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IMPACT OF THE MANUFACTURING CONDITIONS AND OPERATING POSITION ON HEAT TRANSPORT ABILITY OF THE HEAT PIPE FILLED WITH FLUORINERT FC-72

Abstract

Heat pipes are devices, which transfer heat at a minimum temperature difference between evaporating and condensing phase. Operating temperature of heat pipe is determined by the working fluid and vacuum achieved during its production. This paper is focused on the determining the effect of the initial temperature of the ambient air to the performance characteristics of produced heat pipes. In general, the 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, the boiling point of working fluid while increasing ability of heat transport in various positions.

Keywords: heat pipe, heat transport, cooling

1. Introduction

At present there are a number of potential applications where the use of 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. Because of constructing smaller and more powerful devices to be designed with appropriate cooling, transport properties of refrigeration equipment and systems for exhaust heat loss are necessary [1].

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 on such dosage of the amount of working substance, in the range of operating parameters that there is no lack of wetting the surface of the evaporation part and, thus, no 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 [2, 3].

In a variety of experimental measurements, 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 nevertheless heat pipes 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 at three different operating temperatures [4].

2. Heat pipe manufacturing

Heat, thermal and hydraulic characteristics of the heat pipe are determined by transmission phenomena through evaporation and condensation, and the heat transfer medium in the vapour 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 [5].

For experiment a special type heat pipe was produced with heat exchanger in condensation part and filling valve with vacuum-manometer at the top. This design allows to easily and quickly charge and discharge the heat pipe with working fluid and to measure transferred heat flux from evaporator to the condenser. Container of heat pipe was manufactured from copper material with a length of 500 mm, internal diameter of 13 mm, wall thickness 1 mm. The material before manufacturing was mechanically and chemically cleaned. The produced heat pipe was cleaned and dried again. After production procedure the leakage test was performed and produced heat pipes were ready for filling. The Fluorinert FC-72 was used as a working medium. This working fluid is electrically non-conductive, and its use should be of great value especially in electrical equipment where there is risk to conduct the electrical current in the event of failure of the cooling device, which is undesirable. In table 1 chemical-physical properties of the liquid Fluorinert FC-72 are given [6].

The volume of working medium charged in to heat pipe was 20% of total heat pipe volume. After filling the heat pipe was vacuumed and filled valve closed. Charging and vacuuming of heat pipe was carrying out at temperatures 20°C, 0°C, –20°C. After creating the required vacuum the heat pipe was ready to carry out the experiment. The experiment deal with influence of various temperature conditions at heat pipe manufacturing on the heat transfer ability.

Table 1. Chemical and physical properties of Fluorinert FC72 [7]

Properties	Description of properties
Optical properties	Clear, colourless
Average molecular weight	338
Boiling point (1atm)	56°C
Freezing point	–90°C
The estimated critical temperature	449K
The estimated critical pressure	1.8 x 106 Pa
Vapor pressure	30.9 x 106 Pa
Latent heat of evaporation	88 J/g
Liquid density	1680 kg/m^3
Kinematic viscosity	0.38 centistokes
Absolute viscosity	0.64 centipoise
Specific heat capacity	1100 J/(kgK)
Thermal conductivity	0.057 J(mK)
Expansion coefficient	0,00156°C
Surface tension	10 dynes/cm^2
Reflectance index	1.251
Solubility of water	10 ppmw
Solubility in water	<5 ppmw
Impact on the ozone layer	0
Dielectric strength	38 kV, 0.1" gap
Dielectric constant	1.75
Electrical resistance	1.0 x 1015 ohm/cm

Fig. 1. Heat pipe inserted into thermostat liquid bath of – 20°C

3. Experimental measurement and calculation of heat pipe thermal performance

The measurement of heat pipe thermal performance was carried out so that the heat pipe was affix on the measuring stand in a vertical position. The measuring unit consists of electric water heater, water cooler, flowmeter. Heat power supplied to the evaporating part of the heat pipes was 550 W and the temperature of the heating medium was kept at 80°C. Water cooler (heat exchanger) mounted on the condensation part ensured precise measurement of heat removal from evaporator to condenser. The amount of coolant was scanned by ultrasonic flowmeter. To determine the temperature difference of flowed coolant in the water cooler inlet and outlet temperatures were scanned by thermocouples placed at the inlet and outlet of water cooler. The scanned data of the ambient temperature, inlet temperature, outlet temperature, temperature in the tank with electric water heating and flow of coolant in the water cooler was launched in the laptop [8].

Fig. 2. Experimental device

The data from experimental measurement was used for the calculation of the transferred heat output of the heat pipe. For the calculation of the transmitted power by calorimetric method 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. This method describe [9, 10]. Transmitted heat power is determined by the relation:

$$Q = mc_p\Delta t_i \qquad (1)$$

where: Q – the mean steady-state power (W), m - mass flow rate of cooling 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 according to equation:

$$\Delta t_i = t_{v2} - t_{v1} \qquad (2)$$

where Δt_i - difference between medium temperatures of the cooling water in the steady state (°C), t_{v2} – value of the outlet temperature of cooling water (°C), t_{v1} – the flow of cooling water temperature (°C)

3.1. Impact of the operating conditions on heat transport ability of the heat pipe

Experimental measurements of heat pipe thermal performance were carried out at vertical position in the measuring device and with various manufacturing temperatures. On the basis of the measurements results graphs of temperatures were constructed, depending on the conditions during the manufacture of the pipe itself.

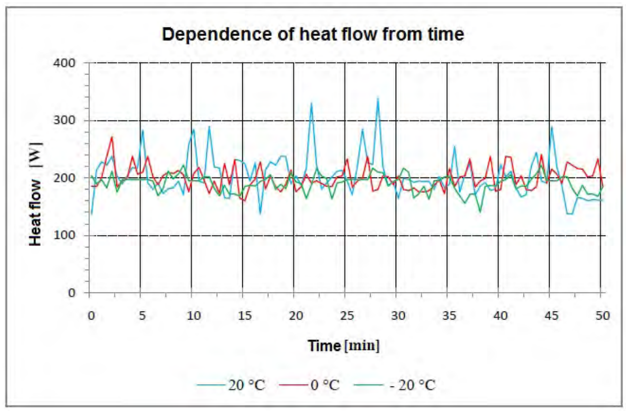

Fig. 3. Dependence of heat pipe flow from time

From the measured values and the graph it is shown that at the manufacturing 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.

3.2. Impact of the inclination angle on heat transport ability of the heat pipe

The determination of the heat pipe performance depending on the tilt angle was taken at different angles of inclination from the vertical plane of 90° to the angle of 45°. After all measurements the table with all the results recorded to the data logger was created. From the measured results average values of inlet and outlet temperature for each angle were calculated separately. The results of

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measured flow have been calculated to the average value. 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. The average temperatures of inlet and outlet water are presented in Table 2. From the computed results graph of performance for different angles was created and shown in Figure 4.

Table 2. Calculated performance and temperatures for each position of the heat pipe

Tilt angle [°]	Performance [W]	T_1 Inlet [°C]	T_2 Outlet [°C]
90	70.22	20.27	20.48
75	76.78	19.89	20.00
60	100.32	19.90	20.20
45	138.77	19.82	20.23

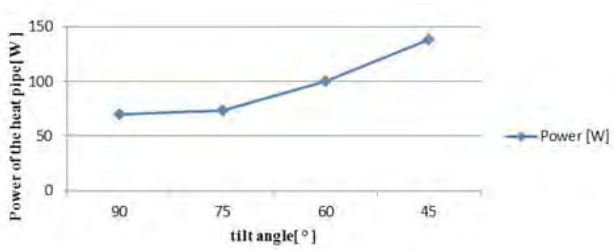

Fig. 4. Dependence of the heat pipe performance on the position

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 increases, 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. The best performance of heat pipe was reached with tilt angle of 45°.

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