УДК 62.192:669.536.42

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RESOURCE CHARACTERISTICS AND TECHNOLOGICAL FEATURES OF LOW TEMPERATURE HEAT PIPES CREATION

The article presents the results of low-temperature heat pipes endurance experiments. The capillary structure of heat pipes has fiber construction. The research results have demonstrated, that heat pipes are reliable and durable devices. Thermal properties of pipes (thermal resistance) in their small series manufacture are within permissible deviations from the average values, typical for such devices.

Ключові слова: *heat pipes, resources, test, durability, reliability, methods*

The introduction. Two-phase heat exchange devices, designed on the basis of heat pipes (HP) and their varieties – thermosyphons (TS), are effective constructions, promising in their application for new types of chemical and energy equipment [1, 2]. HP and TS thermal properties are largely dependent on the physical and technical parameters and characteristics of capillary structure (CS). Metal-fiber capillary structures (MFCS), developed and tested at the Frantsevich Institute for Problems of Materials Science (IPMS), are one of the best types of CS known for today. MFCS for a number of thermal and hydrodynamic characteristics dominate by the CS, which are made of a grid and powder materials [3, 4]. The technological problems of MFCS production are mainly resolved. However, the question of stability of basic operational characteristics of TT, in particular, the values of their thermal resistance of conductivity R_{HP} and operability during long-term operation are studied insufficiently. The obtaining of such kind of experimental data and analysis of respective research results is actual scientific and technical challenge.

The aim of the work was to investigate the influence of time on thermal characteristics of low-temperature heat pipes, as well as to define thermal resistances of HP (R_{HP}) in limited-edition manufacturing of such heat-exchange devices.

The problem formulation. Using of heat pipes in industrial scale allows successfully solving a number of difficult problems of heat transfer, particularly in the difficult conditions of the new technics. Resourse tests of heat pipes allow in practic and highly evaluate the effectiveness of technology solutions.

Failure of heat pipes (sudden or projected) is usually caused by chemical incompatibility of HP structural materials with the working fluid-cooled reactors. The second factor causing failures HP is imperfect of production technologies and substandard technological operations in the pipes production process. During HP failure its elements are destroying (with a loss of tightness required), or chemical decomposition of the liquid-coolant occurs.

Distilled water is the most suitable liquid in a lot of practical problems to be solved when designing cooling systems of devices and equipment. Water is a non-toxic, has high thermal characteristics, fireproof and so on. The disadvantages are the high values of the pressure inside the HP (~1.5 MPa at 200 °C) and insufficient chemical compatibility with the majority of steels and alloys are based on steel.

Inside the heat pipe created with corrosion-resistant steel and filled with water, in result of the interaction of HP elements with the coolant takes place gradually destruction of the passive surface layer formed chemically adsorbed oxygen on the surface of the metal elements (HP housing and its capillary structure). In some areas of HP water or steam react electrochemically with the iron. Thus there is a small selection of Hydrogen exhalation. Hydrogen accumulates at the end of the HP condensation zone, blocking the part of its cooling surface.

To increase the the resource of steady work of HP of corrosion resistant steels (important for practical applications in space equipment) is recommended: 1) the use of steels with a carbon content less than 0.03 %; 2) alloying molybdenum steels; 3) establishment of protective surface layers by etching elements of HP; 4) intensification passivation layer formation on the inner surfaces of of HP (prolonged low temperature oxidation); 5) Use of bidistilled water quality and so on.

One of the methods for solving the problems of compatibility steels with water is plating of inner surface by copper.

Experimental equipment and testing. At the Frantsevich Institute for Problems of Material Science is established experimental stand (fig. 1), by which HP resource tests are carried out. The stand contains six heat pipes with metal fibers capillary structures (CS): copper (copper brand M1) and CS, made of stainless steel (9X18H10T). The choice of materials and HP and CS is due mainly to a range of values of the thermal conductivity of the starting metals. Working liquid-coolant is distilled water. The rationale for the use of water in the HP is it acceptable for the cooling systems operating temperature range and non-toxic.

Heat pipes are installed in a horizontal position and are equipped with electric heaters, aluminum heat sinks-radiators, thermocouples for measuring the temperature of HP. Thermocouples are located on the exterior surface of the HP enclosure along their length. Heat pipes operated cyclically to 9 hours per night. The stand is equipped with Electric Meters permitting control of operating time of HP under load.

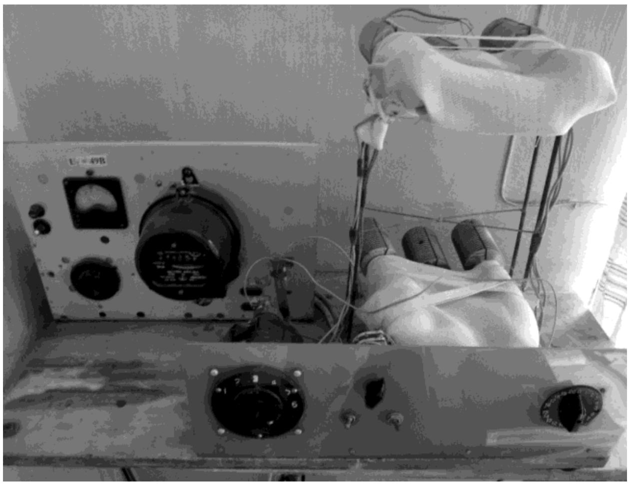


Fig. 1 – Experimental stand for resource studies of low-temperature heat pipes

A group of low-temperature heat pipes (90 pcs) has also been made for the research of thermal resistances. All of them one by one were investigated in a similar experimental stand. Copper HP dimensions with rectangular cross-section and fiber MFCS were as follows: 500×13×7,5 mm; working fluid – acetone. The heat flux, transmitted by heat pipes, did not exceed 20 W. Thermal resistances R_{HP} were determined during the measurement of temperature difference ΔT; wherein thermocouples measuring the temperature were set at the beginning and in the end of HP transport zone.

Copper HP are equipped with highly porous copper capillary structures which have previously for better wetting with water, was subjected to oxidation (heating in air up to 250 °C). Pipes made of steel (HP number 3, 4; table 1) are equipped with steel CS (from similar steel); while CS in the handset number 4 was also subjected to oxidation. Steel pipe number 6 has a capillary structure of copper, which was burnt to the inner surface of the housing with a pre-coated by copper. Experimental HP were repeatedly subjected to so-called "bump" test, during which they operated in the mode of periodic short-term on-off switch.

Table 1 – Characteristics of TT and fiber CS

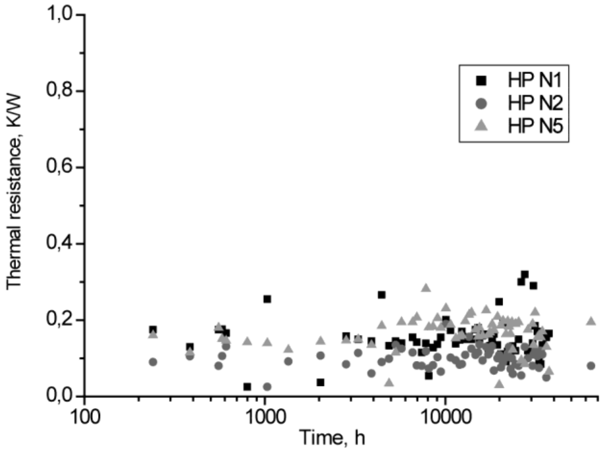
Number	Material of HP frame	Material of CS	Porosity of CS, %	Length of HP, mm	Diameter of HP, mm	Diameter of fiber, mcm
1	copper	copper	78	250	12	40
2	copper	copper	78	250	12	40
3	steel	inoxidised esteel	78	250	12	30
4	steel	oxidised steel	78	250	12	30
5	copper	copper	78	250	12	40
6	steel	oxidised copper	78	250	12	40

Tests and research results. Results of endurance tests of HP are shown in fig. 2, 3. The first 11,000 hours heat pipes were functioning continuously when cooled condensing zones by running water. At the same time delivered to the of HP power was 20 watts.

Then of HP were operating in cycle (frequency switching is 9 hours), air-cooled (heat transfer through finned heat sink). The number of cycles at the initial stage of regular tests is more than 400 experiments. Later tests of HP were carried out continuously. Until now, as indicate the results obtained, all experienced pipes operate without failure. At the end of 100,000 hours of operation the heat pipes are fully operational. Fig. 2 shows the results of tests of copper HP (number 1-3) with copper CS as a function of thermal resistance R_{HP} (one of the basic physical and technical characteristics of the heat pipe) from the time.

Analysis of the data indicates that the characteristics are not changed over a sufficiently long period of time. The scatter of the measured temperatures along the length of HP is connected with a change in temperature in a laboratory room, but the range of thermal resistance R_{HP} remains unchanged.

Heat pipes made of copper-plated stainless steel inside, are equipped with copper capillary structures, during long-term operation does not reduce their heat transfer characteristics (fig. 3).



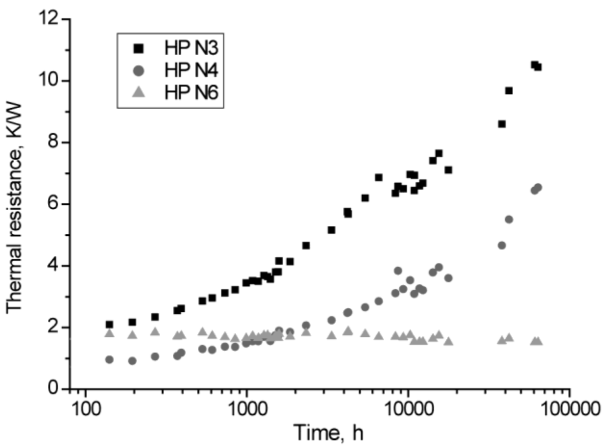


Fig. 2 – Change of the thermal resistance of the copper heat pipes with copper fiber capillary structures with time

Fig. 3 – Change of the thermal resistance of heat pipes made of stainless steel with steel and copper fiber capillary structures with time

Steel HP with CS of stainless steel (number 3 and 4) over long periods of operation are working steadily. However, their thermal resistances R_{HP} increased over time (by 4…6 times). This fact in the theory of heat pipes is known; He explains some of the increasing a number of hydrogen inside the pipe, stands out as the body of HP and developed surface of the porous capillary structure. The presence of hydrogen deteriorates slightly thermal characteristics of HP, but does not violate (essentially) the process of operation the tested heat transfer devices. At the same time, in stainless HP number 6 with copper capillary structure values of thermal resistance with time remain almost unchanged, what is indicating its high reliability and efficiency.

The experiments show, that there is a certain range of R_{HP} values in small production (in vitro) of HP. However, we can assume that in a certain deviation R_{HP} from the average value, HP thermal resistances remain small. This fact makes it possible to suggest, that HPs with MFCS are highly effective two-phase heat transfer devices.

Conclusions

1. Heat pipes with metal fibers capillary structures are highly reliable two-phase heat transfer device possessing a great resource of efficiency and durability. Copper heat pipes with copper capillary structures are able to function for a long time without compromising the basic thermophysical characteristics.

2. The use of water as the heat transfer fluid in heat pipes made of stainless steel with steel capillary structures is possible for HP, the use of which is limited to a short period of operation. A desirable technological process is a preliminary copper plating of the inner surface of stainless HP.

3. In the manufacture of HP small series, their thermal characteristics (such as thermal resistance) may be slightly different from the average values.

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Надійшла до редакції 24.11.2015