

Experimental Analysis of Nano Fluid Filled Heat Pipes at Flat Plate Solar Collector

¹Harendra Kumar Jha, ²Dr. Arun Kumar

¹Ph. D Scholar, Department of Mechanical Engineering, NIT, Patna, India

²Associate Professor, Department of Mechanical Engineering, NIT, Patna, India

Abstract: There is ongoing research and development in heat pipe technology, and new applications are continually being investigated. It is likely that heat pipes will continue to be an important tool for enhancing thermal management and energy efficiency across a variety of industries with further innovation and progress. This study outlines prepared nanofluids of Cu and Ni nanoparticles with a size of about 20 nm with base fluids ethanol, acetone and compared the thermal performance of wickless heat pipes at flat solar collector. It had been found that the Ni nanofluid had a greater thermal conductivity than the Cu nanofluid. The Ni nanofluid specifically displayed a thermal conductivity of 0.3015 W/m-K at a temperature of 60°C at a concentration of 0.5g. The Ni nanofluid's thermal conductivity increased to 0.4325 W/m-K at the same temperature when the concentration was increased to 1g. Overall, the ethanol heat pipe's thermal resistance is 0.074 (°C/W) while the acetone heat pipe's is 0.076 (°C/W). As heat input in both heat pipes increases, thermal resistance will continue to drop. Due to the volume fraction of Cu being lesser than that of Ni nanofluid and Brownian motion of nanofluid, the thermal conductivity of Ni nanofluid is greater than that of Cu nanofluid at 0.5 g nanofluid and continues to rise with an increase in temperature. The highest efficiency for acetone heat pipes found 67.32%, while for ethanol, it was 62.8%. As the mass flow rate increases, thermal efficiency of heat pipe will start decreasing, heat transfer will effectively take place at a lower mass flow rate with better solar radiation, and it will keep decreasing as time progresses.

Keywords: Flat Solar heat collector, Nanofluids, Wickless Heat pipe, Acetone, Ethanol.

1.Introduction:

Researchers are looking for alternate energy sources because fossil fuel resources are depleting and having adverse consequences on the environment as a result. Due to its availability, renewability, little negative effects on the environment, and high potential, solar energy has received the most attention of all the energy sources now in use. There are several difficulties and restrictions that must be resolved, such as being renewable, environmentally benign, and minimising reliance on fossil fuels. The intermittent nature of solar power is one of its key problems. Solar panels' output varies depending on the weather and time of day and can only produce electricity when the sun is shining. To solve this problem, extra energy generated during sunny periods can be stored and used during overcast or night time conditions by using energy storage. Another barrier that prevents solar energy from being widely used is cost. Despite substantial cost reductions over the years, solar energy is still more expensive than conventional fossil fuels in many places of the world. However, solar power is increasingly cost-competitive with fossil fuels as economies of scale and technological improvements are realised.

The development of heat pipe solar collectors (HPSCs) is seen as a significant advancement in the effort to address the problems with traditional solar thermal systems. Researchers have been highly motivated to concentrate their study on HPSCs and its applications because of their special properties.

2. Material and Methods

2.1 Heat Pipes

The evaporator, adiabatic, and condenser are the three components of the heat pipe. The liquid inside the heat pipe vaporizes when the evaporator part is exposed to a heat source, increasing pressure there. Due to the increased pressure, the vapour moves quickly in the direction of the heat pipe's condenser section. The latent heat of vaporization is transferred from the vapour to the condenser, where it is used to turn the vapour back into liquid and lose heat to the heat sink. The heat pipe's adiabatic middle segment has a negligibly small temperature difference. The heat pipe segment depicted in Figure-01.



Figure-01 Heat pipe with water jacket with inlet and outlet of condensing section

2.2 Nanofluid Preparation

In this study, we prepared nanofluid by taking Cu and Ni nanoparticles of 20nm and ethanol as a base fluid. Nanofluid is prepared by the sonication process by adding Cu and Ni at a concentration of 0.5 g to 100 ml of ethanol and again adding 1g of Cu and Ni to 100 ml of ethanol separately. After the sonication process, nanofluid is prepared, and after the preparation of nanofluid, Cu and Ni are tested at room temperature and at 40°C and 60°C, and their physical properties, i.e., density, viscosity, and thermal conductivity, are calculated. By spreading nanoparticles in the base fluid, nanofluids are created. For nanofluid to be used, good dispersion is necessary. As a result, surfactants are occasionally used to increase the stability of nanofluids. In addition, the surface of the scattered particles may be modified, and strong forces may be applied to the clusters of the dispersed nanoparticles, which may improve the stability of nanofluids. The preparation of nanofluids can be done in one step or in two steps. Another new approach for creating nanofluids is the chemical process. Due to their high thermal conductivity and radiation absorption, they can be applied for advanced cooling systems, energy storage, and waste heat recovery applications. To create nanofluids, however, requires proper base fluid mixing and the stability of nanoparticles. Because nanoparticles tend to clump together and settle quickly, resulting in uneven dispersion and poor heat conductivity, this can be a challenging task. To address this issue, a variety of methods, such as sonication, surfactant coating, and magnetic fields, can be used to improve the stability and dispersion of nanoparticles in base fluids as shown in figure 02. Magnetic stirrers, which remove silt using rotating magnetic fields, increase the homogeneity of nanofluid. Frequently, there are two knobs The magnetic stirrer or magnetic mixer has two knobs. The speed of the churning is adjusted with the left knob. On the other hand, the heater is controlled via the right knob. Dispersants or surfactants are frequently used to make nanofluids more stable. These substances can help prevent nanoparticle aggregation by lowering the base fluid's surface tension.

However, as you pointed out, applying too much surfactant or dispersion can have a deleterious effect on the thermophysical properties of the nanofluid. Chemical stability and thermal conductivity may both suffer as a result. Therefore, it is important to use these substances at the proper dosage. If clusters of nanoparticles are found, sedimentation may occur. A brand-new category of fluids known as nanofluids contains particles suspended in a base fluid at the nanometer scale. The percentage volume fraction, or volume concentration, is used to calculate the volume of nanoparticles present in the base fluid. The equation provides the volume concentration of nanofluids.



Figure-02 Nanofluid after sonication method

2.3 Preparation of Flat Solar Collector

A 90-cm²-square wooden box is insulated with thermocol inside the box, and then thermocol is insulated with aluminum foil, which is pasted, and after that, black colour is coated inside the box, and then the box is sealed with glass and sealed with silicon.



Figure-03 After completion of box temperature is recorded inside the box

After preparation of the complete setup Heat pipe is installed in a flat plate collector, and from that collector, sun radiation heat is calculated at the evaporative section as heat input and at the water jacket of both ends as heat output. From this, I have calculated the efficiency of heat pipe for both acetone and

ethanol heat pipes at different times in a day. There are two copper heat pipes. The working fluid, in this example a mixture of acetone and ethanol, is contained in these heat pipes, which are sealed tubes. Both acetone and ethanol are filled in the heat pipes at a 40% filling ratio. The heat pipes are placed within a flat plate solar collector. This collector is a device that takes in solar energy and transforms it into thermal energy. The heat pipes' intended use is to capture solar energy and transfer it to the working fluid inside the heat pipes. A wooden stand supports the heat pipes and the solar collector. The stand ensures that the setup stays in the desired position and offers stability. The evaporative portion of the heat pipes receives heat input. The working fluid is evaporated in this region of the heat pipes. It is unknown where the heat input comes

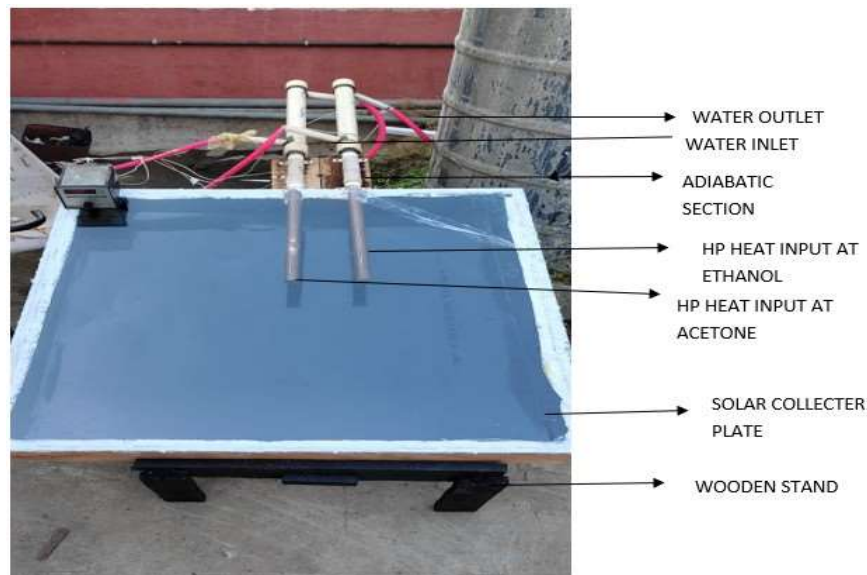


Figure-04 Experimental Setup

3. Results and Discussion

The outcomes of the experiment unambiguously show that the thermal conductivities of the nanofluids made of copper (Cu) and nickel (Ni) will differ. It had been found that the Ni nanofluid had a greater thermal conductivity than the Cu nanofluid. The Ni nanofluid specifically displayed a thermal conductivity of 0.3015 W/m-K at a temperature of 60°C at a concentration of 0.5g. The Ni nanofluid's thermal conductivity increased to 0.4325 W/m-K at the same temperature when the concentration was increased to 1g as shown in figure 05. At noon, the acetone heat pipe had a temperature of 92°C and the ethanol heat pipe had a temperature of 93°C. At noon, the maximum heat input for acetone heat pipes is 0.7450 kW, while for ethanol heat pipes it is 0.7648 kW. The acetone heat pipe produces 0.4820 kW of heat, and the ethanol heat pipe produces 0.4472 kW of heat. Figure 06 shows the highest efficiency for acetone heat pipes is 67.32%, while for ethanol, it is 62.8%. Overall, the ethanol heat pipe's thermal resistance is 0.074 (°C/W) while the acetone heat pipe's is 0.076 (°C/W). As heat input in both heat pipes increases, thermal resistance will continue to drop. Due to the volume fraction of Cu being lesser than that of Ni nanofluid and Brownian motion of nanofluid, the thermal conductivity of Ni nanofluid is greater than that of Cu nanofluid at 0.5 g nanofluid and continues to rise with an increase in temperature. The mass flow rate starts increasing, the overall thermal resistance will also start increasing. As the temperature difference of heat source and heat sink starts decreasing, the mass flow

rate will increase, reducing the heat transfer rate. From figure 07, As the mass flow rate increases, thermal efficiency of heat pipe will start decreasing, heat transfer will effectively take place at a lower mass flow rate with better solar radiation, and it will keep decreasing as time progresses.

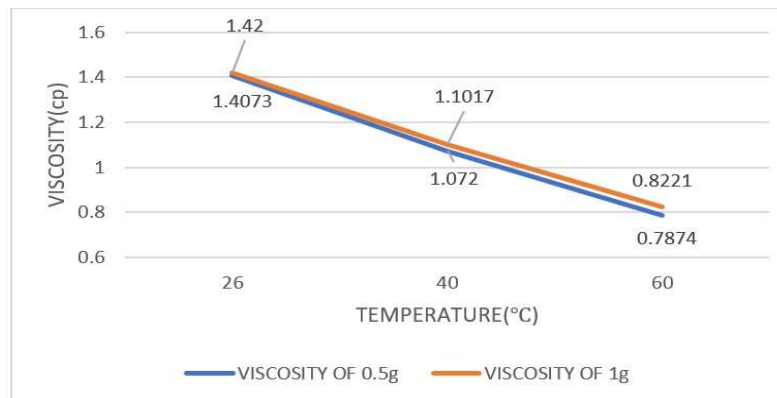


Figure-05 viscosity and temperature of 0.5g and 1g of nanofluid.

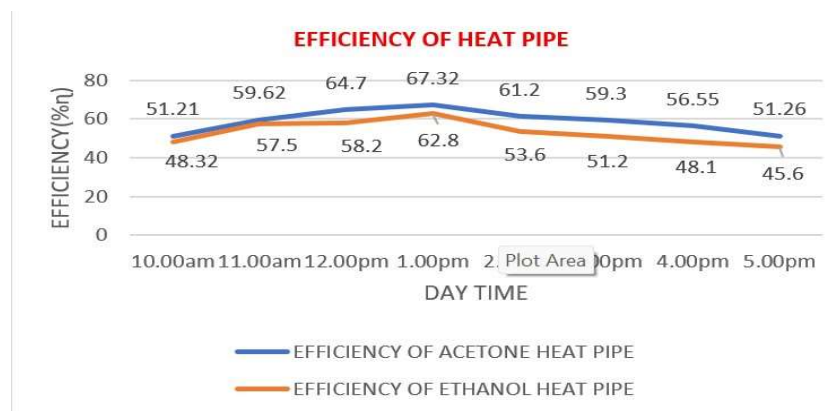


Figure-06 Efficiency variation of heat pipe with day time.

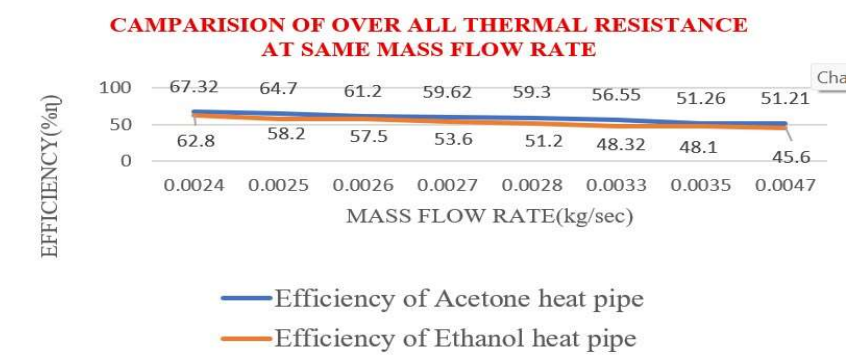


Figure-07 Efficiency and mass flow rate of both the heat pipe.

4. Conclusions

The thermal efficiency of a straight copper heat pipe charged with ethanol and acetone; an experimental examination was carried out. Under various experimental circumstances, the acetone heat pipe's optimal thermal efficiency was 67.32%, while when ethanol was employed, it was 62.80%. And the minimum efficiency was 51%, while the ethanol efficiency was 45%. At the same time, the heat input for acetone is less than the heat input for ethanol. The heat intake is greatest at 1.00 pm, when the solar intensity is greatest. The thermal conductivity of nickel-based nanofluid is greater than that of cu-based nanofluid for two reasons: Nanoparticle concentration: The amount of nanoparticles present can alter the thermal conductivity of a nanofluid. Higher nanoparticle concentrations usually increase thermal conductivity. The nickel-based nanofluid is anticipated to have a larger concentration of nanoparticles than the copper-based one, resulting in enhanced thermal conductivity throughout. Particle-fluid interaction: Interactions between nanoparticles and the base fluid can cause changes in thermal conductivity. Heat transfer efficiency could be improved if nickel nanoparticles distribute more evenly and agglomerate less in the base fluid than copper nanoparticles, increasing the thermal conductivity of the nickel-based nanofluid. Thermal conductivity of nanofluids normally increases with temperature. This is primarily due to a couple of factors: Enhanced Brownian motion: As the temperature rises, the Brownian motion of the nanoparticles within the nanofluid becomes more active. Increased mobility results in enhanced particle dispersion and reduced agglomeration, resulting in more heat transmission and higher thermal conductivity. Reduced viscosity of the base fluid: As temperature rises, the viscosity of the base fluid decreases. The results showed that the acetone heat pipe have a higher energy transferring and provide a higher water temperature in the water jacket.

Future Scope

The performance of the nanofluid-filled heat pipe can be improved by looking at the effects of several operating factors, including heat input, working fluid flow rate, and ambient conditions. To improve the performance of the entire system and the efficiency of heat transmission, optimize these variables.

REFERENCES

- [1] M. J. Alshukri, A. K. Hussein, A. A. Eidan, and A. I. Alsabery, "A review on applications and techniques of improving the performance of heat pipe-solar collector systems", *Solar Energy*, vol. 236,(2002), pp. 417–433.
- [2] M. Ahmad louydarab, T. D. Anari, and A. Akbarzadeh, "Experimental study on cylindrical and flat plate solar collectors' thermal efficiency comparison" ,*Renew Energy*, vol. 190,(2022),pp. 848–864.
- [3] M. J. Alshukri, A. A. Eidan, and S. I. Najim, "The influence of integrated Micro-ZnO and Nano-CuO particles/paraffin wax as a thermal booster on the performance of heat pipe evacuated solar tube collector", *J Energy Storage*, vol. 37, (2021), p. 102506.
- [4] A. Allouhi and M. Benzakour Amine, "Heat pipe flat plate solar collectors operating with nanofluids" , *Solar Energy Materials and Solar Cells*, vol. 219, (2021), p. 110798.
- [5] R. Daghigh and P. Zandi, "Improving the performance of heat pipe embedded evacuated tube collector with nanofluids and auxiliary gas system", *Renew Energy*, vol. 134, (2019), pp. 888–901.
- [6] Y. Y. Gan, H. C. Ong, T. C. Ling, N. W. M. Zulkifli, C. T. Wang, and Y. C. Yang, "Thermal conductivity optimization and entropy generation analysis of titanium dioxide nanofluid in evacuated tube solar collector", *Appl Therm Eng*, vol. 145,(2018), pp. 155–164.
- [7] K. K. Panda, I. V. Dulara, and A. Basak, "Numerical simulation of high temperature sodium heat pipe for passive heat removal in nuclear reactors", *Nuclear Engineering and Design*, vol. 323,(2017) pp. 376–385.
- [8] M. J. Muhammad, I. A. Muhammad, N. A. Che Sidik, and M. N. A. W. Muhammad Yazid, "Thermal performance enhancement of flat-plate and evacuated tube solar collectors using nanofluid: A review", *International Communications in Heat and Mass Transfer*, vol. 76, (2016). pp. 6–15.
- [9] S. S. Harikrishnan and V. Kotabavi, "Performance Study of Solar Heat Pipe with Different Working Fluids and Fill Ratios", *IOP Conf Ser Mater Sci Eng*, vol. 149, (2016). no. 1, p. 012224.