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Laboratory Evaluation of thermal Performance of Injection of Nanofluid and Normal Fluid into a Heat Pipe with the Aim of Optimizing Process Energy

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Abstract

In this research, nano-operating fluids and ordinary fluids have been used. In principle, the temperature profile and thermal resistance when using different fluids have been studied in laboratory. The experiments are conducted to measure and compare temperature and thermal resistance of pure water, metal oxide nano fluid, ammonia, methanol and ethanol which fills heat pipes. The temperature values are measured in different length of heat pipe. In addition, the temperature profiles are obtained in different power. The experiments are conducted for pure water and non-pure solutions with variable concentrations that are between 0.1 mili gram per litre to 100 mili gram per litre. Also, the concentration of 50*ppm* nano particles is the effective amount of metal oxide and keeps the pipe wall temperatures in the optimum values. The experiments show the higher power cause to the higher convective heat transfer and the lower temperature profile, ultimately. More details are achieved in the following results. So, the experimental results show the temperature interval for methanol is 21.24 to 23.56 centigrade degree. In addition, the temperature interval for ethanol is 11.01 to 12.34 centigrade degree and average difference between the temperature profile for methanol and ethanol is 47.08%, approximately. Finally, laboratory results show that the thermal properties of the nanofluid have been significantly improved. Therefore, a high heat transfer coefficient can be expected if the nanoparticles are well distributed in the fluid.

Keywords

Water, Thermal Resistance, Heat Pipe, Thermal Profile, Operating Fluid, Nano

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1. Introduction

In general, the heat is transferred from a high temperature point to a low temperature point [1]. In other words, it is to transfer heat from a place with a high temperature to a place with a lower temperature [2]. Meanwhile, heat pipes are used as tools to improve heat transfer in industry [3]. In addition to industries, in different parts of a process can be used heat pipes with different dimensions [4]. For example, heat pipes are used in ventilation systems, purification systems, fluid transfer systems, etc. Today, the use of heat pipes is strangely applied and widely used in various industries [5]. The study of temperature changes along the heating pipe is one of the goals of scientific studies in recent years [6]. The trend of temperature changes along the heating pipe is expected to improve by injecting nanofluids into the heating pipe instead of injecting pure water [7]. Therefore, in recent years, studies have been conducted to improve the rate of heat transfer [8]. Since nanoparticles have nanometer dimensions, they have a very high specific surface area and as a result, they can dramatically increase the efficiency of heat transfer processes

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[9]. The results of previous studies show that if the solubility of nanoparticles in the base fluid increases, the nanofluid created in mass transfer and heat transfer processes can be used with certainty [10].

Therefore, the temperature profile along the heating pipe is investigated in this study [11]. Also in this research, the thermal resistance has been measured as a parameter preventing heat transfer [12]. In order to evaluate the thermal resistance, different heat capacities have been studied in order to have a more comprehensive look at the performance of the heating pipe [13].

In principle, heat pipes are used for the purpose of easier and faster heat transfer from a high temperature point to a low temperature point [14]. Therefore, on one side of the heat pipe, the evaporation operation takes place and on the other side, the condensation operation takes place [15]. Since the transfer heat transfer coefficient for evaporation and condensation processes is a significant number, the amount of heat transfer will be a significant and very large number [16]. Of course, the type of operating fluid used in heat pipes is very important. In this research, nano-operating fluids and ordinary fluids have been used. In principle, the temperature profile and thermal resistance when using different fluids have been studied in laboratory and compared.

2. Materials and Methods

The heat pipes are among the tools used in various industries. Therefore, examining their efficiency and performance is of special importance. The heat pipe under study, like other heat pipes, is equipped with a condenser and heater. The fluid inside the heating pipe is transferred from the condenser to the heater and heats up during the movement and turns into a vapour phase. After the operating fluid reaches the heater, it is compressed and transferred to the condenser. As a result, liquid and steam are constantly moving inside the heating pipe. In other words, condensate and evaporation phases are constantly occurring along the heating pipe. The length of the heat pipe under study is about 18 cm and its diameter is about 2 cm. Also, a heater with a power of one tenth of a watt has been used to heat the fluid inside the pipe. It should be noted that the power of the capacitor used in this test is about twenty-five hundred watts. Since the performance evaluation of the operating fluid is considered. In this study, fluids such as ammonia, methanol, pure water and nanofluids were used.

As mentioned before, given that nanofluids can cause a huge revolution in the heating and refrigeration industries. In this study, the thermal performance of injected ferric oxide nanofluids has been compared with the performance of conventional fluids such as pure water, ammonia and methanol. Therefore, the temperature profile of the fluid injected into the heat pipe for the purpose of this research is given in the results and discussion. Since thermal resistance acts as a barrier to heat transfer, so this item is also measured as one of the basic parameters in the results section. Also, for the fabrication of ferric oxide nanofluids, a certain concentration of ferric oxide nano powder was dissolved in one liter of distilled water and then the resulting solution was placed in an ultrasonic device with a frequency of 60 Hz for 3 hours. For other injectable fluids such as pure water, ammonia and methanol, their common form, which is available in the market, has been used. The average size of nanoparticles mixed with distilled water is 65 nanometers and the thermal power applied to nanofluids and ordinary fluids is 30 watts, 40 watts, 50 watts and 60 watts. The studied heating pipe has been evaluated to optimize the operating conditions. In this heating pipe, nanofluid is used instead of pure water. In the study, a nanofluid with a specific concentration is injected into the condenser part of the heat pipe. The temperature profile along the heating pipe is investigated in this study. Also in this research, the thermal resistance has been measured as a parameter preventing heat transfer. At the first, the nano ferric oxide is made and nano fluid utilizes by dispersing the particles in nano size in pure cooling water. The effects of quantity of nano particles that are dispersed in the cooling water are surveyed on the operational parameters such as temperature distribution of the pipe wall and heat pipe thermal resistance. Also, the concentration of 50 *ppm* nano particles is the effective amount of metal oxide and keeps the pipe wall temperatures in the optimum values. The experiments show the higher power cause to the higher convective heat transfer and the lower temperature profile, ultimately. The results show that if nanofluid is used as the operating fluid, the temperature profile is significantly improved and the rate of heat transfer from a warmer environment to a lower temperature environment is significantly improved.

3. Results and Discussions

The temperature profile along the heating pipe is investigated in this study. Also in this research, the thermal resistance has been measured as a parameter preventing heat transfer. In order to evaluate the thermal resistance, different heat capacities have been studied in order to have a more comprehensive look at the performance of the heating pipe. As shown, the Figure 1 shows the temperature distribution of pure and nanofluid. The experimental data show the trend of fitted curves are decreasing, severely. The five polynomial with so good regression values are calculated in this study. So, the estimation of temperature profile of pure water and nanofluids can be happened by the proposed correlations.

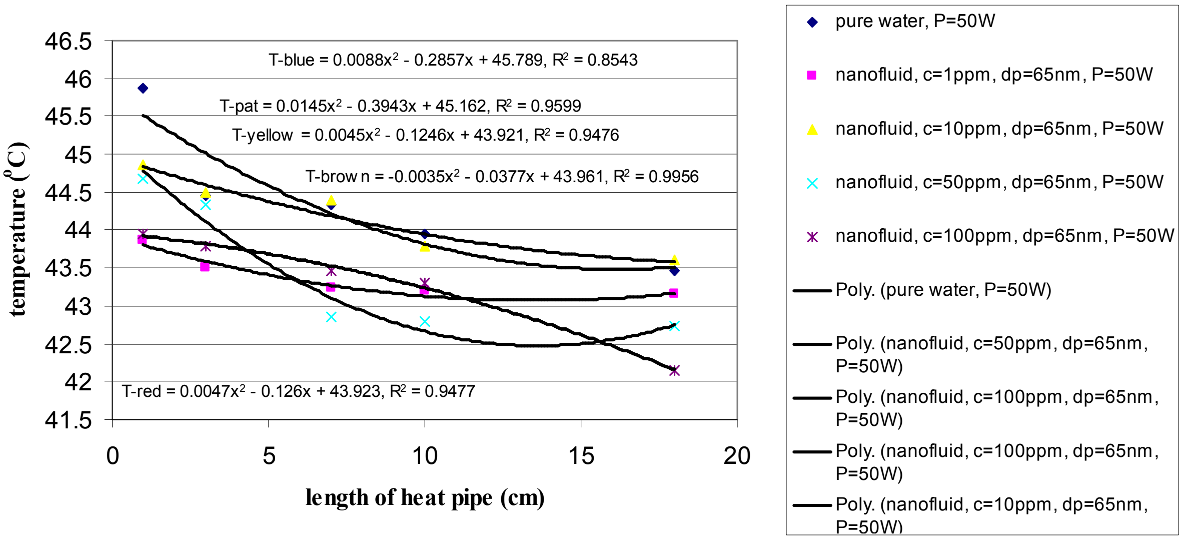

Figure 1. Temperature profile in the length of heat pipe.

The trends of temperature changing in the length of heat pipe for 60Watt are shown in the Figure 2. In addition, the five experimental correlations are shown in this Figure. The average size of nanoparticles which are dispersed in the pure water is 65nm.

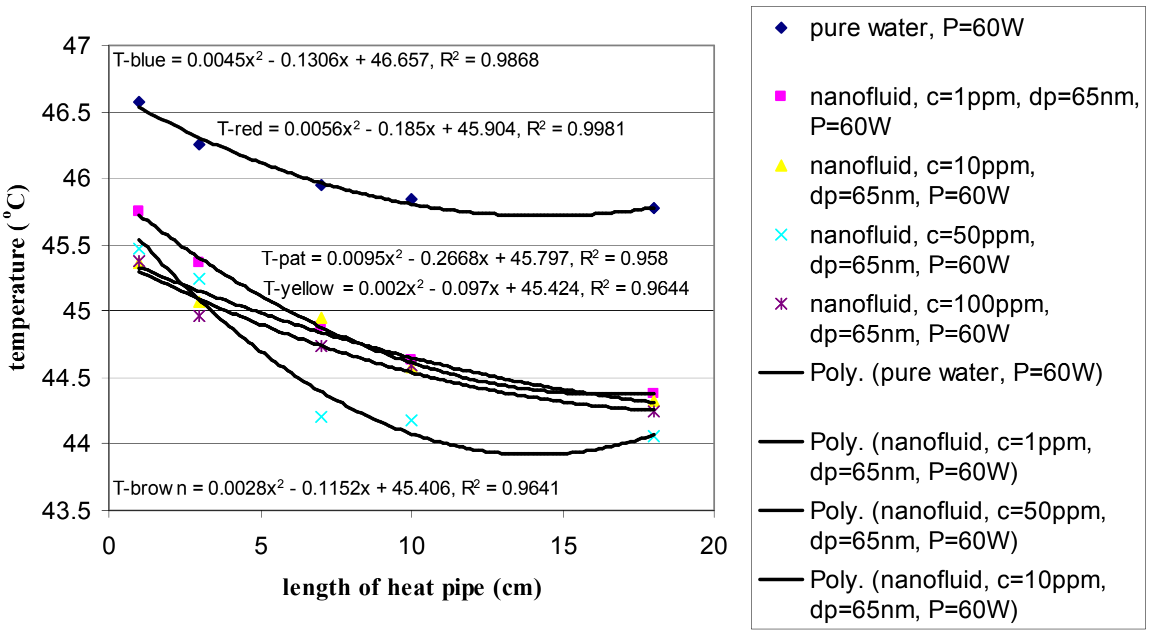

Figure 2. Temperature profile in the length of heat pipe.

According to Jang and Choi correlation, the thermal conductivity of cooling nanofluids is affected by the concentration, temperature, and particle size. The Equation 1 shows the relations. So, the temperature alters which are obtained in the Figures are approved by Equation 1.

$$h \propto (k_b / d_p) \mathrm{Re}_{dp}^2 \Pr \varphi \qquad (1)$$

Due to the Equation 1, Increasing the concentration of nano particle, ϕ , the input power and usage of smaller nano particles makes the higher thermal conductivity of nano fluids than the base fluids according to the Equation 2.

$$K_{eff} = k_b(1-\varphi) + k_p\varphi + 3C\frac{d_b}{d_p}k_b \mathrm{Re}_{dp}^2 \Pr \varphi \qquad (2)$$

The Figure 3 shows the thermal resistance of pure water and nanofluid with optimum concentration (50ppm) through the heat pipe. The experimental results are investigated in the 30 Watt power. Also, two experimental correlations are calculated in this Figure. The orders of the defined polynomials are second and their regression is near one.

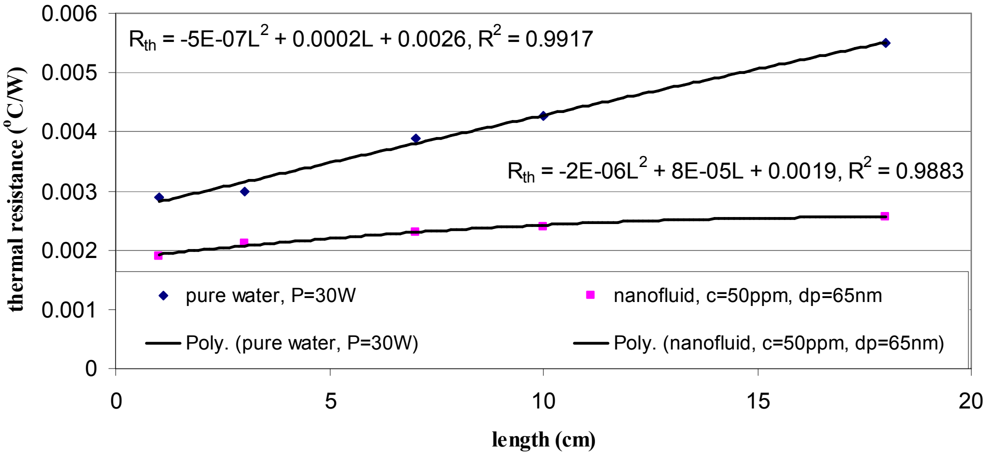

Figure 3. Thermal resistance versus heat pipe length.

The Figure 4 illustrates the thermal resistance changes in the heat pipe for 40W as input power. In addition, two experimental correlations with high accuracy are defined in this Figure. Averagely, the thermal resistance is decreased 62.1% when nanofluid is applied instead of pure water.

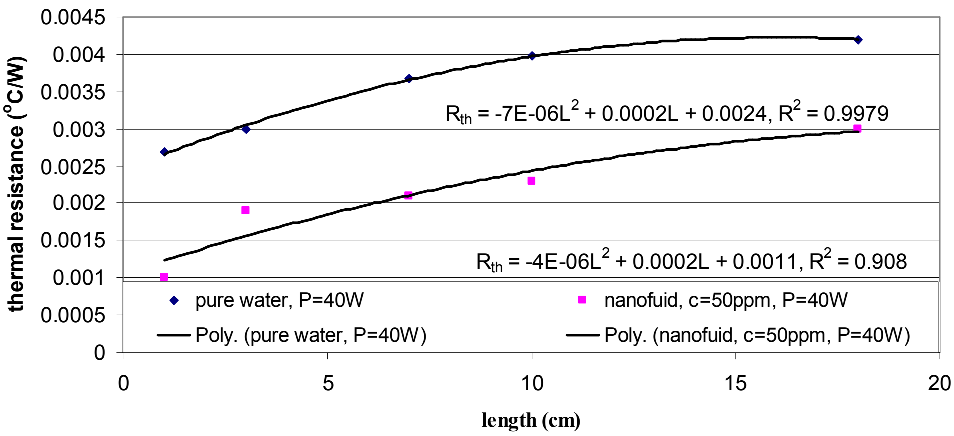

Figure 4. Thermal resistance versus heat pipe length.

The Figure 5 shows the thermal resistance of pure water and nanofluid. The best concentration of nanofluid is 50ppm. The regression for curve fitting of pure water and nanofluid is about 0.983 and 0.9615, respectively.

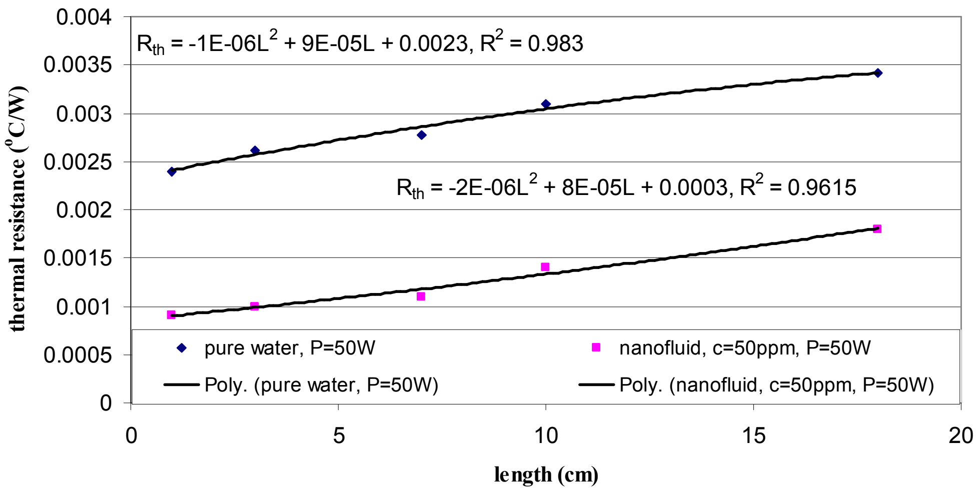

Figure 5. Thermal resistance versus heat pipe length.

The Figure 6 illustrates the thermal resistance of pure water and nanofluid when the input power of heat box is 60Watt. The thermal resistance of nanofluid is 58.2% lower than pure water.

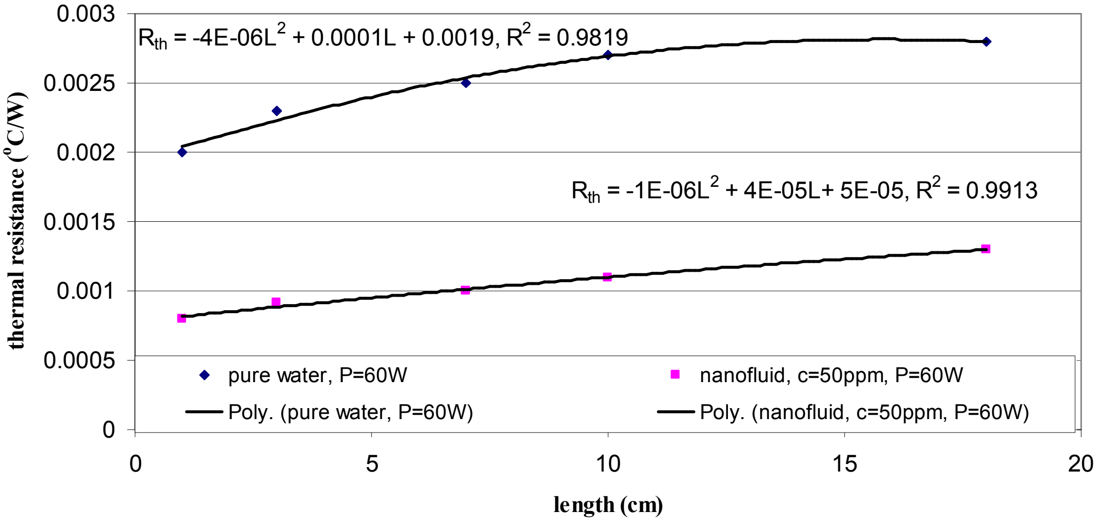

Figure 6. Thermal resistance versus heat pipe length.

This part of experiments surveys the effect of nano fluid concentrations on the thermal resistances of the heat pipe under various heat loads. The amounts of thermal resistances are calculated as Equation 3. Where R_{th} is the thermal resistance of the heat pipe. ΔT_t is the temperature difference of the tube, $(°C)$ and $Q_{ex.}$ is the input load (W). Therefore, the unit of thermal resistance in SI system will be $\left({}^{\circ}C/_{W}\right)$.

$$R_{th} = \frac{\Delta T_t}{Q_{ex.}} \qquad (3)$$

Figure 7 shows decreasing in wall temperature of pipe which contains ammonia, methanol and ethanol. The input power as heat flux is 60W. The experimental results show the average difference between temperature profile for methanol and ethanol is approximate 21.2%.

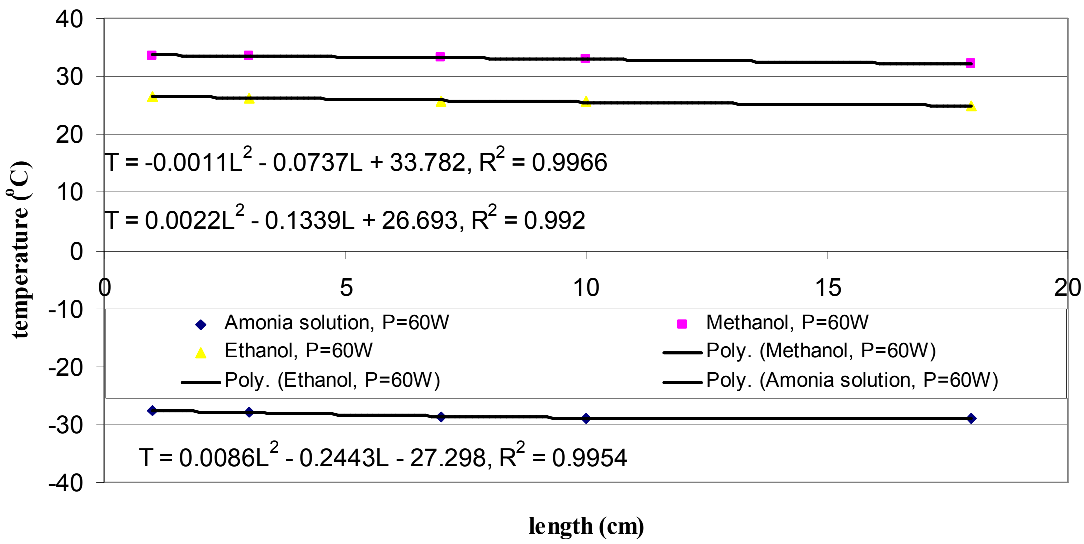

Figure 7. Temperature profile in the length of heat pipe.

The regressions of three polynomials are calculated in the Figure 6. The accuracy of temperature profiles is so high and is near one. The temperature interval for methanol is 32.11 to 33.67 centigrade degree and the temperature range for ethanol is between 24.99 and 26.56 centigrade degree.

4. Conclusion

Investigations about the performance of heat pipes contain nano ferric oxide is done experimentally, in this wok. At the first, the nano metal oxide (ferric oxide) is made and nano fluid utilizes by dispersing the particles in nano size in pure cooling water. The effects of quantity of nano particles that are dispersed in the cooling water are surveyed on the operational parameters such as temperature distribution of the pipe wall and heat pipe thermal resistance. Also, the concentration of 50 *ppm* nano particles is the effective amount of metal oxide and keeps the pipe wall temperatures in the optimum values. The experiments show the higher power cause to the higher convective heat transfer and the lower temperature profile, ultimately. More details are achieved in the following results. So, the experimental results show the temperature interval for methanol is 21.24 to 23.56 centigrade degree. In addition, the temperature interval for ethanol is 11.01 to 12.34 centigrade degree and average difference between the temperature profile for methanol and ethanol is 47.08%, approximately. The empirical results show, temperature interval for methanol is 32.11 to 33.67 centigrade degree and the temperature range for ethanol is between 24.99 to 26.56 centigrade degree. Totally, the results show that if nanofluid is used as the operating fluid, the temperature profile is significantly improved and the rate of heat transfer from a warmer environment to a lower temperature environment is significantly improved.

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