Electronics Cooling Using the Porous Metallic Materials

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Abstract

The paper presents some results regarding the obtaining of some copper heat pipes with a porous copper internal layer for electronic components cooling. The heat pipes were realized by sintering of spherical copper powders of 90 ÷ 125 µm size directly on the internal side of a copper pipe of 18 mm in diameter. The obtained pipes were then brazed in order to obtain a heat pipe of 0.5 m in length. After that, the heat pipe was sealed and filled with a small quantity of distilled water as working fluid. To establish the total heat transport coefficient and the thermal flow transferred at the evaporator, some external devices were realized to allow the heating of the evaporator and the cooling of the condenser. Water heat pipes are explored in the intermediate temperature range of 303 up to 500 K. Test data are reported for copper water heat pipe, which was tested under different orientations. The obtained results show that the water heat pipe has a good thermal transfer performance in the temperatures range between 345 and 463 K.

Keywords : porous metallic materials, heat pipe, electronic cooling, total heat transfer coefficient

1. Introduction

All electronic components, from microprocessors to high power converters, generate heat and the rejection of this heat is necessary for their optimum and reliable operation. As electronic design allows higher throughput in smaller packages, dissipating the heat loads becomes a critical design factor. Many of electronic devices require cooling beyond the capability of standard metallic heat sinks. The heat pipes met this need and they rapidly became a main stream thermal management tool.

A heat pipe is a passive, two-phase sealed device that rapidly transports large amounts of heat with a minimal temperature drop [1]. The operational temperature range of the given application determines the type of the heat pipe technology to be used. The temperature range of 400 – 700 K is defined as intermediate in the aim of the heat pipe technology classification [2].

Ambient temperature heat pipe technologies in the temperature range of 200 to 400 K have been quite advanced due to their wide range applications in commercial electronic cooling and others, with copper water heat pipes are the most widely used.

The recommended maximum temperature for the water heat pipe operation is about 400 K because life test data are available only up to this temperature.

While it is possible to use water as the heat pipe working fluid possibly up to 550 K, test data have not been available at higher temperatures range [3].

The paper presents our research results regarding the obtaining of some isotropic porous copper materials by sintering directly on the internal side of a copper pipe of 18 mm diameter, in order to obtain a water heat pipe for cooling of electronic components.

2. Experimental and Results

The porous copper layer realized from a spherical copper powder, and applied on the internal side of some copper pipes of 18 and respectively 15 mm in diameter, was sintered in argon at the temperature of 950 °C. The length of these pipes having the porous copper material on the internal wall was chosen between 74 and 200 mm depending on the sintering conditions. The thickness of the porous layer was chosen of 1 mm, the same with those of the copper pipes. The porous material characteristics are presented by the authors in other paper [4]. These pipes were then taper welded using a Cu-Sn-Ag alloy. After that the obtained pipe having a length of 325 mm was closed at the ends with two lids (both of them soldered with the same solder alloy). A lid was soldered after the distilled water was introduced into the pipe. This lid was endowed with a mounting hole for the manometer mounting after removal of the air inside the pipe. The water quantity was of 30 g. Figure 1 shows the general view of the copper pipes with the porous copper layer on the internal side of the pipe and the main sizes and some adopted characteristics for the obtained thermal pipes are presented in table 1

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Table 1. sizes and some adopted characteristics of the obtained thermal pipes.

Characteristics	Pipe 1	Pipe 2
External diameter of pipe, $D_{e1,2}$ [m]	0.018	0.015
Internal diameter of pipe, $D_{i1,2}$ [m]	0.016	0.013
Internal diameter of porous layer, $D_{v1,2}$ [m]	0.014	0.011
Thickness of pipe = thickness of porous layer, $\delta_{1,2}$ [m]	0.001	0.001
Medium porosity of the porous layer, $P_{1,2}$ [%]	54	56.5
Spherical copper powders size, d [μm]	90 ÷ 125	90 ÷ 125
Total length, L [m]	0.325	0.325
Evaporator length = condenser length, $L_{ev} = L_{cond}$ [m]	0.130	0.130
Pipe vacuum pressure, P_i [torr]	10^{-3}	10^{-3}

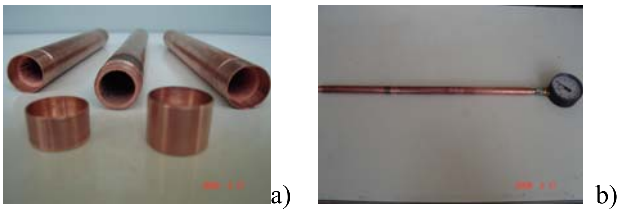
a) b)

Fig. 1. Copper pipes with a porous copper internal layer:a) pipe parts and adapting pieces, b) assembled heat pipe

Since the heat pipe is a sealed device, no measurements can be made inside the pipe. The external testing of the heat pipe is simple in conception. The evaporator region is heated, the condenser region is cooled, and the heat transfer rate and the temperatures are computational deduced by measuring of the thermocouple voltage at the evaporator and by measuring of the internal pressure with a manometer.

In our experiments the goal was to establish the maximum operational temperature of the water heat pipe up to 345 K and to determine the total heat transfer coefficients at the evaporator and the thermal flow transferred to the evaporator. Figure 2 shows the schedule of the experimental setup.

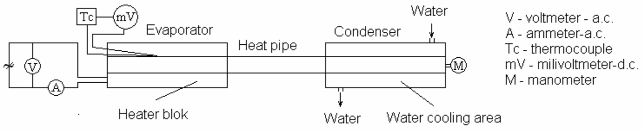

Fig. 2. The schedule of the experimental setup for estimating the thermal transfer performance of a water heat pipe.

For all the used power supply, the thermal pipe achieved the steady state conditions in a time period of fifteen minutes and with the increasing of the power supply the curves moved to the left. With the increasing of the voltage the transferred thermal flow at the evaporator increases. (Fig. 3a)

Table 2. Measured parameter values.

U V	I A	R Ω	P W	U_t mV	T_1 °C	P atm	T_2 °C	k W/m^2K
Water flow under gravity aiding orientation								
32.35	**0.34**	94.5	**11**	2.998	**72**	0.981	**70**	**748.29**
44.68	**0.47**	94.5	**21**	4.608	**107**	1.156	**105**	**1428.57**
54.6	**0.577**	94.5	**31.5**	11.569	**142**	3.615	**140**	**2142.86**
68	0.72	94.5	**49**	14.399	**192**	12.56	**190**	**3333.33**
Water flow under gravity opposing orientation								
32.35	**0.34**	94.5	**10**	2.953	**70**	0.981	**69**	**680.27**
44.68	**0.47**	94.5	**20**	4.561	**105**	1.156	**105**	**1360.54**
54.6	**0.577**	94.5	**29**	6.206	**140**	3.584	**139**	**1972.79**

The orientation does not has a significant impact on the heat pipe performance under forced convection water cooling. The heat transfer continues to increase with the operational temperature increasing (Fig. 3b).

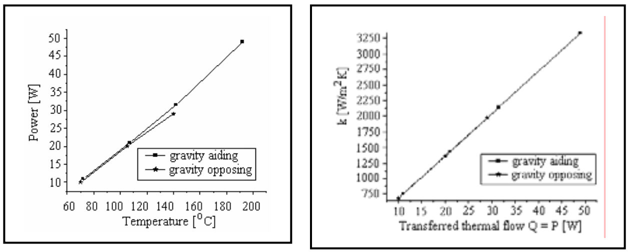

Fig. 3. a) The transferred thermal flow at the evaporator as a function of operating temperature and heat pipe orientation b) Total thermal transfer coefficient at the evaporator as a function of transferred thermal flow

3. Summary

Increasing of thermal transfer surface area can be realized by increasing of the specific surface area of the porous layer.

The thermal flow that can be transferred, depends on the voltage supply at the evaporator, the effective specific surface area, the working fluids and their thermo-physical properties and the type of condenser cooling. All these characteristics command the performance of the thermal transfer of the heat pipe.

4. References

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