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Original Research Article

Parametric investigation of moving properties of zinc oxide nano-fluid

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Abstract: The nano fluid is a magic fluid which can enhance the heat transfer. The specific area of nano particles is very high. So, these particles can use in different fields. The zinc oxide nano fluid has different properties such as non toxic and useful for mass and heat transfer fields. Also, heat pipe is a power full device which can improve the heat transfer. So, a heat pipe and zinc oxide nano fluid as the operating fluid is used in this paper. Temperature distribution, nano fluid density and nano fluid shear stress is considered in this work. The results present better temperature distribution of zinc oxide nano fluid relative to the pure water.
Keywords: Rheological parameters; Zinc oxide nano fluid; Temperature distribution; Heat flux

INTRODUCTION

Generally, attempts of humans during the industrial history have been tended to higher heat transfer rates and making heat exchangers in smaller size [1- 3]. Although the metallic particles suspended in the fluids have higher thermal conductivities and had been proposed to heat transfer augmentation in the heat exchangers, but they also are responsible of erosion, corrosion, pressure drop and pipe blockage [4-6].

Therefore, adding particles in millimeters or even micrometre size, have encountered problems. Suspensions with millimeter or micron sized particles are famous to cause severe problems in heat transfer apparatus [7]. However, particles in large size tend to quickly settle out of suspension and cause to severe clogging by passing through micro channels. Thereby, the pressure drop increases severely [8, 10-11]. Furthermore, the abrasive actions of these particles cause the erosion of pipelines and industrial equipments [12-14]. Nowadays, developing technology represents the utilization of nanofluids as working fluids in heat transfer equipments. 'Nanotechnology'' is one of the important branches which uses substances in nano size in many revolutionary variations that can significantly improve device performance, which relates to engine cooling systems, petroleum and chemical plants, the technology of communication, resistor materials, sensor applications, drug delivery, pharmaceutical industries and several areas of practical importance [7]. However, traditional fluids have poor heat transfer properties compared to most solids. Some experimental investigations have revealed that water has a remarkably higher thermal conductivity and greater heat transfer characteristics than conventional oily fluids. A theoretical model and an experimental setup are proposed to describe the heat transfer performance of water flowing in a heat pipe. The experimental results illustrate that the thermal conductivity of nano particles is higher than the thermal conductivity of the macro particles. In 2001, a heat pipe consisting of aluminum wick presented a much higher effective thermal conductivity. The convective heat transfer feature and flow performance of water in a tube are experimentally investigated by Scientifics. The other researchers investigated the increase in thermal conductivity with temperature for oily fluids with water as the base fluid and glycerol as suspension substances [13 and 14]. The results indicated an increase in enhancement characteristics with temperature, which makes the wick even more attractive for applications with higher energy density than usual room temperature measurements reported earlier. The other Scientifics performed boiling experiments, varying the conditions of fluids. The measured pool boiling curves for oily fluids saturated at 60 centigrade degree demonstrated that the critical heat flux increases dramatically (200% increase) compared to pure water [13-14]. In 2004, some researchers investigated the thermal performance of fatty fluids in meshed heat pipes [13]. The circular meshed heat pipe had a length of 170 mm and an outer diameter of 6 mm. The heat pipe thermal resistance ranged from 0.17 to 0.215C/W. The measured results showed that the thermal resistance of the heat pipes with fatty fluids is lower than that of pipes containing pure water [13]. Recently, Scientifics demonstrated that a fatty fluid consisting of Ethanol molecules in distilled water enhanced grooved heat pipe thermal performance [11-12]. Similar experiments are observed in another recent study by authors. This study is focused on the temperature distribution in a heat pipe. Their result also showed that copper heat pipe thermal performance is higher than that for a conventional heat pipe [10]. The present study aims at assessing the effect of zinc oxide nano fluid as the working fluid on the temperature distribution in an aluminum heat pipe. The obtained results are compared with data collected from pure water.

MATERIALS AND METHOD

An experimental system is set up to measure the thermal distribution of circular heat pipes. The local heat pipe temperature is measured using four isolated Omega type-T thermocouples. Two thermocouples are attached to the evaporator; one is attached to the adiabatic section; and the last one is attached to the condenser section (for ambient temperature). All thermocouples are calibrated against a quartz thermometer. The uncertainty in temperature measurements is ±0.1 C. Two heater bars (maximum 120 W) are used as a heat source in the heating section.

Modeling for temperature prediction

Figure 1 shows the heat pipe in three sections. For a fully-thawed low-temperature heat pipe, the vapor phase can be assumed to be saturated and uniform. Therefore, there is no need to solve the energy equation for the vapor phase.

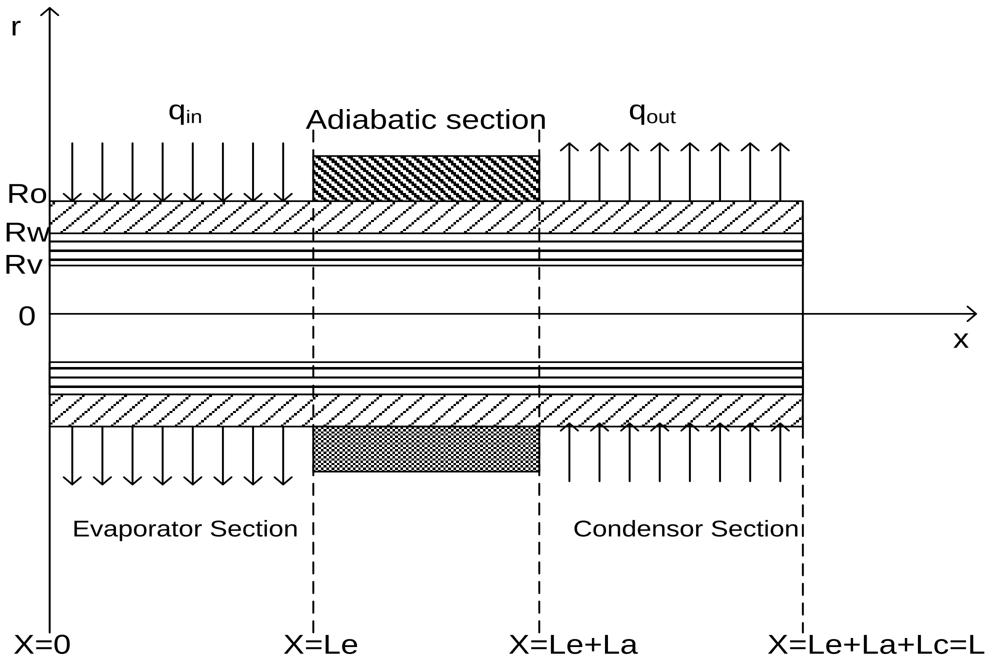

Fig 1: The experimental heat pipe in three sections

Results show the axial vapor and wall temperature distributions of a metallic heat pipe with zinc oxide nano fluid as the working fluid. These results show that the vapor temperature is uniform along the heat pipe. The authors believe that the wall temperature in the evaporator and the condenser sections is almost uniform, except near the interfaces with the adiabatic section where axial conduction in the wall is most pronounced. In the present study, the heat pipe is heated uniformly over the evaporator section and convectively cooled in the ambient as condenser section. The vapor temperature is assumed uniform along the heat pipe, and a one-dimensional heat conduction model is used for the wall and liquid-wick regions. For steady-state operation, the convective boundary condition at the outer wall surface ($r = R_o$) is:

$$Q = 2\pi R_o L_c h(T_{wall,c} - T_b) \qquad 1$$

Where Q is the heat input, h is the convective heat transfer coefficient, $T_{wall,c}$ is the wall temperature in the condenser section, and T_b is the bulk temperature of the coolant. The vapor and wall temperatures are obtained as follows:

$$T_v = T_b + \frac{Q}{2\pi L_c}\left(\frac{\ln(R_o/R_w)}{k_{wall}} + \frac{\ln(R_w/R_v)}{k_{eff}} + \frac{1}{hR_o}\right) \quad (2)$$

And the equation 3 can predict the wall temperature for $0.0 \le x \le L_e$.

$$T_{wall}(x) = T_b + \frac{Q}{2\pi L_c}\left[\left(\frac{\ln(R_o/R_w)}{k_{wall}} + \frac{\ln(R_v/R_v)}{k_{eff}}\right)\left(1+\frac{L_c}{L_e}\right) + \frac{1}{hR_o}\right] \qquad 0.0 \le x \le L_e \quad (3)$$

Also, the wall temperature for the $L_e \le x \le L_e + L_a$ can be written as equation 4.

$$T_{wall}(x) = T_b + \frac{Q}{2\pi L_c}\left[\left(\frac{\ln(R_o/R_w)}{k_{wall}} + \frac{\ln(R_w/R_v)}{k_{eff}}\right) + \frac{1}{hR_o}\right] \qquad L_e \le x \le L_e + L_a \quad (4)$$

The wall temperature for $L_e + L_a \le x \le L$ can be written as equation 5

$$T_{wall}(x) = T_b + \frac{Q}{2\pi h R_o L_c} \qquad L_e + L_a \le x \le L \quad (5)$$

Where k_{wall} is the thermal conductivity of the heat pipe wall, and k_{eff} is the effective thermal conductivity of the liquid-saturated wick.

RESULTS AND DISCUSSION

Heat transfer in heat pipe and thermal specifications are considered in design and performance of experiments. The heat pipe which is made aluminum wick is used to investigate the temperature distribution of zinc oxide nano fluid in the heat pipe. Also, the heat pipe capacity to tolerate the input powers is surveyed by different amounts of input power. Blow figures illustrate the results related to the heat pipe performance and the rheological properties of zinc oxide nano fluid in the rotational viscometer.

Temperature profile

The effect of power supply and zinc oxide nano fluid on the amounts of temperatures through the length of heat pipes are shown in Figures 2 to 5. Temperature decreases from the evaporator to the condenser through the length. The length of heat pipe which is used in these experiments is 18 cm. Figure 2 shows the temperature changes in heat pipe emerging 20 watt power. The volume percentage for the Figure 2 is 2%. The experimental and theoretical temperature distribution has decreased from 33 to 32.7 and 32.8 to 32.2, respectively.

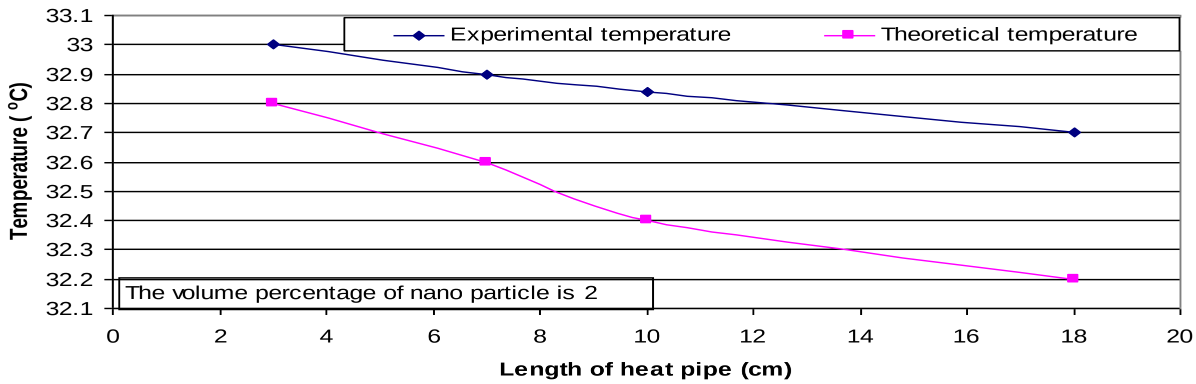

Fig 2: Temperature profile through the pipe length at 20 W, 2% nano particles.

In Figure 3, the experimental temperature distribution is compared with the theoretical temperature distribution. The experimental temperature changes from 30 C to 29.4 C. The start and the end point for temperature in theoretical model is changed from 29.9 C to 29.1 C.

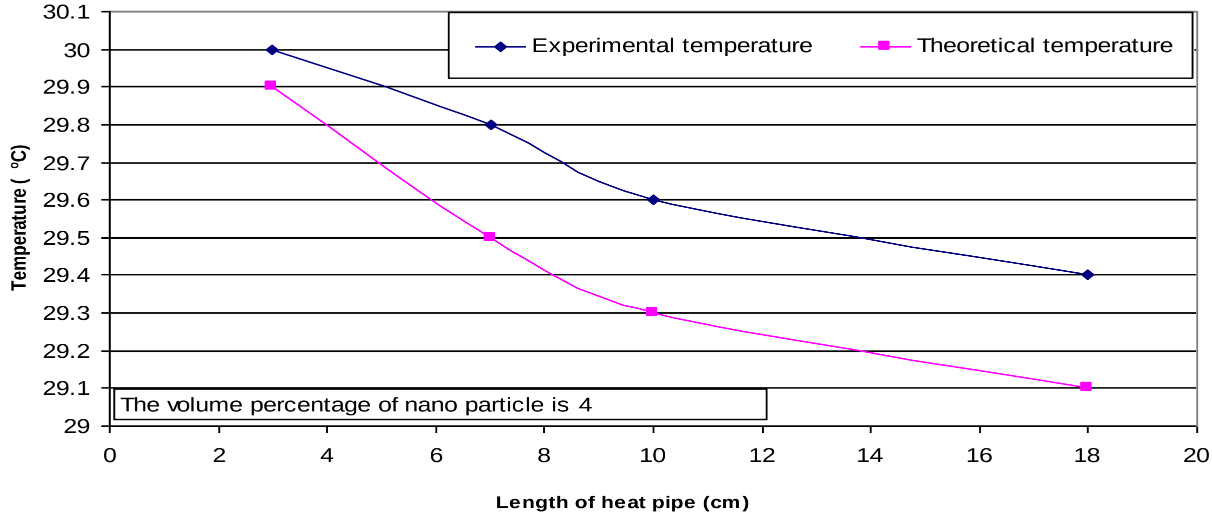

Fig 3: Temperature profile through the pipe length at 20 W, 4% nano particles.

Figure 4 and Figure 5 show the variations of temperature through the heat pipe for 6 and 8 volume percentage. The experimental temperature variation for 6% of nano particles is 26.6C to 25.7C and from 25 to 23.6 when 8% of zinc oxide nano particle is used. The range of temperature changing in a theoretical state for 6 and 8 volume percentage are 26.3C to 25.2C and 24.9C to 23.3C, respectively.

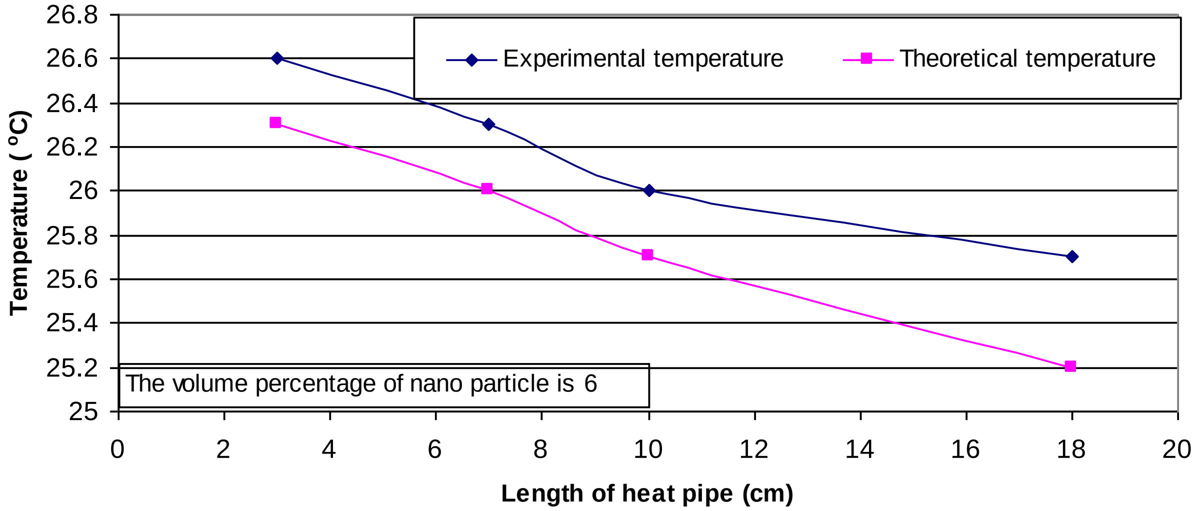

Fig 4: Temperature profile through the pipe length at 20 W, 6% nano particles.

Usage of 8 vol% of zinc oxide nano particle with aluminum wick and input power values of 20 Watt through the 18 cm heat pipe, obtain decreasing trend of start point of temperature.

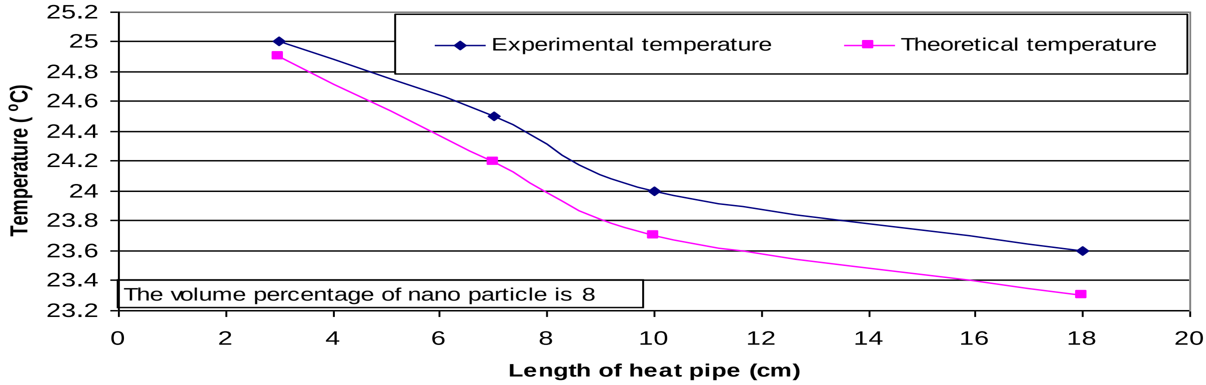

Fig 5: Temperature profile through the pipe length at 20 W, 8% nano particles.

CONCLUSION

This paper discusses the thermal enhancement of heat pipe performance using zinc oxide nano particle and aluminum metal as internal wick. In the present case, distilled water in a 211 micrometer wide x 217 micrometer deep grooved circular heat pipe is experimentally tested. Input power is 20 W and results of the performance test are as follows: A). Aluminum wick shows good heat transfer performance when the zinc oxide nano fluid passes through the heat pipe as working fluid. B). The lower amounts of temperatures are obtained through the heat pipe, when the concentration of zinc oxide nano fluid is 8%.

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