IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

MATHEMATICAL MODELLING OF ENGINEERING PROBLEMS
Vol.2, No.1, 2015, pp.5-8
http://dx.doi.org/10.18280/mmep.020102

STUDY ON THE HEAT TRANSFER CHARACTERISTIC OF HEAT PIPE CONTAINING MAGNETIC NANO-FLUIDS STRENGTHENED BY MAGNETIC FIELD

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ABSTRACT

In order to improve the heat transfer rate of heat pipe, an experimental research method was introduced, it is that using magnetic field to enhance the heat transfer of nano-magnetic fluid vacuum heat pipe. In this experiment, through the preparation of nano-magnetic fluid as well as the independent design the heat exchanger test-bed, the heat transfer of nano-magnetic fluid heat pipe was studied in different types and intensities of magnetic fields. The study found that the heat transfer of nano-magnetic fluid heat pipe was the best. Every kind of magnetic field could enhance the heat transfer of nano-magnetic fluid heat pipe, in which the static DC magnetic field did the best and the maximum raise rate was 19.2%.

Keywords*:* Magnetic fields, Nano-magnetic fluid, Heat pipe, Heat transfer.

1. INTRODUCTION

With the rapid development of modern industry, the contradiction of energy demand increases and strain energy supplies is more and more serious. The heat pipe wins great attention due to its unique advantages in saving energy and new energy development. The world of heat pipe exchanger’s applied research has been made in the following several aspects: (1) the results with heat pipe exchanger recycling industries of waste heat of exhaust; (2) using heat pipe or heat exchanger to remove the heat generated by the power electronic originals or electronic instrument; (3) as the use of natural energy of the heat exchanger; (4) as a chemical reaction heat exchanger equipment [1], heat pipe is becoming more and more popular in these few of the application. How to improve heat exchange performance of heat pipe, and develop heat pipe with higher efficiency, is now the direction and responsibility of the heat pipe technology.

The study found that Cu-water nano fluid heat transfer within the heat pipe the self-oscillations flow has some particularity in some conditions. Nano fluid can rise to strengthen the role of heat transfer [2]. The water surface tension after being magnetized dropped significantly. The increase of the magnetic field strength fluctuates with the water surface tension in decline. When the magnetic field strength increased to certain degree, the strength of the surface tension of the water drop is doomed to reduce [3-4].

Wu Songhai study found that water vapor condensation heat transfer coefficient in the experiment under the influence of magnetic field, the biggest coefficient without magnetic field is the function of the 10% increase, but at the same time as the increase of liquid membrane Reynolds number, the water vapor condensation heat transfer coefficient of the magnetic field by weakening [5], at the same time after the evaporation of the magnetic field on distilled water rate is 1.1 times without magnetic field, and evaporation rate with the increase of the magnetic field strength increases, when the magnetic field strength remain, the evaporation ratio increases with increasing the temperature [6].

Zhang Yunfeng [7], such as found under the action of magnetic field, oil and water heating rate of change rules is consistent, but in the same magnetic field intensity and heat flux, the oil heating rate than water. But with the increase of the magnetic field strength and magnetized the extension of time, the rate of temperature are increased obviously. Zhao Meng [8] through the experimental study found that the magnetic field under the function of the resistivity of viscosity increases with the size of the magnetic field, the viscosity of the role of the time. Magnetic field effect reaches a certain time, the resistivity of viscosity achieve stability. Along with the increase of the magnetic field, the resistivity of viscosity increases, after the magnetic field is up to a certain intensity, viscosity no longer increases.

To sum up, the use of magnetic liquid and magnetic fields to strengthen heat transfer, this has a great significance to scientific research. In view of the heat transfer characteristics of heat pipe has a strong magnetic field and can improve the thermal conductivity, the liquid experimental proposed through the additional magnetic field to enhance the effect of heat pipe heat transfer of nano magnetic liquid vacuum.

2. THE EXPERIMENT DEVICE AND METHOD

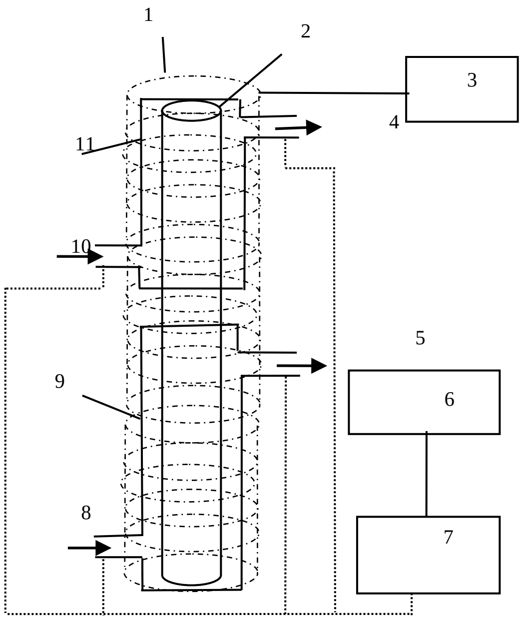
Experiment equipment and measuring systems including the vacuum heat pipe, and the main magnetic spirals, DC voltage regulator, computer Labview temperature gathering system, the multiple thermocouple checking instruments, as shown in figure 1 below. Heat pipe diameter of copper is 16 mm long, 1000 mm, and external use PVC control casing type heat exchanger. To prevent heat exchanger in heat exchanger, to the appearance of bread a layer thickness of 28 mm blessed with flexible foam rubber, heat preservation material, and the insulation layer around the foil to abate heat exchanger and outside radiation heat transfer.

The experiment, provide hot water tank to keep water temperature in the constant temperature 90 ℃, cooling water and hot water flow, the flow measurement are from pressure regulator to power supply and then produce a magnetic field spirals, heat exchanger temperature of import and export by thermal resistance thermometer. After the experiment is in a stable state, the experimental data is collected by checking instrument directly.

3. MATHEMATICAL MODEL

The main reason of the improvement of the heat transfer performance of the nano fluid is remarkably enhance the thermal conductivity of the fluid. Although there are some half experience is used to calculate formula of two phase flow coefficient of thermal conductivity, but so far, no a more precise theory to describe the nano the thermal conductivity of the fluid. Two phase flow mixture of the coefficient of thermal conductivity is based on the following formula [9]:

$$\mathrm{k}_{eff} = \frac{k_p \alpha_p \left(dT/dx\right)_p + k_f \alpha_f \left(dT/dx\right)_f}{\alpha_p \left(dT/dx\right)_p + \alpha_f \left(dT/dx\right)_f} \tag{1}$$



1. Add magnetic spirals 2. Vacuum heat pipe 3. Dc voltage regulator 4. Cooling water export 5. Heating water export 6. Computer Labview temperature gathering system 7. The multiple thermocouple inspection instrument 8. Heating water entrance 9. Heating section 10. Cooling water entrance 11. Condensing section

Figure 1. Heat pipe heat transfer characteristic test principle diagram

Hamilton and Crosser [10] put forward a model, used to Calculation when two phase coefficient of thermal conductivity of over 100 than liquid-solid mixture of the coefficient of thermal conductivity:

$$\frac{\mathrm{k}_{eff}}{\mathrm{k}_f} = \frac{k_p + (n-1)\mathrm{k}_f - (n-1)\alpha\left(\mathrm{k}_f - \mathrm{k}_p\right)}{k_p + (n-1)\mathrm{k}_f + \alpha\left(\mathrm{k}_f - \mathrm{k}_p\right)} \tag{2}$$

Type k_p is discontinuous phase particles to the coefficient of thermal conductivity of the fluid and k_f is medium the coefficient of thermal conductivity. α is the volume of particles and n is experience form factor. $n = 3/\psi$, ψ refers to the spherical particles, defined as a degree, the size and the particle equal the surface area of the ball and the particle surface area than the.

The above formula is suitable for suspension micron or mm level two mixture of solid particles, not the right formula in nano fluid is used to calculate the coefficient of thermal conductivity, can use type are calculated.

From Hamilton and Crosser model can see nanotubes the thermal conductivity of the fluid and dependent on the volume of particles share and spherical degrees. For a given particle shape, suspended solid particles have nano. The thermal conductivity of the fluid volume share with particles increases. When a particle volume share certain, by reducing the spherical particles can increase the degree of nano fluid coefficient of thermal conductivity, this shows that the shape of the nanoparticles and properties of the thermal conductivity of the fluid nano has very big effect. At the same time, show that the nanoparticles can increase the traditional liquid heat transfer coefficient of thermal conductivity of the medium.

4. THE EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Without magnetic field under the action of heat pipe different medium vacuum of the comprehensive experimental research and analysis

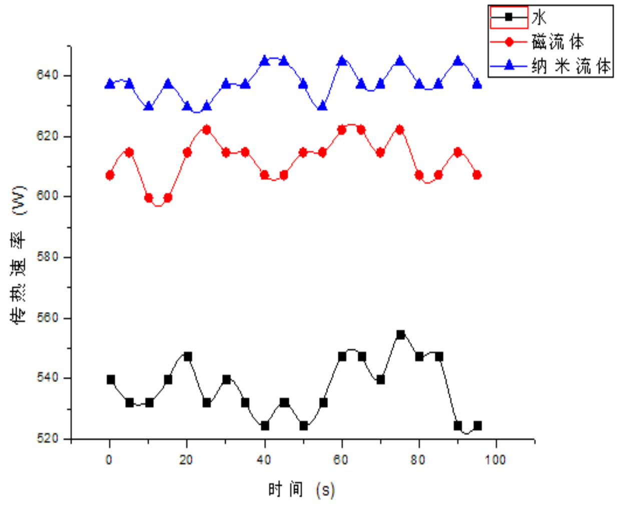


Figure 2. The relationship between heat transfer rate of heat pipe with different working fluid and time in the absence of magnetic field.

We can see from the chart 2, without magnetic field in function, nano magnetic liquid and the vacuum heat pipe heat transfer rate prepared than water medium high heat pipe vacuum, take many average, respectively, than water medium vacuum heat pipe high 18.7% and 14%. Mainly because prepared and magnetic liquid contains nano solid particles and surfactant impact: solid particle collisions increase the thermal conductivity of the fluid. Surfactant reduces the surface tension of liquid, help to liquid boiling vaporization the number of core increase.

4.2 In Dc magnetic field different medium under the action of heat pipe vacuum of the comprehensive experimental research and analysis

We can see from figure 3, in dc magnetic field effect, the heat pipe heat transfer rate three root increased. And with the increase of the magnetic field strength dc transfer rate rising. In In addition, with the increase of the magnetic field strength, nanometer vacuum heat pipe heat transfer rate of resistivity rate the biggest, followed by magnetic liquid vacuum heat pipe, both working than water rate of heat pipe vacuum.

This is mainly because in the evaporator, because the magnetic field of the dc effect, make nano magnetic liquid and the resistivity of apparent density increases, strengthened the magnetic liquid natural convection heat transfer. In the condensing section, static magnetic field on the phase dc diffusion plays a promoting role, accelerate the steam condensate. Dc magnetic field in the evaporator and condenser period, strengthen the joint action of heat pipe heat transfer.

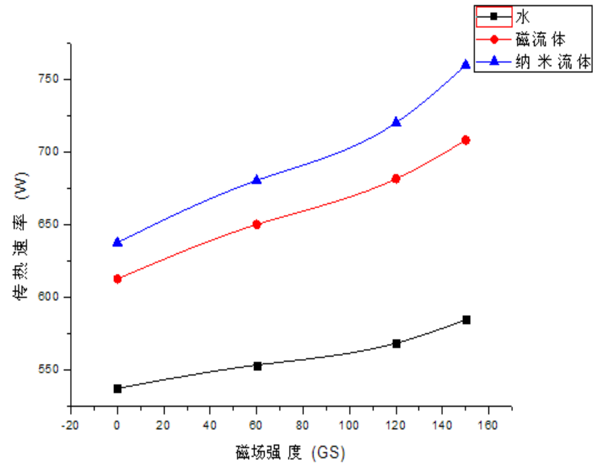


Figure 3. The relationship between heat transfer rate of heat pipe with different working fluid and magnetic field intensity in DC magnetic field.

4.3 Research and analysis of communication under the action of magnetic field different medium vacuum heat pipe of the comprehensive experimental

In figure 4 it can be seen in exchange magnetic field effect, three working medium heat pipe heat transfer rate of vacuum has different rate increase. But as the exchange of the magnetic field strength increases, and heat pipe heat transfer rate of three root the rate is lower first improve the phenomenon, namely in 7 GS came peak.

In the experiments of the magnetic field of the exchange on magnetic field changes every second 50 times, the magnetic field has a strong saturated with ability. Make fluid by a magnetic field force, the magnetic field strength and fluid temperature field and closely related. Due to temperature change so that the field force change and cause fluid flow generally called thermal magnetic convection, the existence of the thermal magnetic convection to strengthen the evaporation period natural convection [11]. But may be due to the magnetic field direction, in constant speed change the direction of the force, magnetic field is also in constant change, heat convection of magnetic strength has been improved, but not with the increase of the magnetic field strength has a peak, so exchange heat pipe heat transfer will strengthen the magnetic field a peak.

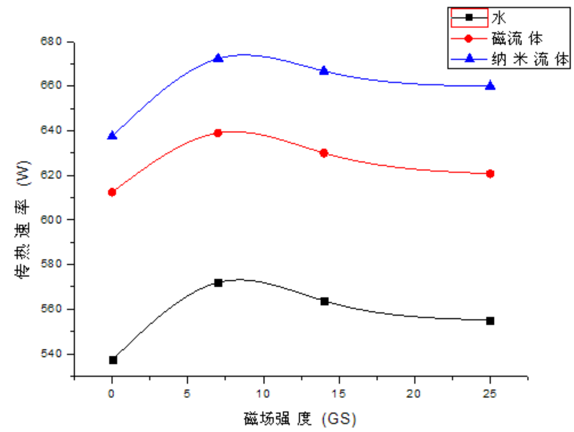


Figure 4. The relationship between heat transfer rate of heat pipe with different working fluid and magnetic field intensity in AC magnetic field

4.4 Magnetic field gradient under the action of heat pipe different medium vacuum of the comprehensive experimental research and analysis

It can be seen from the chart 5, in magnetic field gradient under the action of heat pipe heat transfer, three root rates improved to varying degrees. But the rate is not large, nano magnetic liquid heat pipe is 4.9%, 4.3%, and for vacuum heat pipe prepared and water medium heat pipe is only 3.4%. The reasons, on the one hand, the magnetic field gradient to a certain extent improve the apparent density of the magnetic fluid and strengthen the magnetic liquid natural convection heat transfer. On the other hand, is in not uniform magnetic field gradient thermal magnetic fluid also exist, and strengthen the convection section of the evaporation in natural convection.

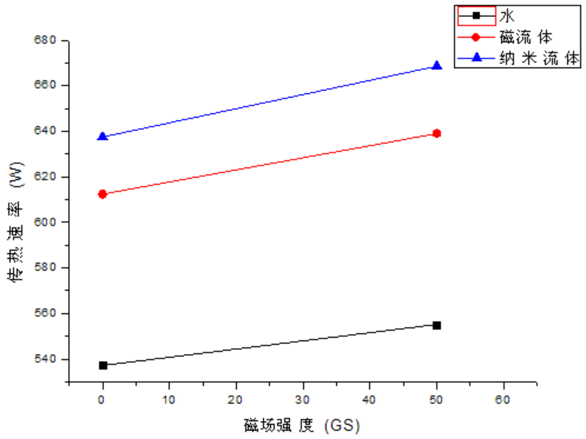


Figure 5. The relationship between heat transfer rate of heat pipe with different working fluid and magnetic field intensity in gradient magnetic field.

5. CONCLUSIONS

(1) Dc magnetic field and magnetic field and magnetic field gradient communication can improve various working medium heat pipe heat transfer rate of vacuum.

(2) Better than magnetic liquid heat pipe heat resistivity nano, magnetic liquid water heat pipe heat pipe is better than working.

(3) Improve the heat transfer of heat exchange magnetic field, but also to a peak rate of heat pipe water medium strengthening effect is the best. Exchange in July about the magnetic field can make heat pipe heat transfer rate achieve maximum, along with the increase of the magnetic field strength, heat pipe heat transfer speed rate but rather dropped.

(4) Magnetic field gradient transfer rate increase heat pipe is not big. In the 50 GS gradients, medium, under the action of water and nano magnetic liquid vacuum heat resistivity of the heat transfer rate increase rate of 3.4%, 4.3% and 4.9%.

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