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INFLUENCE OF TEMPERATURE DURING MANUFACTURE OF THE HEAT PIPE FILLED WITH FLUID FC-72 ON ITS FUNCTION

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ABSTRACT

Heat pipes transfer heat at a minimum temperature difference between evaporating and condensing phase. Operating temperature of heat pipe is determined by working fluid and vacuum achieved during production. This paper is focused on determining the effect of initial temperature of ambient air to the performance characteristics of produced heat pipes. In general, a decrease in pressure decreases the boiling liquid. Based on this it can be presumed that achieving a lower temperature during production of heat pipe, the lower vacuum, while the boiling point working fluid while increasing ability to heat transport.

INTRODUCTION

At present there are a number of potential applications where heat pipes bring interesting effects, especially in terms of reliability of cooling some temperature exposed components and equipment. Excellent transport properties for heat dissipation can be used in a variety of technical applications of cooling, in particular the cooling of electrical components and equipment.

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1. HEAT PIPE AND ITS PROPERTY

Heat pipe is a device using heat transfer from warmer place to a place of lower temperature. Heat pipes operate on the principle of gravitational forces on the working substance (condensate flows into the evaporating part of the walls of the pipe by gravity). The heat flow is dependent on the thermal resistance of the liquid film on the wall of condensation part. Correct operation is conditioned upon such dosage amount of working substance, in the range of operating parameters, there is no lack of wetting the surface of the evaporation part and thus decrease of performance. Conversely large excess liquid in the evaporation part leads of the boiling and to the development of large steam bubbles and formation stroke [1]. Apart from heat pipes other devices that use phase change are investigated [2], [3].

In a variety of experiments, it was found out that although the heat pipes made of the same materials were used and the same amount and types of process materials, they have different transport capabilities. One possible reason could be a different temperature during filling and exhausting heat pipes. This presumption is confirmed by experimental measurements which used three working materials at three operating temperatures. As working materials water, ethanol and Fluorinert FC72 were used. As the most common working fluid ethyl alcohol is used for its application and at temperatures below 0°C. Water compared to ethanol has better thermal capacity. Fluorinert was used to ascertain its characteristics as a working medium. This fluid is electrically non-conductive, and its use should be of great value especially in electrical equipment where there is the risk to conduct the electrical current in the event of failure of the cooling device, which is undesirable.

2. PROCEDURE FOR PREDUCTION AND MEASUREMENTS OF HEAT PIPES AT DIFFERENT FILLING TEMPEATURES

Heat, thermal and hydraulic characteristics of heat pipe are determined by transmission phenomena through evaporation and condensation, and the heat transfer medium in the vapor flow and the liquid phase in the thermal tube. Heat pipes are usually in cylindrical shape, because in addition readily available materials (pipes necessary dimensions), this shape also provides advantages in terms of thermal and strength parameters. Different shapes can be found in practice, as well as the heat pipe with a flat rectangular cross-section, triangular or other cross-section. When making heat pipes, it is necessary to follow the procedure of certain operations. The way of implementation is then dependent on the technological possibilities of the workplace [1]. For production heat pipe copper tube has been used of length 500 mm, internal diameter 10 mm and 2 mm wall thickness. Thereafter copper capillary was used with an outer diameter of 1,3 mm and an internal diameter of 1 mm and copper pipes with diameter of 13 mm and 1 mm wall thickness. These parts were cleaned mechanically and chemically. The produced heat pipe was cleaned and dried again. After production the leakage test was performed and heat pipes were ready for filling.

Experimental measurements were carried out on heat pipes in a vertical position (Fig. 1). Three measurements were carried out with various filling temperatures. Working fluids were charged in following temperatures: 20°C, 0°C, –20°C (Fig. 2). For the calculation of the transferred heat output of the heat pipe calorimeter is used. For calculation of transmitted power, the following parameters had to be determined: temperature difference of cooling water that flows through the condenser, scanned on entry and exit from the cooler, with a certain mass flow rate and specific heat capacity of water. Transmitted heat power is:

$$Q = m c_p \Delta t_i \tag{1}$$

where: Q – mean steady-state power (W), m – mass flow rate of cool water (kgs^{-1}), c_p – specific heat capacity of water at constant pressure ($Jkg^{-1}K^{-1}$), Δt_i – contrast medium temperature of the cooling water in the steady state (°C). Unlike medium temperature cooling water is calculated as $\Delta t_i = t_{v2} - t_{v1}$, where Δt_i – difference medium temperature of the cooling water in steady state (°C), t_{v2} – value of the outlet temperature of cooling water (°C), t_{v1} – cooling water temperature (°C).

To the condensing part of the heat pipes heat power 550W was approximately supplied and the temperature of the heating medium was kept at 80°C. On the condensation part water cooler was mounted, which ensured precise measurement of heat removal. In order to determine the temperature difference, thermocouples were placed at the inlet and outlet of cooler. The amount of coolant was scanned by ultrasonic flow KAMSTRUP. On the basis of the measurements graphs of temperatures were constructed, depending on the type of heat pipe and on the conditions during the manufacture of the pipe itself. The equipment was also used by the researchers at University of Zilina as in [4–10].

From the measured values and the graph it is visible that at the filling temperature of 20°C, 0°C and –20°C, the transmitted power of the heat pipe changes only slightly. Based on this fact, we can argue that the Fluorinert FC72 as the working substance is poorly affected by the ambient temperature and therefore do not have to impose additional requirements for the production of heat pipes.

Fig. 1. Heat pipe in an ice bath to 0°C and cooling thermostat to 20°C

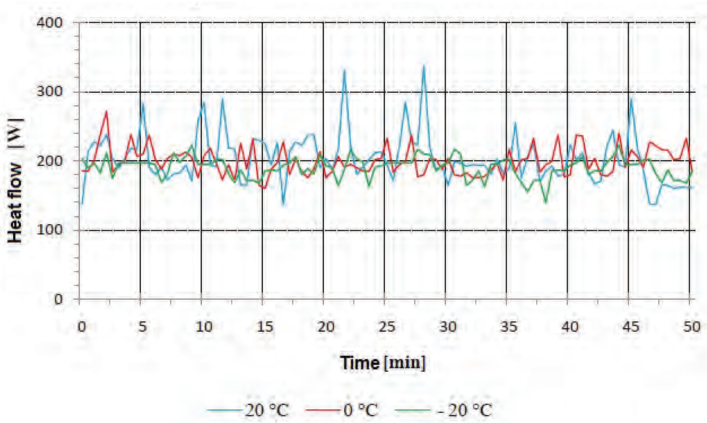

Fig. 2. Chart transferred during the performance of individual heat pipes produced at ambient temperature 0°C.

3. EXPERIMENTAL MEASUREMENTS OF GRAVITATIONAL HEAT PIPES PRODUCED USING 20°C AT DIFFERENT ANGLES

Measuring heat pipe at different angles was performed with Fluorinert FC 72 by volume of 20% of the total inner volume of the heat pipe. Mass of empty heat pipe was 883,1 g, while of the full heat pipe 902,798 g. Mass of working fluid in amount of filling 20% of total volume of the heat pipe was 19,698 g

Experimental measurement was carried out the same way as is described in the chapter 2 (Fig. 3). The difference was that in the determination of the performance, depending on the tilt angle measurements were taken at different angles of inclination from the vertical plane of 90° and the angle of 45 to 15° discreetly. This was carried out so that the heat pipe affix on the stand in a vertical plane an angle of 90° and electric water heater was turned on. When the water in the tank reached 80°C, the water supply and flow meter was turned on. Measuring equipment was connected to the laptop and heat pipe was placed under the defined angle in heated water. The program was launched in the laptop that records each temperature to be measured and the ambient temperature, inlet temperature, outlet temperature and the temperature in the tank with electric water heating. Every minute was recorded from the flow meter and flow of coolant – water. When the inlet and outlet temperatures on the heat pipe were stable, the measurements in the vertical plane was completed. Subsequently heat pipe was pulled out of the thermostat, dried, cooled and ready for the next measurement. These steps were repeated for all tests at the desired angle of the heat pipe.

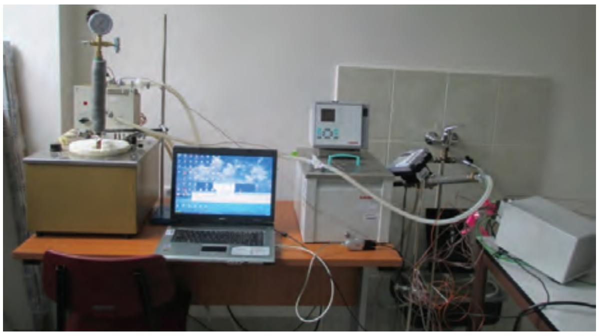

Fig. 3. Experimental device

Table 1. The calculated performance values of the average values of the individual temperatures for each position of the heat pipe

Tilt angle, °	Power, W	T_1Inlet, °C	T_2Outlet, °C
90	70,224	20,275	20,485
75	36,784	19,89	20
60	100,32	19,9	20,2
45	138,776	19,82	20,235

After all measurements the table was created with the results recorded in data logger. From the measured results average values of inlet and outlet temperature for each angle separately were calculated. The results of measured flow have been calculated to the average values. These calculated values were implemented to the calculations of heat pipe performances (1) at different angles of inclination. Based on the results, the values of performances at different angles were compared and the best performance of the heat pipe was determined. From the computed results table of performance was created (Tab. 1) for different angles. The average temperature of inlet and outlet water are presented in the graph (Fig. 4).

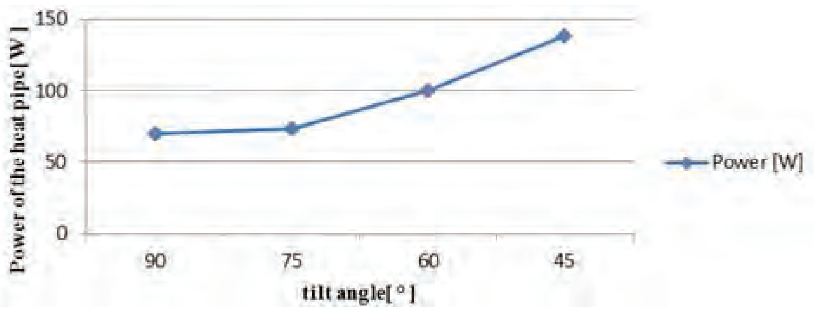

Fig. 4. Graph of the performance of the heat pipe from its position

4. CONCLUSIONS

Based on experimental measurements, it is possible to argue that the impact of ambient temperature has no significant effect on the transport properties of heat pipes with a working medium Fluorinert FC72. The difference between the heat pipes was approximately 20 W. The power of heat pipe at different angles of inclination was determined by experiments and calculations. With increasing tilt angle of the heat pipe, the performance increase, which was caused by better condensation run into the evaporating section of the heat pipe by gravity. This can be observed in the graphical display of calculated results (Fig. 3). The best performance of heat pipe was reached with a working fluid Fluorinert FC72 tilt angle of 55° and calculated value is 140,448 W.

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