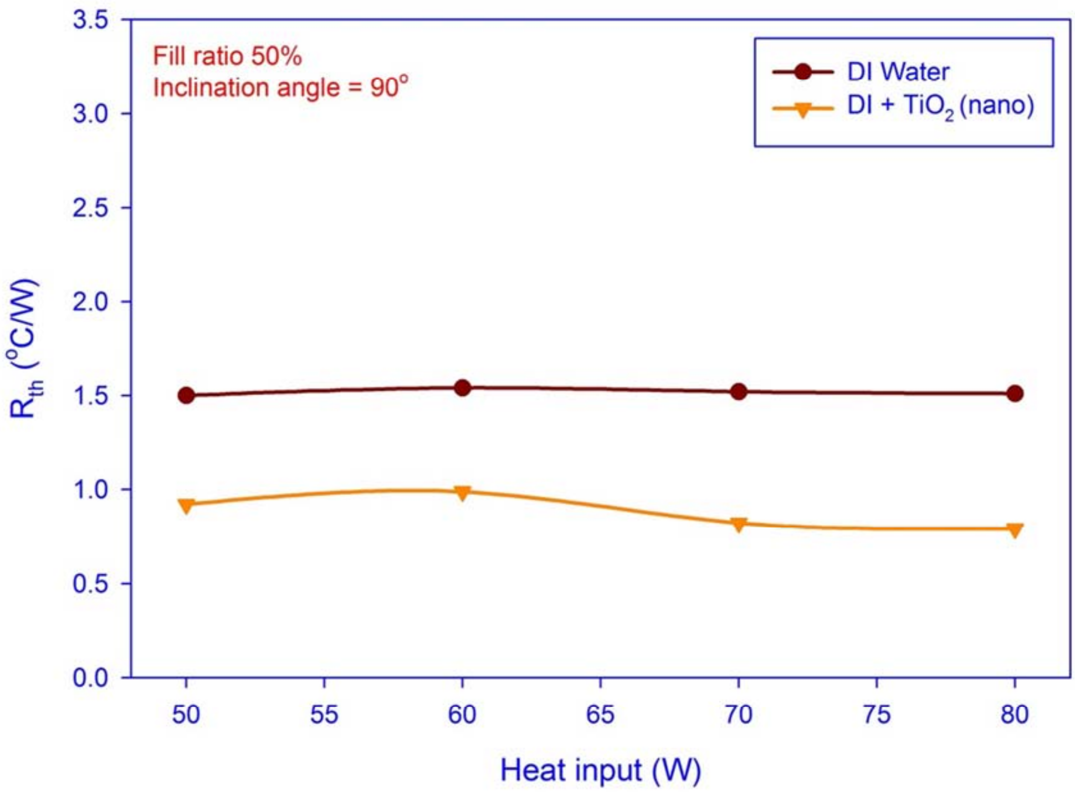

Figure 5. *Rth Vs heat input fill ratio 50% inclination angle 90°.*

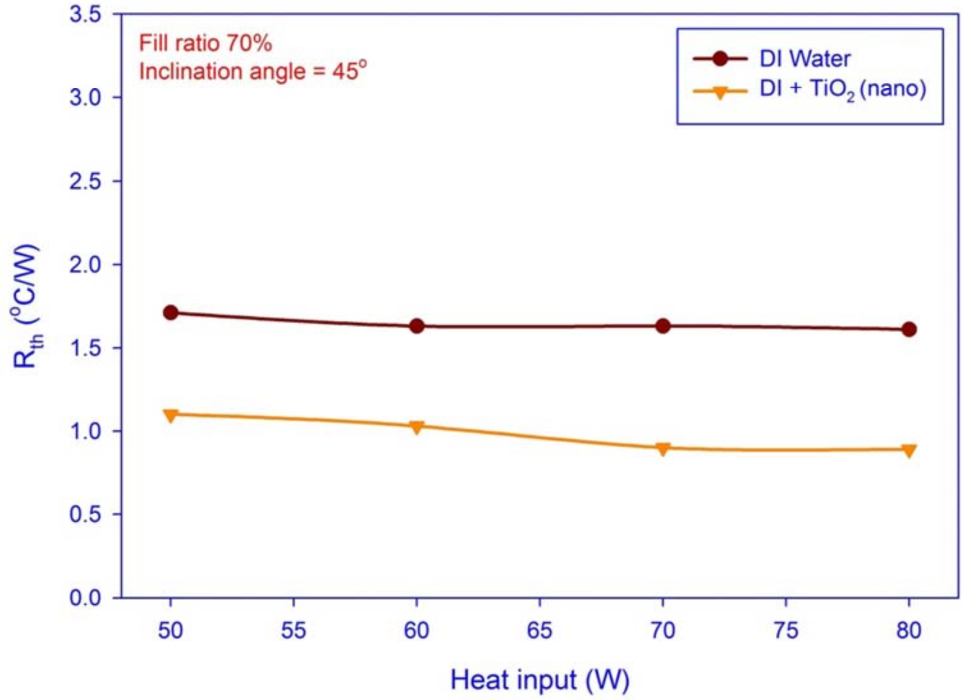

Figure 6. *Rth Vs heat input fill ration 70% inclination angle 45°.*

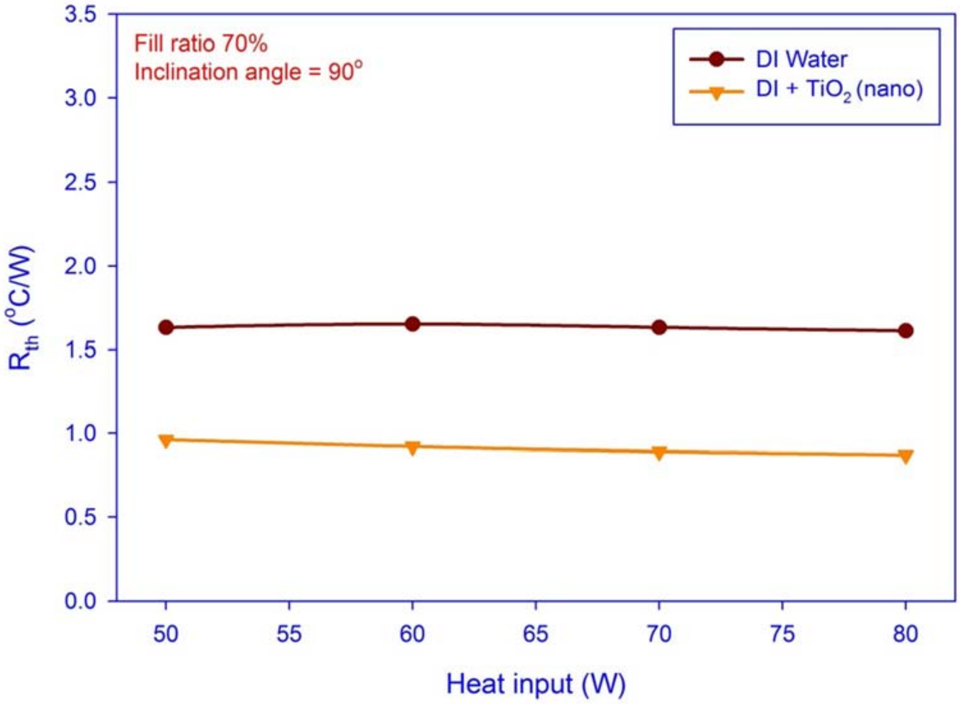

Figure 7. *Rth Vs heat input fill ratio 70% inclination angle 90°.*

3.2. Efficiency of Fin

In order to obtain the high efficiency, the experiment is designed with the condenser section was surrounded by 34 number of rectangular fins, from Figure 8-11it is clear there is a drastic change in efficiency when filled with 70% of working fluid. This due to the formation of thin liquid film inside the condenser section. Whereas 50% of charge value of the working fluid exhibits high efficiency in all heat inputs in both the orientation of FTHP (45° and 90° because of strong positive influence of capillary action (internal groove). The maximum efficiency (87%) was achieved at 50% of charge value of the TiO_2 nano fluid in the orientation of 90°. During this flow and heat transport takes place smoothly.

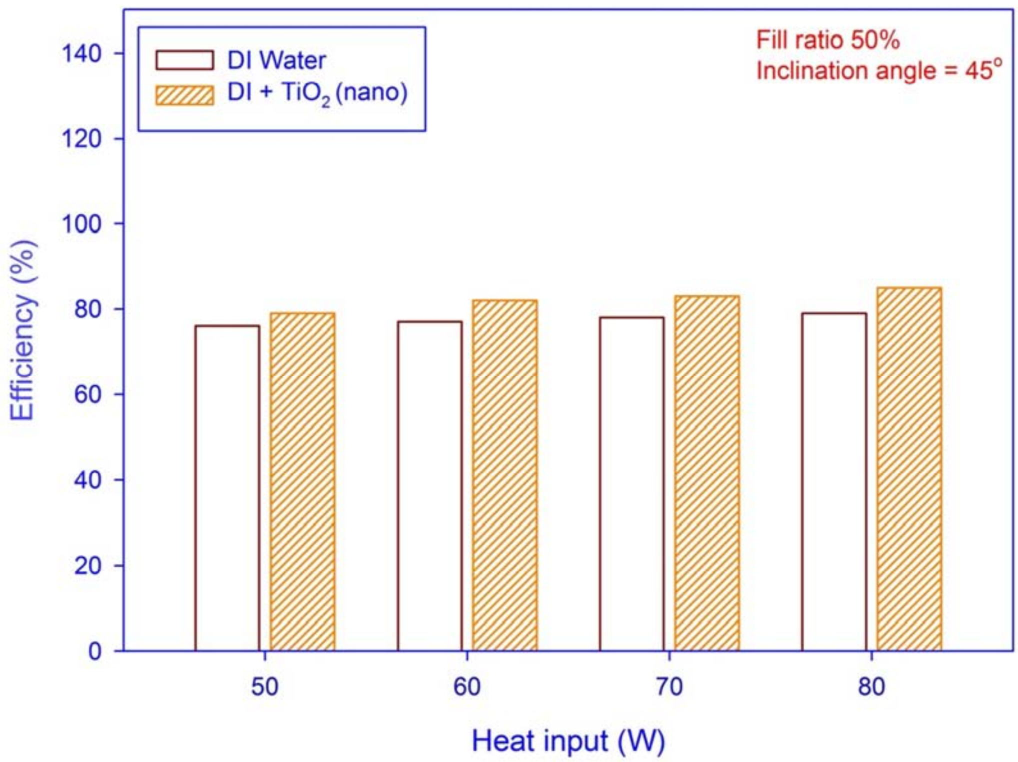

Figure 8. *Efficiency Vs heat input fill ratio 50% inclination angle 45°.*

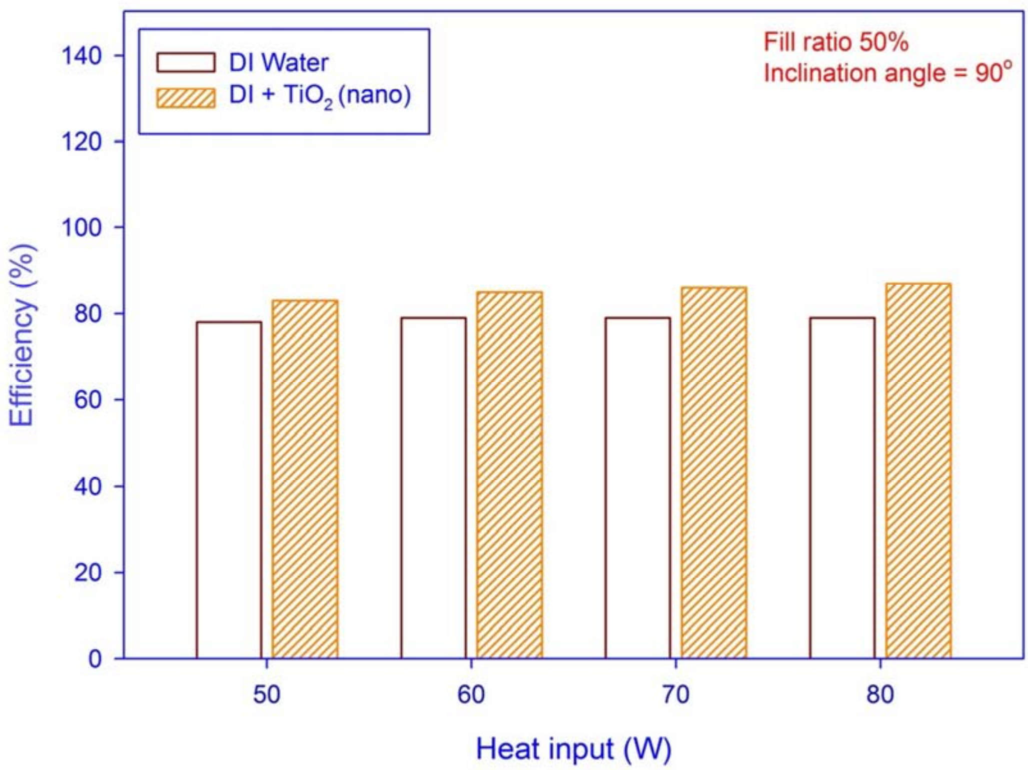

Figure 9. *Efficiency Vs heat input fill ratio 50% inclination angle 90°.*

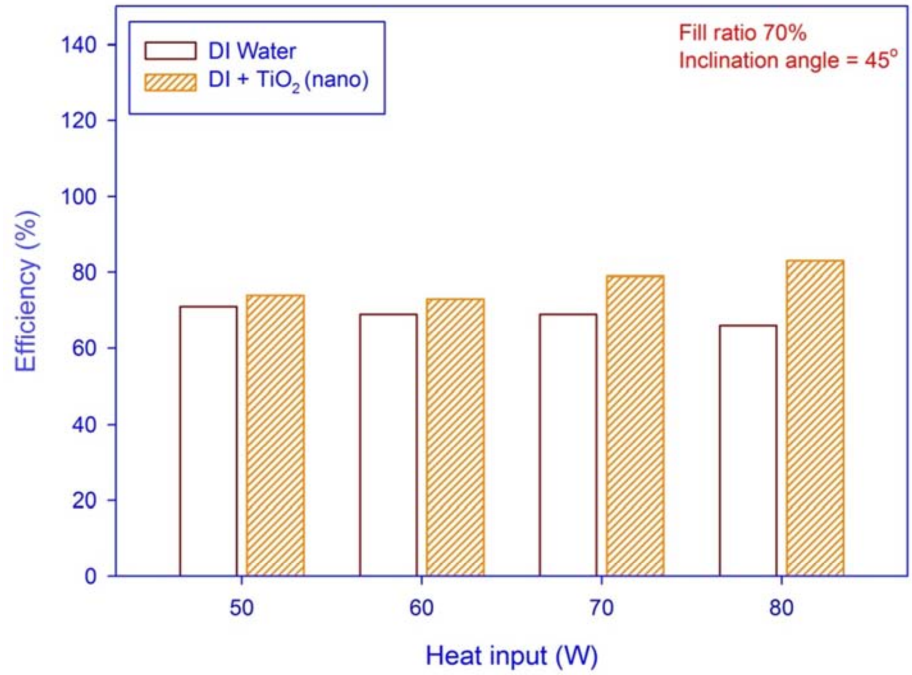

Figure 10. *Efficiency Vs heat input fill ratio 70% inclination angle 45°.*

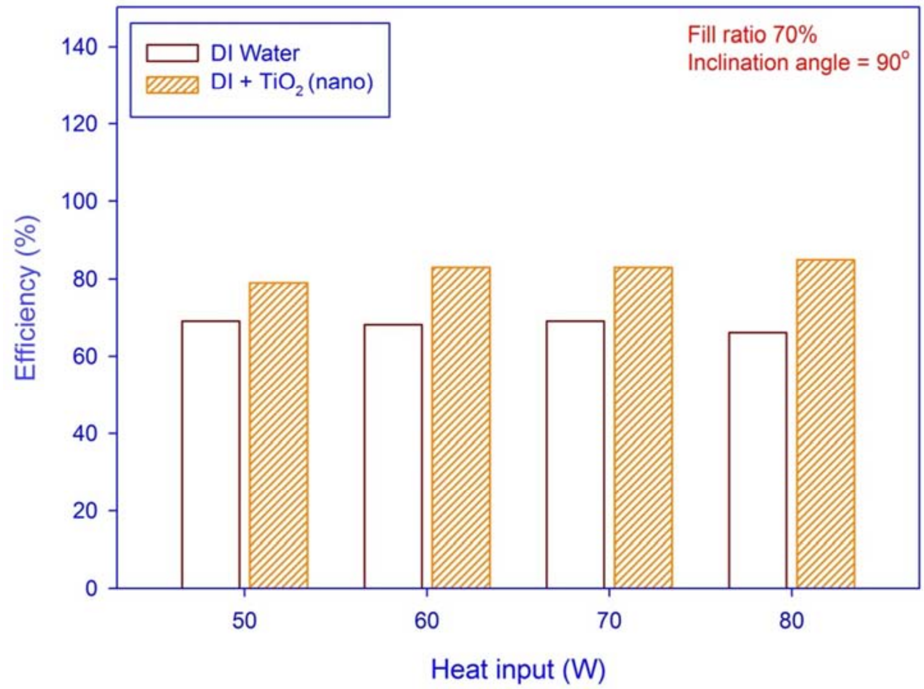

Figure 11. *Efficiency Vs heat input fill ratio 70% inclination angle 90°.*

4. Conclusion

This articles deals with the thermal enhancement of the grooved FTHP performance by charging 50% and 70% of DI water and TiO_2 nanofluid as the working fluids which is experimentally tested with two orientations were 45° and 90°. Tilt angle had a strong effect on thermal performance of FTHP such that when tilt angle increases, due to the strong influence of gravitational force on the flowing of working fluid, particularly on the nanoparticles, the FTHP of rectangular fin efficiency increases. FTHP resistance increased with increasing fill ratio. The TiO_2 nano fluid filled FTHP performed better in the 90° orientation at both the fill ratios (50% and 70%). Both the the resistance and efficiency was drastically changed in case of DI water shows higher values of resistance and low efficiency in all cases. Results indicate that the TiO_2 nano fluid has remarkable potential as a working fluid for FTHP of higher thermal preface**s.**

Nomenclature

TiO_2	Titanium di oxide
CNT	Carbon nano tubes
FTHP	Flat type heat pipe
mLHP	Miniature loop heat pipe
RSM	Response surface methodology
DI	Di ionized
SEM	Scanning electron microscope
V	Voltage, volts
I	Current, amps
R_{th}	Thermal resistance, °C/W
Q_{in}	Heat input, W
T_{avg} (evap)	Arithmetic mean temperature in evaporator section, °C
T_{avg} (condenser)	Arithmetic mean temperature in condenser section, °C
Gr	Grashof number
Nu	Nusselt number
T_{atm}	Atmospheric temperature, °C
$T_{fin\ avg}$	Arithmetic mean temperature in fins, °C

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