EFFICIENCY IMPROVEMENT OF HEAT PIPE BY USING GRAPHENE NANOFLUIDS WITH DIFFERENT CONCENTRATIONS

by

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In the present study thermal performance of heat pipe were validated experimentally. Circular, auxiliary grooved heat pipe were charged with graphene nanofluid with different concentrations (0.6%, 0.75%), orientation, and flow rate are fixed as 90° and 100 mL per minute. All the experimental results are validated and compared to base fluid (deionized water). From the experimental results, increasing nanofluid concentrations increases thermal performance and decreases thermal resistance. Although the wall temperature of heat pipe higher with graphene/water nanofluid than base fluid. Thus, graphene nanoparticles are suitable for heat pipe to increase their performance and capillary action.

Key words: *nanofluid, graphene, heat transfer analysis, wall heat transfer, heat pipe*

Introduction

Remove the heat from electronic devices, mechanical components and other applications are immense problem nowadays. Heat pipes invented to solve these problems in many industries. Generally heat pipe is a promising technology of cooling components or devices in various applications. It is a type of heat exchanger having three sections are evaporator, adiabatic, and condenser, transport the heat from evaporator to condenser without any external source. Transporting the heat happens because of working fluid inside an evaporator. It is a sealed pipe.

Based on the application, geometry and wick structure, heat pipes are discriminate circular heat pipe, flat plate type, loop heat pipe, rotating heat pipe, miniature heat pipe, thermosyphon, variable conductance heat pipe sintered heat pipes, *etc*. Many researchers are working in this area and found that every tiny changes affect the performance the heat pipe. Working fluid inside the pipe plays an important role to improve the performance of heat pipe. Nanofluids and refrigerants promote thermal performance and efficiency of heat pipe than base fluid, deionized (DI) water, in efficient manner. From the literature survey each and every working fluids accords divergent results.

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Literature survey

Peyghambarzadeh *et al.* [1] investigated the thermal performance of circular heat pipe with different working fluids (ethanol, methanol, and water). Compare to all working fluids methanol give a low thermal performance than ethanol and water. In contrast methanol have high heat flux. Finally he concluded that compare to all three working fluids ethanol and water is a best working fluid than methanol. Wei *et al.* [2] enhanced thermal performance by using silva with aqueous solutions. Compared to pure water for same volume of aqueous solutions displayed low thermal resistance than water. De Francescatonio *et al.* [3] conducted an experiment with binary mixtures with different concentrations. It showed better dry out limit or thermal resistance and increase thermal performance compare to base fluid. Margonic flow provides better mechanism than capillary force or gravitational force in heat pipes. Saravankumar *et al.* [4] and Govindasamy *et al.* [5] explored that the emission reduction can be done by using corn oil and Spirulina Algae. Hrabovsky *et al.* [6] used thermosyphon instead of heat pipe. He evaluated the thermal resistance of four working fluids, fluorinert FC-72, acetone, ethyl alcohol and water. Comparing an above working fluid acetone and fluorinert gives good cooling effect and acetone have very low thermal resistance than other fluids. He confirmed that acetone achieve best cooling effect than other working fluids. The potential flow of gases was analyzed using simulation method [7]. Yasushi *et al.* [8] used three types of sintered copper powders in heat pipe namely type-1a, type-1b, and type-2 and water working fluids. Type-1a and type-1b, are spherical in shape but type-1b is smaller than type-1a, type-2 is irregular in shape. He concluded type-1a and type-1b are shows fine results compare to previous empirical results. But type-2 has higher effective thermal conductivity than other two types. Tharayil *et al.* [9] concluded that heat load increases with increase in total entropy generation and decrease with increase of nanofluid concentration, but increase in increase of volume fraction of nanoparticles. As well as for same volume concentration total entropy generation reduced and average percentage by second low of efficiency increases. In miniature loop heat pipe heat transfer coefficient increases in evaporator with decrement of thermal resistance and wall temperature of evaporator especially while using nanofluids as working fluids in heat pipes. He used graphene – water nanofluids with different concentrations. Inclusion of graphite to the medium increases stability and thermal conductivity of PCM [10]. Amiri *et al.* [11] experimentally tested thermophysical and rhelogical properties of graphene nanoplatelets based water nanofluids. He used pristine graphene nanoplatelet with 0.55-3.74 nm thickness and mixed by acid-functionalized procedure. Two aqueous nanofluids, GNP-COOH and GNP-SDBS with different concentrations were prepared. Kumar *et al.* [12] engrossed three working fluids in thermosyphon GNP-COOH-water had significant thermophysical property at covalent functionalization than non-covalent (GNP-SDSB-water) nanofluids. He proves that for same state of working fluids covalent nanofluids delivered good thermal performance than non-covalent nanofluids. The GNP-SDSB-water is increase pressure drop and viscosity than GNP-COOH-water. Kim *et al.* [13] discovered graphene oxide-water nanofluids thermal resistance are diminish than DI water and wider thermal performance. Different level of concentrations provides different thermal conductivity and thermal resistance. Screen wire mesh inside the heat pipe formed hydropholic surface. Increasing heat load, increases heat transfer coefficient. Lower volume concentrated level of GO-water nanofluid higher boiling heat transfer rate and capillary limit. Screen mesh with coating and their wetting properties supports heat pipes mechanism and their thermal conductivity. Asirvatham *et al.* [14] investigated the heat transfer performance of thermosyphon with graphene-acetone nanofluid. Different concentrations of nanofluids provide different thermal performance range and thermal conductivity. Increasing heat load and concentration increases thermal conductivity. Thermal resistance of evaporator increases when increase heat load and decrease in condenser section. From his investigation is was clear that graphene nanofluids provide better thermal conductivity and capable to use in electronic cooling applications. Salem [15] investigated the heat pipe heat transfer capacity and pressure drop of graphene oxide-water nanofluids with different volume concentrations. Working fluid is prepared by using modified hummer method. Four different concentrations are taken for experiment. Compare to base fluids GO-water nanofluid enhance thermal conductivity. Increment in concentration of nanoparticles increases viscosity, shear stress, friction factor pumping power and pressure. Convective heat transfer coefficient and Nusselt number has increased by increasing Reynolds number. But when the temperature increases the viscosity decreases. He analyzed all mentioned parameters with circular heat pipe by changing Reynolds number and volume concentration of nanofluid.

There is a plenty of researches going on in heat pipes especially in graphene materials. It is a novelty in cooling technology of modern industries and other applications. In the present work also based on heat pipe with graphene only. The performance and efficiency of heat pipe is validate experimentally. Thermal resistance and evaporator wall temperature is predicted with different concentrations of working fluids.

Experimentation

Experimental set-up details

Heat pipe is fabricated by copper material. It is circular in shape and fully insulated. Total length of the pipe is 200 mm. Heat pipe is connected with rotameter, watt meter, auto transformer, pressure gauge data logger, and PC. Auto transformer controls the power supply for heat pipe, watt meter displays the power in watts. Rotameter controls the flow rate of coolant. The T-type thermocouples are used to examine the temperature for each part of the heat pipe. Thermocouples are connected with data logger followed to PC. Line diagram of experimental set-up is shown in fig. 1:

- type of heat pipe: auxiliary groove heat pipe
- material: copper
- shape: circular
- total length: 200 mm (L_e = 60 mm, L_{adi} = 60 mm, L_c = 80 mm)
- inner and outer diameters: 8.5 mm and 9.5 mm
- working fluid: graphene nanoparticles, DI water
- rotameter: max 0.5 L per minute
- auto transformer: 230 V
- wattmeter: 0-1000 W
- thermocouples: T-type, 9 nos

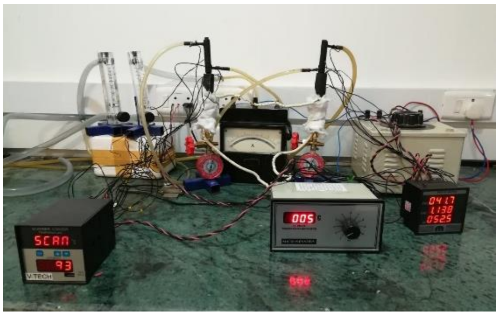

Figure 1. Experimental set-up

Working fluid

Graphene nanoparticles are used as a working fluid. Nanoparticle size is 150-200 nm.

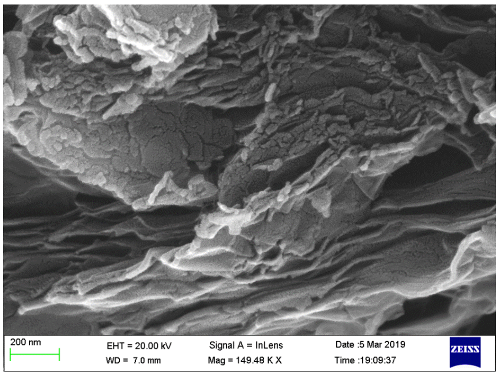

Figure 2. The FESEM image of graphene nanoparticles

Graphene nanoparticles are mixed with DI water with 0.6% and 0.75% concentrations by two-step method. After complete the preparation of working fluid, it is inject to heat pipe at 50% filling ratio. The FESEM image of graphene is shown in fig. 2.

Observational methodology

The heat pipe is filled with working fluid, thermocouples connected to data logger, watt meter and auto transformer are connected then connections are checked initially. Now the heat pipe is ready to work. The 10 W input power is given initially. Orientation of heat pipe is 90°, flow rate of coolant is 100 mL per minute. Temperature are noted by PC until it come to steady-state. After completing an initial reading, power input is increases from 10 W to 50 W, at 10 W intervals. The readings are taken for different power input. The same procedure has followed after changing the working fluids. All the reading are tabulated, thermal resistance and efficiencies are calculated.

Results and discussion

Thermal resistance and efficiency of heat pipe was calculated by following equations and the calculated values are plotted in figs. 3 and 4.

$$R_{\text{th(overall)}} = \frac{T_{\text{evp}} - T_{\text{cond}}}{Q}, \quad h_{\text{overall}} = \frac{Q}{\Delta T_{\text{overall}}}, \quad F = \frac{V_{\text{e}}}{V_{\text{t}}}$$

where

$$V_{\text{e}} = \frac{\pi}{4} d^2 L_{\text{e}}, \quad V_{\text{t}} = \frac{\pi}{4} d^2 L_{\text{t}}$$

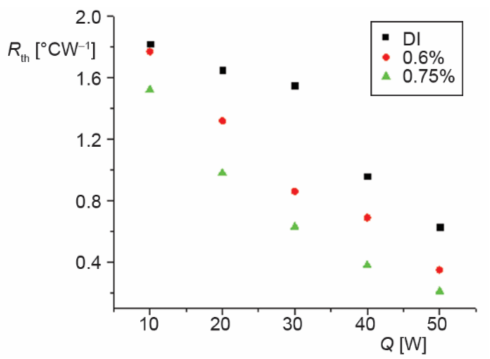

Figure 3. Thermal resistance of heat pipe according to heat load

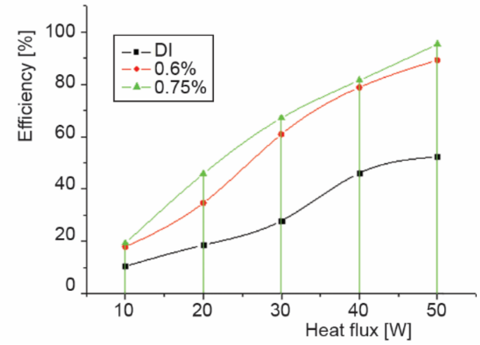

Figure 4. Thermal efficiency of heat pipe according to heat load

Overall thermal resistance of nanofluid with various concentrations along with base fluid for different input powers are recorded and shown in the fig. 3. By seeing the graph, can clearly say that thermal resistance decreases has the heat flux increases. This happen as the concentration of graphene nanofluid increases, the overall thermal resistance decreases. Among all the concentrations 0.75 vol.% of graphene nanofluid has less thermal resistance. The reason of increasing an efficiency with the increasing concentration of nanofluid can be related to the increasing of fluid thermal conductivity.

When graphene nanoparticles used in heat pipe, its increases thermal efficiency and performance more than 34%. Auxiliary groove inside the heat pipe increases the capillary action used to molecules move. Thus conduction and convection take place without and external source. The 100 mL per minute flow rate offers proper condensation for all working fluids. While comparing graphs at 0.75 vol.% thermal efficiency attain 95%. It is somewhat higher than 0.6 vol.%. But DI water shows very low efficiency than graphene nanoparticles. According to the data in fig. 4 graphene nanofluids with different concentrations is more efficient than other nanofluids and base fluid.

The T_{wall} revaluation

When heat pipe is heated, wall inside of evaporator temperature increases then decreases in condenser section. Initially, position of thermocouples and wall temperature were measured for base fluid, 0.60%, 0.75% to see the temperature difference for the different heat load. From fig. 5 wall temperature increases when increase in length. But in condenser section condensation take place and release latent heat. By the time wall temperature inside the condenser reduced and almost reach at initial temperature. Thus inside heat pipe change the phase from liquid to vapor to liquid. Thus, the surface temperature of heat pipe agrees well with their natural phenomena.

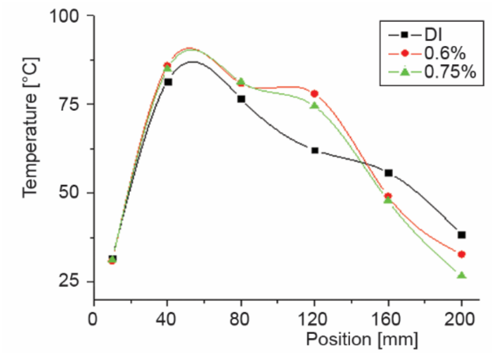

Figure 5. The T_{wall} according to length of heat pipe

Conclusions

Heat pipe is circular in shape made of copper material with auxiliary grooves. Working fluids are DI water and graphene nanoparticles (0.6%, 0.75%). The heat pipe is validated at different working fluid and heat load. From the experimental works the results are obtained.

- Increasing heat load enhance thermal efficiency but decrease thermal resistance.
- Concentration level of graphene nanoparticles changes the performance of heat pipe.
- Increasing the concentration level increases thermal performance.
- The T_{wall} increases in evaporator section constant at adiabatic and decreases in condenser section.
- At 0.75 vol.% of graphene increases efficiency than 0.6 vol.%. When compare these result to base fluids, graphene is a promising nanofluid for cooling applications.

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Nomenclature

d – diameter of the pipe, [m^2]
F – filling ratio in evaporator, [%]
$h_{overall}$ – overall heat transfer coefficient
L_e – evaporator section length, [m]
L_t – condenser section length, [m]
Q – heat load, [W]
$R_{th(overall)}$ – overall thermal resistance, [°CW^{-1}]
$\Delta T_{(overall)}$ – overall temperature difference, [°C]
T_{evp} – temperature at evaporator section, [°C]
T_{cond} – temperature at condenser section, [°C]
V_e – volume of evaporator section, [m^3]
V_t – volume of total pipe, [m^3]

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