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Experimental Study on the Heat Transfer Performance of Rectangular Plate-type Heatpipe

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Abstract

Heat pipes are nowadays being used for cooling purposes in various fields, including electronic circuit boards and automobile parts that cause large amounts of heat. Nano particles are added to the working fluid, which is a heat transfer medium. In this study, the model of the product does not take on the traditional circular pipe shape, but takes on an integral structure with multiple rectangular channels which have fine grooves on their inner surface. This increases the surface area allowing the working fluid to contact a wider area, thereby improving the heat transfer performance. An empirical study will be performed on the heat transfer effect of this product, examining the temperature change characteristics of each part as a function of time.

Keywords: Groove Heat Transport Capability Performance Test, Heat Transfer Performance, Nanofluids, Nanoparticle Heatpipe

1. Introduction.

Heat pipes are nowadays being used for cooling purposes in various fields, including electronic circuit boards and automobile parts that cause large amounts of heat. This is because they are devices that are able to transfer large amounts of heat at fast rates, and are popular as the most appropriate heat control device for resolving thermal imbalances in many areas, ranging from small electronic devices to very large heating devices and HVAC systems[1].

The operating principle of a heat pipe is as shown in Figure 1. When heat is applied to the working fluid, repeated phase changes are effected due to the rise in temperature of the fluid, and its evaporation and condensation. Here, latent heat is transferred outside through the groove wick shape of the frame surface. [2]Using this principle, heat pipes are able to release large amounts of heat at fast rates.

They are heat transfer mechanisms able to transfer heat even over long distances. Many types of fluid are used as the heat transfer medium inside heatpipes, and metal particles are added to fluids such as acetone, ammonia or distilled water so as to enhance heat transfer performance. However, because large particles are used, the resulting sedimentation causes difficulties in their use. Accordingly, recent studies are being performed in the use

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of nano-sized particles for the working fluid, and the use of inner vacuum pressure to resolve the sedimentation issue, with studies underway to enhance the excellent dispersion stability and heat transfer characteristics of such fluids[3].

It has been reported that nano particles are not only able to resolve the sedimentation issue but also to increase thermal conductivity to levels far exceeding existing levels, and fluids using such nano particles have recently been named nanofluids[4].

In this study, a groove type heatpipe with not one but 8 channels has been produced to increase the contact area with the working fluid, thereby accelerate the heat transfer. Also, fine grooves have been made on the inner surface of these channels, increasing surface area, allowing the working fluid to come into contact with a wider area, thereby increasing the cooling performance. Meanwhile, the inner working fluid was formed by adding nano metal particles to acetone. A vacuum was made inside the channels to minimize the sedimentation. The ends of the specimen were heated, after which the temperature change characteristics of each part over time were measured and studied.

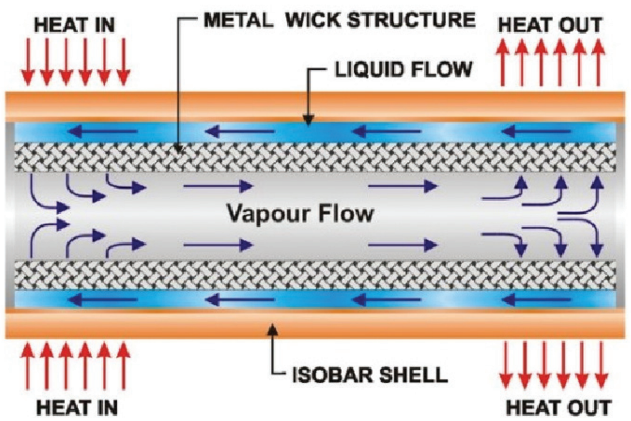


Figure 1. Operating principle of the heatpipe.

2. Experimental Device and Method

The specimen used for the experiment had a rectangular shape of 2.5mm thickness, 55mm width and 14 channels. The pitch between the upper and upper cross-sections of these channels was designed to be very small, with very small grooves of a height not exceeding 0.5mm to increase contact area. The dimensions thereof are as shown in Figure 2. The specimen was designed with a total length of 500mm, including the evaporator, adiabatic section, and condenser. To produce these parts, molds were developed, and extrusion molding was performed. As for the material used, the AL6061-T4 aluminum alloy, with high workability and thermal conductivity, was used. As for the inner working fluid, a commercial product made by mixing nano metal particles with acetone was used[5,6], and as for the amount of working fluid, approximately 40% of the total volume of the rectangular channels was injected. Vacuum pressure was applied to the inside to prevent sedimentation of particles.

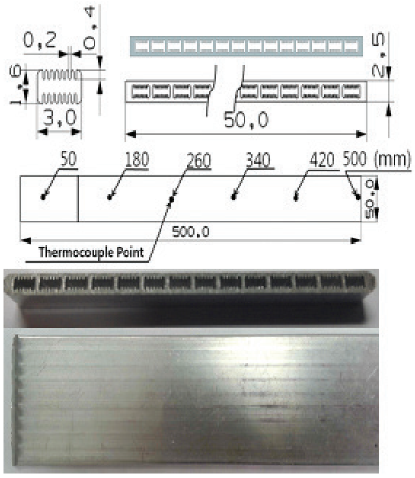


Figure 2. Drawing of the specimen and photo of the finished product (Unit: mm).

Next, to verify the performance of the heatpipe, an experimental device was prepared as shown in Figure 3. The heating source was water heated with a heat place, with an error not exceeding 0.5°C. Testing was performed changing the temperature of the heated water from 80°C to 90°C then 100°C.

So as to apply an even heat source to the evaporator side, 100mm at the end of the specimen was placed in water kept at a constant temperature and heated. Japanese YOKOGAWA DA100-13-1F was used to analyze and measure temperature distribution. K-type thermocouples (Ø1.0) were attached on the surface of the outer wall of the pipe on each of the points indicated in the cross-sectional drawing of Figure 2 to measure temperature.

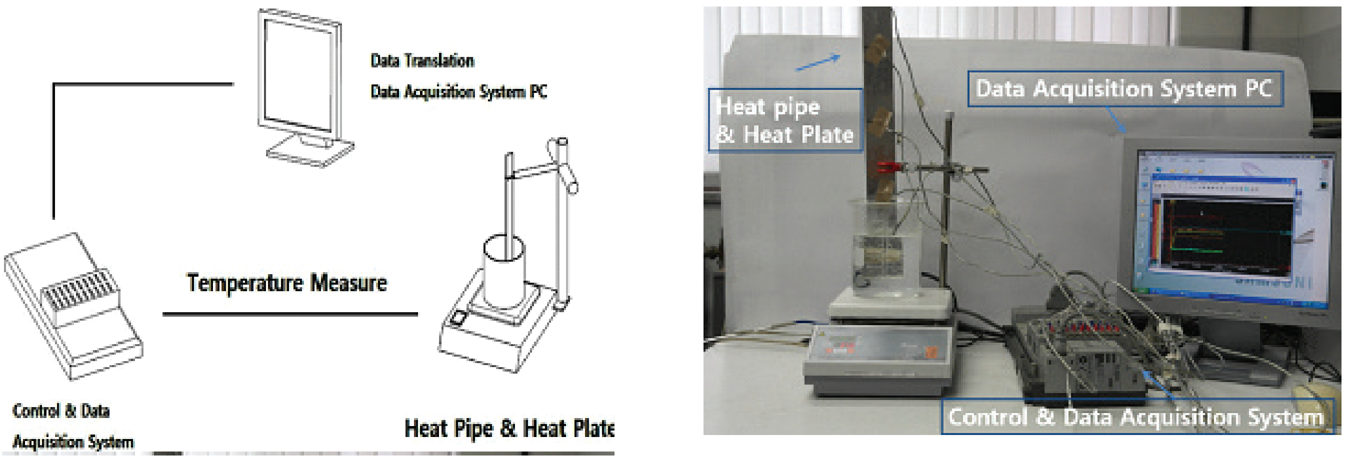
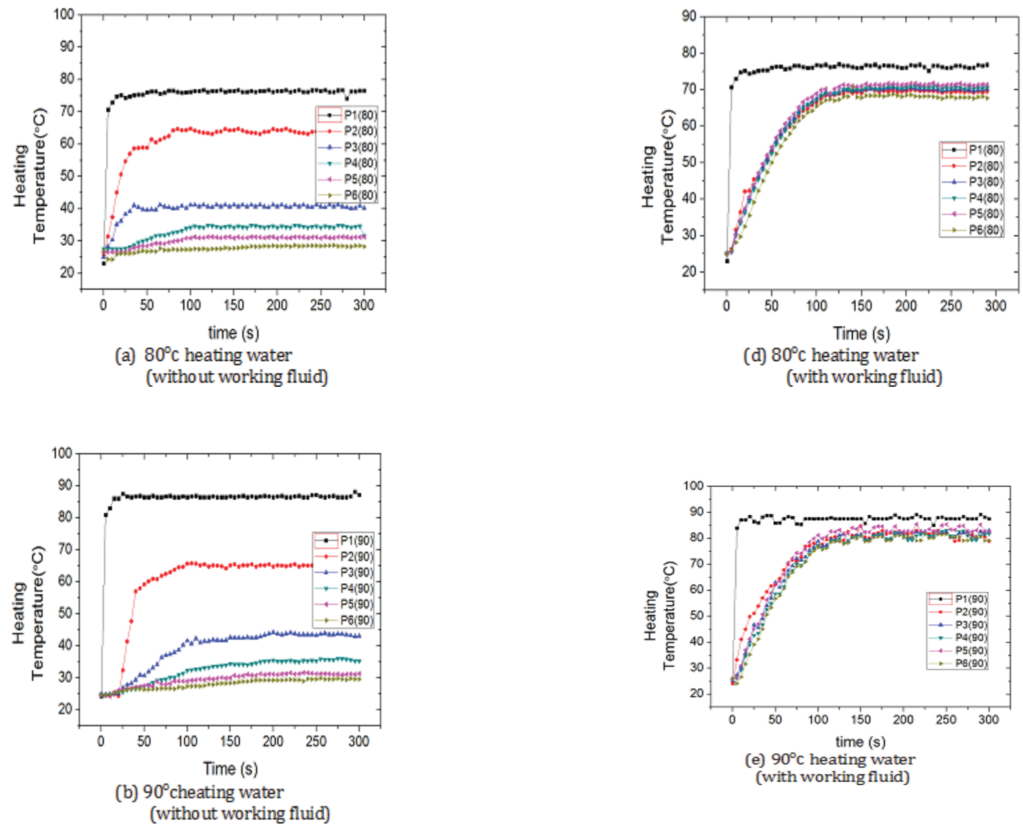


Figure 3. Composition of the experimental device and photo of actual experiment.

3. Results of the Experiment and Discussion



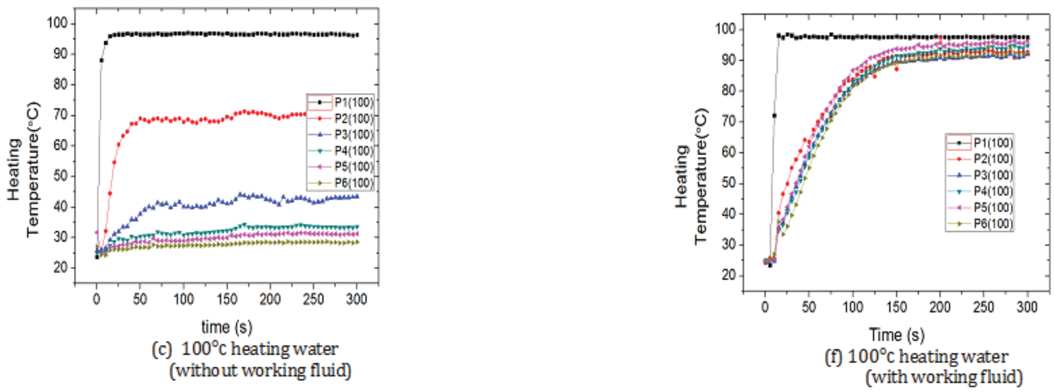


Figure 4. Specimen temperature distribution according to changes in heating temp (with working fluid vs. without).

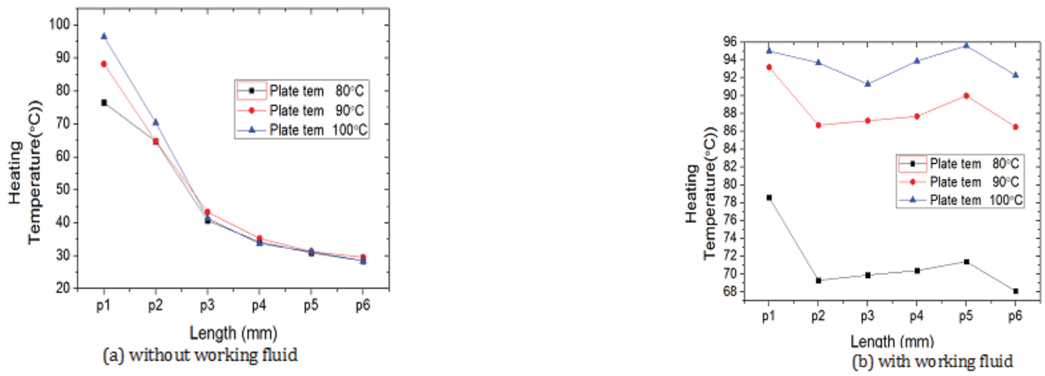


Figure 5. Temperature of the specimen according to distance.

Figure 4 shows the temperature change distribution graphs for each point according to the presence and absence of the fluid injected inside the specimen. Figure 4(a), (b) and (c) show the specimen without the working fluid injected inside, and Figure 4(d), (e) and (f) show the specimen with the working fluid injected. First, analyzing Figure 4(a) where the heat source was heated to 80°c, the temperature at point p1, where the temperature of the surface of the specimen inside the heating water is measured, rose sharply within

2 to 3 seconds of being placed in the water. The temperature stayed constant, with a 3~4°c difference from the 80°c water heating source. The temperature changes at the other points were compared to point p1 as follows. First, as for p1,

80mm away from the surface of the heating water, the temperature rose rapidly to around 60°c within 40 seconds, then rose slowly thereafter, maintaining a constant temperature of around 65°c from 80 seconds onward. Next, from point p3, the temperature maintained decreased as the distance from the heating source was increased, maintaining 30°c at point p3. Therefore it was shown that the heat was not well transferred to the end. Similar results were obtained for Figure 4(b) and 4(c), where the heating source was respectively at 90°c and 100°c.

Next, Figure 5(d) shows Figure 4(a) with the working fluid injected inside the pipe. From 130 seconds onward, the temperature is maintained almost constant. A temperature of 65-70°c was maintained from p2 to p3. This confirmed that thermal energy was very rapidly and stably being transferred over a long distance. As we can notice, the obtained result was significantly different from the result of Figure 4(a), and good heat transfer results were achieved. Similar results have been obtained for Figure 4(e) and (f), with the working fluid injected. The results for specimen (f) where the heating water has been heated to 100°c showed the most stable and effective heat transfer.

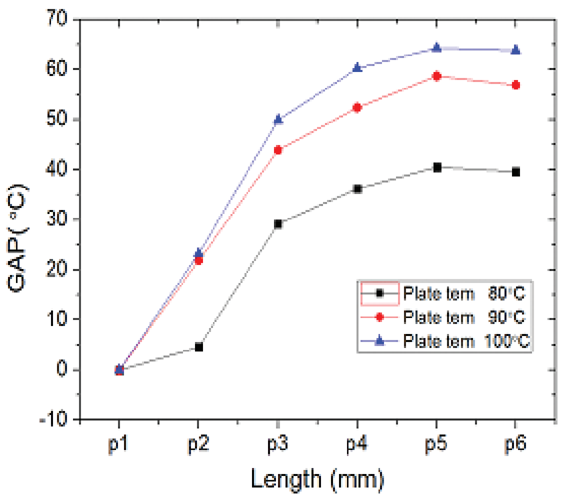


Figure 6. Gap between temperatures with and without working fluid at each point.

Lastly, Figure 6 shows graphs for each point showing the temperature gap between the specimen with the working fluid charged and the specimen without the working fluid. A large temperature difference according to the presence or absence of the nanofluid can be seen. Whereas for p1, which is inside the heating source, the difference is not large, a large difference is evident from point p2 onward. The temperature at p2 with the nanofluid and an 80°c heat source has a gap of around 2.9°c from the result without nanofluid, but the temperature difference is around 30°c from p3 onward, and around 40°c at p5. As for a high heating source temperature of 100°c, the temperature gap for p4 and p5 was very large, up to around 60°c. In conclusion, this temperature gap represents the energy thermally transferred purely by the working fluid, excluding the thermal transfer of the plate, and the specimen in this study was shown to have quite excellent heat transfer performance.

4. Conclusion

This study proposed a heatpipe consisting of multiple rectangular channels with small grooves in their inner surface. The heat transfer effect of this product was determined experimentally, and the following conclusions were drawn.

First, the specimen charged with the working fluid maintained an even temperature distribution throughout, relative to the specimen that was not charged with the working fluid. It was seen that thermal energy was stably and rapidly transferred over a long distance, affected little by distance. The results when the heating source was at 100°c showed the most stable heat transfer and the best heat transfer effect.

Next, testing the change in temperature of the specimen according to distance from the heat source placed at the end of the specimen showed that without the working fluid, the temperature dropped rapidly as the distance from the heating source increased. On the other hand, for the specimen with the working fluid injected, considerable heat is transferred to the end, and it was seen that applying a heating source at 100°c, at least 90% of the temperature of the heating source was transferred.

Lastly, comparing the change in temperature of the specimen according to distance from the heat source placed at the end of the specimen, the temperature gap when the heating source was at 100°c was very large, up to 60°c.

5. Acknowledgement

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