The effect of operating parameters on the heat transfer in the heat pipe

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Abstract. Heat pipes are a good solution for temperature stabilization, for example, of microelectronics, because these kinds of systems are without any moving parts. Experimental research of the effect of operating parameters on the heat transfer in a cylindrical heat pipe has been conducted. The effect of the working fluid properties and the porous layer thickness on the heat flux and temperature difference in the heat pipe has been investigated. The temperature field of the heat pipe has been investigated using the IR-camera and K-type thermocouples. The data obtained by IR-camera and K-type thermocouples have been compared. It is demonstrated that the power transferred from the evaporator to the condenser is a linear function of the temperature difference between them.

1. Introduction
The heat pipe is a passive heat exchanger without moving parts, operating in a wide range of temperatures and heat fluxes. Due to their constructional advantages (flexibility, compactness), high heat transfer, and high efficiency without additional energy consumption, heat pipes have found an application in many areas from microelectronic cooling to space applications [1].

Heat pipes are capable to transfer large amounts of heat with insignificant temperature differences along their length, transform heat fluxes, create isothermal conditions over relatively large areas, operate in zero gravity, and within the temperature range from 4 K to 3000 K using an appropriate refrigerant.

Heat pipes are distinguished by their apparent simplicity of design, low weight, no moving parts, and complete autonomy. They don't require energy consumption for pumping the refrigerant.

According to the temperature range, heat pipes are divided into cryogenic (below 200 K), low-temperature (200-550 K), medium-temperature (550-750 K), and high-temperature (above 750 K). At the moment, many types of heat pipes have been developed, such as thermosyphon, pulsating heat pipe (PHP), loop heat pipe (LHP), microfinned heat pipe, etc.

Heat pipes up to 0.5 m long can have an equivalent thermal conductivity coefficient up to (3-10) · 10^4 W/(m·K) and above. The analysis shows that the mass per surface unit of traditional finned-tubular radiators falls within the range of (5-7) kg/m², and radiators based on heat pipes – (0.8-3) kg/m². Modern designs of radiators based on heat pipes allow up to 0.2 kW of heat to be removed into space from each square meter of the surface of the...
refrigerator-radiator at a temperature of 273 K.

The processes occurring inside the heat pipe are quite complex and still not clearly understood. Heat pipes are often investigated as closed objects, it is difficult to accurately determine the distribution of evaporation and condensation zones, and the available numerical models also do not allow this. Therefore, experimental studies of processes in a heat pipe will be conducting using the visualization method with an IR camera. The heat pipe regions with minimum and maximum temperatures, as well as temperature gradients, will be determined, which will allow understanding the processes taking place in the heat pipe at a new level.

2. Experimental setup

The paper considers the results of the experimental study of the effect of operating parameters on the heat transfer in a heat pipe. The copper heat pipes with a wall of Ø 6 x 0.5 mm, a length of 170 mm, and various thicknesses of the porous layer are explored. To obtain a porous layer, fine copper powder is used. Heat pipes are made by heating in a vacuum furnace. The porous layer thickness is ranged from 0.5 to 1.5 mm. The porosity of the wicks obtained is 40%. Water is used as a working fluid.

Figure 1 presents the schematic representation of the experimental setup. Heat is supplied to the evaporation zone by means of a ceramic ring heater. The condenser is cooled by a liquid heat exchanger, which receives water from the LOIP FT-211-25 thermostat. The experimental setup is equipped with a temperature-measuring system including the Titanium HD 570M infrared camera and K-type thermocouples [2].

![Figure 1. The schematic representation of the experimental setup.](image)

3. Results and discussion

The paper is dedicated to the investigation of the porous layer thickness effect on the heat flux and temperature difference in the heat pipe. The temperature field along the heat pipe is recorded using the IR camera. The temperature is measured using thermocouples in the evaporator and condenser zone and adiabatic part of the heat pipe. The temperature measurement results (Fig. 2), obtained employing an IR camera (Fig. 3) and thermocouples are compared.
Experiments were carried out to study the heat transport ability of the heat pipe for different heat fluxes (ranged from 10 to 40 W). The dependence of the heat flux on the temperature difference between the evaporator and the condenser for a porous layer thickness of 1.5 mm is determined experimentally (Fig. 4).
4. Conclusion
The manufactured heat pipe has demonstrated high thermal conductivity equal to 1.3 kW/m K. It is more than three times higher than that for copper rode with the same sizes.

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References
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