Development of Copper Short Fiber Wick Heat-pipe for Data Center

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ABSTRACT The development of a server for a data center with a further improvement in performance and a higher heat generation density and a higher calorific value of a processing device is progressing. Furukawa Electric has analyzed quantitatively the pressure drop in the heat pipe, and has clarified that the maximum heat transfer rate is improved drastically with a cover structure in the groove tube, and has developed a heat pipe with a structure using a copper short fiber as the cover. We would like to introduce the technology regarding the copper short fiber wick heat pipe in this paper.

1. INTRODUCTION

Recently a server for a data center with a further improvement in performance, due to the improvement in higher heat generation density and in higher calorific value of a processing device is progressing. Since a heatsink corresponding to the higher heat generation density and higher calorific value is requested, Furukawa Electric has already developed the heat pipe typed heatsink, and which has been implemented as the heatsink for data center requesting higher radiation performance.

Figure 1 shows an example of the heatsink for the data center. As further trend for development of the server, the heat generation will be more increasing without changing housing shape, and we think that the increasing of a maximum heat transfer rate per any one heat pipe is needed because of the limited space for installing a heat pipe and thus realizing a cost reduction.

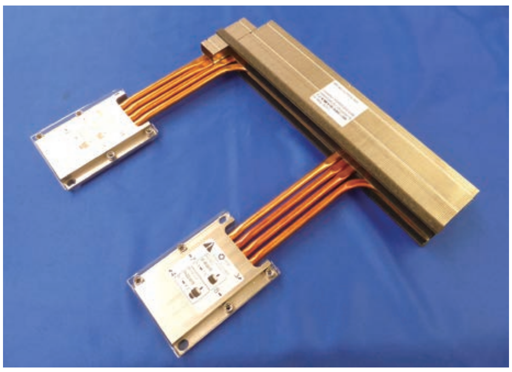

Figure 1 External view of a heat sink for data center.

As for Furukawa's heat sink of heat pipe for data center, a composite sintered heat pipe, which is a heat pipe with a sintered copper powder in the heat input portion of a groove tube, shown in Figure 2, is used. The composite sintered heat pipe controls the pressure drop of the liquid flow in condensation and insulation portion of the groove, and the reflux of liquid is improved by the high capillary pressure of the sintered copper powder of the evaporation portion.

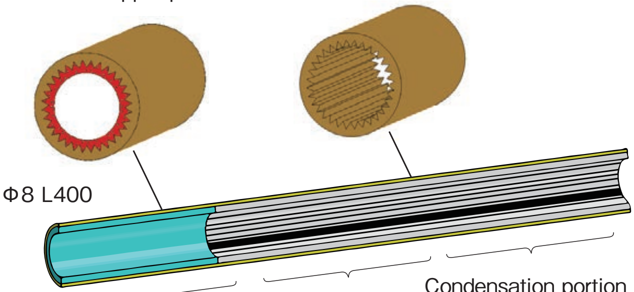

Figure 2 Structure of a composite sintered heat pipe.

The author has discovered that it is effective to control the pressure drop of the counter flow for improving the maximum heat transfer rate based on quantitatively analyzing the capillary pressure of the wick installed in the composite sintered heat pipe and the pressure drop of the working fluid of the heat pipe during circulation. The solution has been applied to the current composite sintered heat pipe in order to develop the heat pipe with the improved maximum heat transfer rate. It was confirmed that the copper short fiber installed on the inside the groove is effective to control the counter flow pressure drop.

In this paper, we report the influence of the copper short fiber wick on the pressure drop of the counter flow.

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2. THE INSIDE STRUCTURE OF THE COMPOSITE SINTERED HEAT PIPE

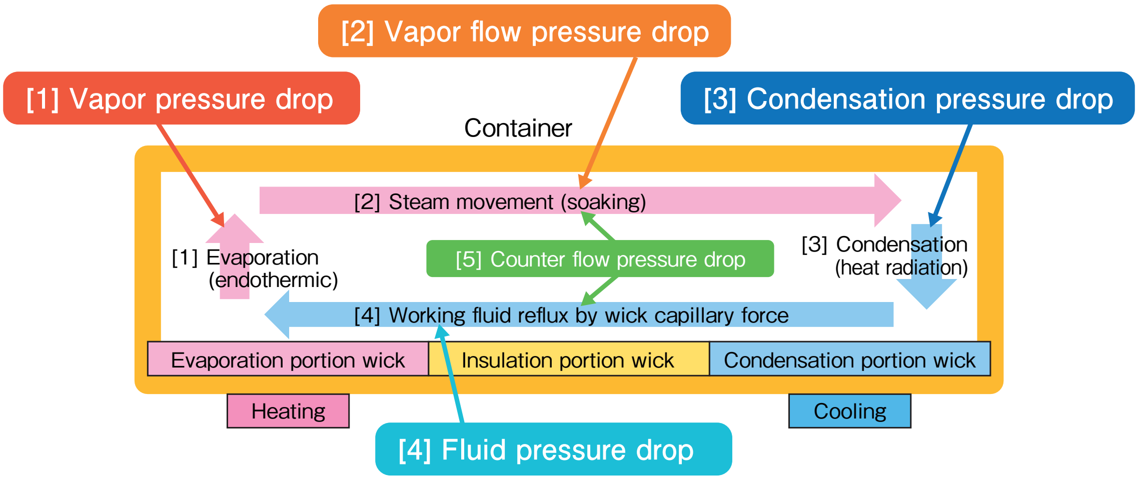
In the heat pipe, as shown in Figure 3, [1] the state of the working fluid is changed from liquid to vapor at the evaporation portion (the heat input portion), [2] flowing from evaporation portion to the condensation portion (the cooling portion), [3] changing the state from vapor to liquid at the condensation portion, [4] returning from the condensation portion to evaporation portion by the capillary pressure. In this way, the circulation of the working fluid is moving between the evaporation portion and the condensation portion, and the heat transfer is occurring between the evaporation portion and the condensation portion in the tubular container.

In order to plan to maximize the heat transfer rate, we quantitatively analyzed the capillary pressure and the pressure drop of evaporation, vapor flow, condensation and liquid flow during the liquid circulation for the current composite sintered heat pipe. The maximum heat transfer rate was determined by the equation of balance between the capillary pressure of the wick and the pressure drop on the circulation of liquid. According to the result of calculations, since the performance of the current composite sintered heat pipe did not reach to the expected value with the pressure balance equation, another pressure drop factor not including the above calculation is assumed. We presumed the pressure drop, which was due to the flow liquid scattering in the groove by vapor, the pressure drop of counter flow, and we evaluated the extended effect of each of pressure drops on the maximum heat transfer rate based on the following equation,

Capillary force = [1] vapor pressure drop + [2] vapor flow pressure drop + [3] condensation pressure drop + [4] liquid flow pressure drop + [5] counter flow pressure drop

The result is shown in Figure 4.

If the counter flow pressure drop can be eliminated, the maximum heat transfer rate will be expected to be twice of the current heat pipe, as shown in Figure 5 and we considered this method to eliminate the pressure drop for the counter flow.



Formula for determining the maximum heat transfer rate
Capillary force = [1] Evaporation pressure drop + [2] Vapor flow pressure drop + [3] Condensation pressure drop + [4] Liquid flow pressure drop + [5] Counter flow pressure drop

Figure 3 Formula for determining the maximum heat transfer rate.

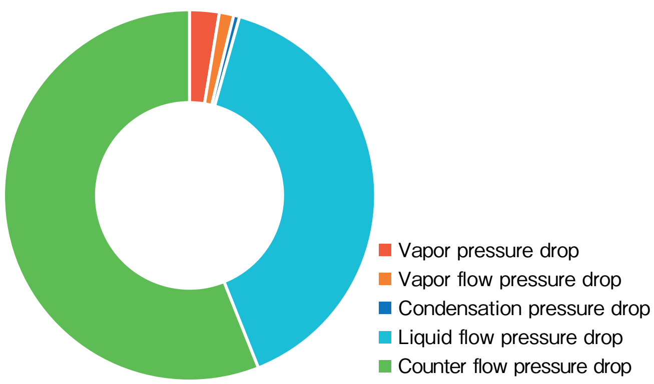


Figure 4 Calculation result of pressure drop.

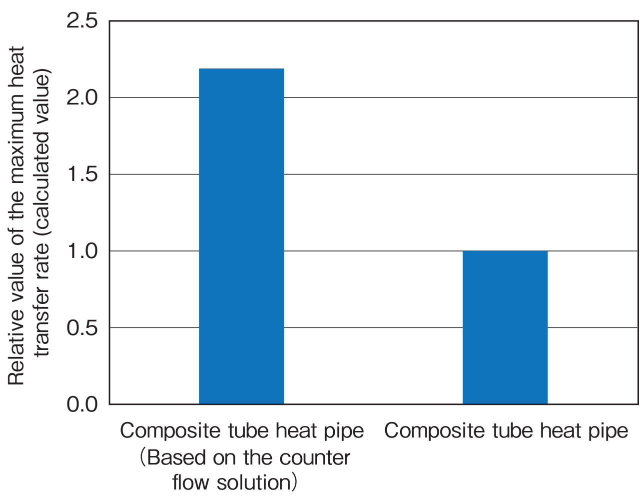


Figure 5 Prediction of the maximum heat transfer rate based on the counter flow solution.

We would like to explain the counter flow pressure drop again. The groove portion makes the liquid return from the condensation portion to the evaporation portion for the composite sintered heat pipe. However since the liquid flow is opposite to the vapor flow, it is difficult for the liquid to return by the vapor repelling. This phenomenon is called the counter flow pressure drop, also known as the counter pressure drop.

We think that based on the cover structure attached in the aperture of the groove portion, the gas-liquid separation between the vapor and liquid is accelerated and the counter flow is prevented from occurrence.

We checked whether the copper short fiber attached in the aperture of the groove is functioning as the cover.

3. EXPERIMENTAL METHOD

3.1 Manufacturing of Experimental Heat Pipe

The copper short fiber sintered body, which does not completely occupy the space of the groove, was loaded in the copper groove tube of a ϕ8 mm of diameter and a total length of 400 mm, and the evaporation portion and the insulation portion was formed, as shown in Figure 6. Water was injected as the working fluid and the experimental heat pipe was manufactured.

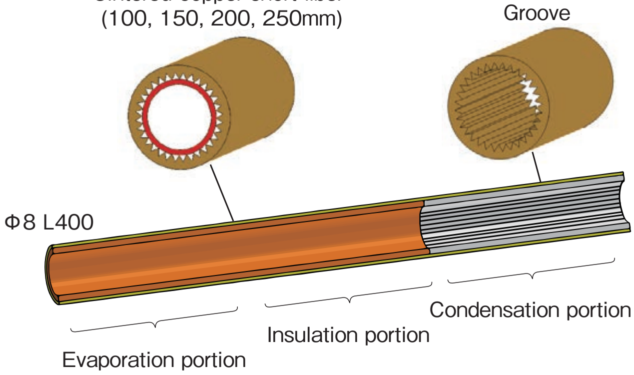


Figure 6 Structure of the copper short fiber heat pipe.

The length of sintered copper short fiber was 100, 150, 200 and 250 mm in the longitudinal direction of the heat pipe. The purpose of the length of sintered body of 250 mm was for checking of the effect on the condensation portion.

In order to clarify the effect of the counter flow, a heat pipe with the copper powder which can enter the space of the groove was manufactured instead of the copper short fiber. The length of sintered copper powder was 60, 100,150 and 200 mm in the longitudinal direction of the heat pipe.

Furthermore, in order to check the effect of combination of the evaporation portion structure, the heat pipe with the combination of a copper powder and a copper short fiber was manufactured, shown in Figure 7. In this case, the length of the evaporation portion of the sintered copper and the length of the insulation portion of the sintered copper short fiber are 60 mm and 190 mm respectively.

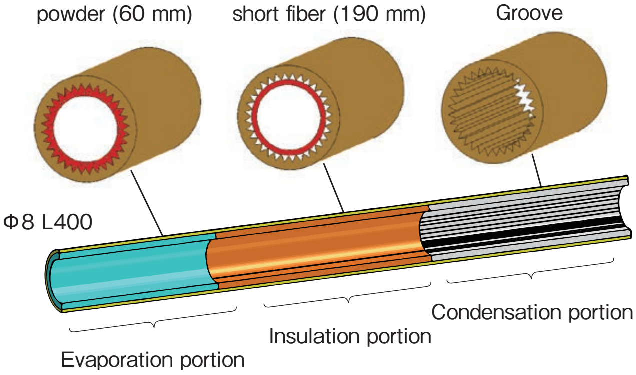


Figure 7 Structure of the combination of a copper powder and a copper short fiber heat pipe.

3.2 Heat Pipe Measurement Condition

As shown in Figure 8, the grease applied on the evaporation portion of heat pipe and the half cut copper heater block was loaded there in a longitudinal length of 40 mm. Heating of the heater block was done with a heat connection of the cartridge heater through grease.

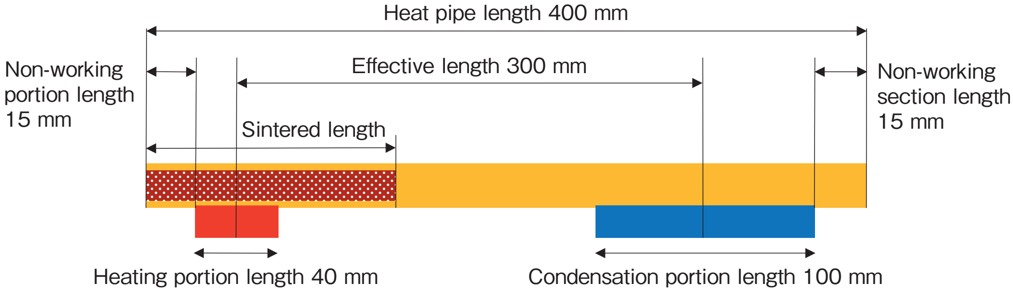


Figure 8 Heat pipe measurement system.

As for the condensation portion side, after grease is applied on the heat pipe, the cool block of the aluminum was loaded there in a longitudinal direction of 100 mm. The length of the non-working section of the condensation portion of the heat pipe was 15mm as well as the evaporation portion. The cooling block was cooled by connecting of water cooling jacket of copper through grease.

The horizontal installation arrangement was checked with the goniometer and the measurement was done at constant operating temperature of 50°C. The maximum heat transfer rate is defined as the heat input just before the rapid increasing of heat resistance obtained by the temperature difference between the heater block and the insulation portion of the heat pipe.

4. THE RESULTS OF MEASUREMENT

The results of measurement for each of heat pipes are shown in Figure 9. As for the sintered copper short fiber heat pipe, the maximum heat transfer rate was increasing along with the increase of the length of the sintered fiber in the range of 100 mm to 200 mm. The result shows that the copper short fiber functions the role of cover as predicted, and the pressure drop caused by counter flow was decreasing. In the case of the length of 250 mm, the maximum heat transfer rate tended not to improve because the effect on the condensation portion has appeared.

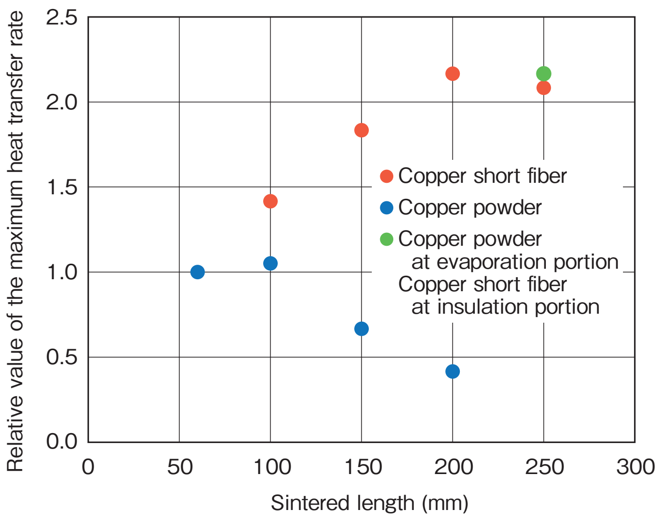


Figure 9 Heat pipe measurement results on changing of sintered lengths.

As for the sintered copper powder heat pipe, on the contrary, the maximum heat transfer rate is decreasing along with the increase of the sintered length in the range of 100 mm to 200 mm. According to our thinking, since the sintered copper powder completely entered in the space of groove, the pressure drop of the liquid flow through the sintered body was increasing along with the increase of the length of the sintered copper, and the maximum heat transfer rate was decreased.

Comparing the sintered copper powder length of 60 mm with 100 mm, the maximum heat transfer rate for 60 mm was smaller than 100 mm. In this area, increasing of the pressure drop of the counter flow might be more influenced than the decreasing of pressure drop based on shortening of the sintered copper powder length.

Heat pipe with only sintered copper fiber had a large thermal resistance on low heat input and there is the practical issue of the evaporation portion structure. The heat pipe with the combination of the copper powder (sintered length of 60 mm) and the copper short fiber (sintered length of 190 mm) was measured. Even though the thermal resistance of the heat pipe was not different from copper powder only heat pipe, the maximum heat transfer rate was almost same as the heat pipe with the length of sintered copper short fiber of 250 mm and improved twice over the only sintered copper powder of 60 mm length, as shown in Figure 9. The maximum heat transfer rate was almost reconciling with the expected value from calculations.

The above result shows that the trial cover of the copper short fiber has a space between the groove portion and the copper short fiber and functions as a cover as expected.

5. CONCLUSION

Based on quantitatively analyzing the capillary pressure of the wick installed in the composite sintered heat pipe and the pressure drop during circulation of the working fluid of the heat pipe, we confirmed that the elimination of the pressure drop of the counter flow was effective in improving the maximum heat transfer rate, and we developed the heat pipe of a larger maximum heat transfer rate based on the above solution.

It is effective on eliminating the pressure drop of the counter flow for the copper short fiber to install at the aperture of groove as the cover and we found that the cover needs the minimum length required.

Here after, as for the structure of the cover, along with keeping the control for the pressure drop of the counter flow, we would like to pursue the most suitable structure, based on the cost reduction and improvement of the workability of the installation for the sintered copper short fiber.

In response to upgrading needs furthermore, we would like to improve the performance of the heat pipe and contribute to the better function of electro appliances implementing this advanced heat pipe.