INVESTIGATION OF HEAT PIPE'S PERFORMANCE PARAMETERS DEPENDING ON DIFFERENT CONDITIONS

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Abstract: *The article deals with effect of the nano-fluids on the performance parameters of heat pipes. Stainless steel heat pipe was filled with a nano-fluid, a solution of copper sulphate and ferric chloride, up to 20% of the total volume of the heat pipe. Solutions of the nano-fluids were produced in the following concentrations: 1%, 2%, 3%, 4% and 5%. The performance parameters were measured on the experimental setup. The experimental measurements were carried out for different operating temperature and measured results show that the concentration of working fluid has effect on performance of the heat pipe..*

Keywords: NANO-FLUID, COPPER SULPHATE, FERRIC CHLORIDE, PERFORMANCE PARAMETERS

1. Introduction

Rising energy costs and tightening the standards for reducing CO_2 emissions requires more particularly in areas of high energy efficient solutions. Effective option is energy recovery of waste heat [1]. Waste heat is produced by various technological processes in industrial and energy production. To recover waste heat is necessary to choose the right type of technology, which mainly depends on the type of uses and applications of such a device. For efficient use of waste heat are also used heat pipes [2]. Heat pipes are used for efficient transfer of heat while maintaining low temperature differences. Therefore, the development and optimization of the key to greater efficiency and broader application of heat pipes. The advantage of the heat pipe is that even with small dimensions can transfer high thermal performance while its construction is simple with a long life, reliability and durability [3]. Different types and quantities of substances affect labor transfer characteristics of the heat pipe. It is therefore important that a well working medium and the type of material used, in view of the used application. In this so that we can re-use the waste heat, are usually used heat exchangers of gravity or capillary heat pipes [4].

2. Theoretical analysis of gravitational heat pipes

The heat pipe is a device that is widely used as a heat exchanger. It has several advantages such as simple structure, long life, high efficiency and easy maintenance. Its performance parameters affect various factors, but in particular the working fluid, amount of the workload and filling process. The heat pipe comprises a closed outer shell and a working fluid provided within the pipe. The pipe operates in a vertical or slightly sloping position of each coupling portion located above the evaporation portion. In the vapour of the working fluid evaporates and condenses the condensation part. [4] The condensate then flows into the evaporator section by the action of gravity along the smooth inner wall. (Fig.1)

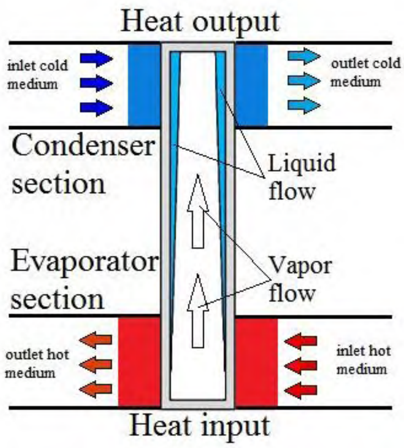

Fig. 1 Function of gravitation heat pipe

The transferred heat flow depends on the thermal resistance of the liquid film on the wall of the condensation part. Correct operation of the tube is conditioned in such a dosing quantity of working fluid, in the range of operating parameters to avoid insufficient wetting of the surface evaporation and thus decreased performance [5]. Conversely, too much excess liquid in the vapour of boiling over leads to the release of large steam bubbles when surging phenomena. Heat transfer between the vapour phase of the working fluid and the inner wall of the tube is mainly influenced by the character of the flow of the falling film of liquid.

3. Production gravitational heat pipes

The heat pipe was made of several parts. All the parts were made of stainless material. Casing pipe forms a hollow round bar stainless steel AISI 304, cut to a length of 500 mm with an inner diameter of 10 mm and a wall thickness of 1 mm (Fig 2). The bottom of the pipes (plugs) were turned off round bar of stainless material (304) to the required size (Fig. 2). Into the centre of the end caps were drilled holes with a diameter of 1.4 mm, where was subsequently placed a needle designed for filling process. All these parts were bonded by soldering (Fig. 2). By this process was made stainless gravitational heat pipe before filling the working substance.

Fig. 2 Stainless steel pipe, cap, closed end of the tube (respectively from left to right side)

In this research are presented experiments with heat pipe filled by the working substance to 20%. The amount of working fluid was determined based on previous research. These results shows, that optimal amount of working medium is 20-25% of the total heat pipe volume.

The heat pipes were weighed before and after filling the working substance at 22% of its capacity. The evaporation of the working medium was carried out by fast heating of the jacket pipe. The evaporation of the working fluid took place up to 20% filling, the filling needle was then closed with metal tongs and end of the needle has entered into a joint using a silver solder and flame.

Working medium – nano-fluid

As a working medium were chosen following nano-fluids: solution of distilled water with ferric chloride and solution of distilled water with cooper sulphate. These solutions should provide higher heat transfer of the heat pipe in comparison with distilled water.

In order to determine the optimum performance, the solutions were prepared in concentrations from 1% to 5%. Ferric chloride ($FeCl_3$) is a yellow-brown but the transmitted light as a purple red hygroscopic inorganic compound (darkness of the colour depends on the degree of oxidation by oxygen), which is under the action of atmospheric moisture flow able self. Copper sulphate ($CuSO_4$) is is an inorganic compound that combines sulfur with copper (anhydride), which turns blue water intake.

Fig. 3 Five percent solution of $FeCl_3$ (left) and $CuSO_4$ (right)

4. Experimental setup

The measurement was carried out on an experimental setup (Fig. 4), where the gravitational heat pipe was placed. Evaporating part of the heat pipe was heated with water in the range from 40 °C to 90 °C and the condensation part was cooled with water at 20 °C. In total were done six measurements and the temperature difference between the tests was 10°C.

For a correct analysis of the performance parameters of the heat pipe was needed precisely defined following values:

- Water temperature at the inlet and outlet of cooling (°C)

- Flow rate of the refrigerant circuit (l/ min).

In order decrease heat loses, the evaporation part of the pipe was insulated with glass wool into the environment. The measured values were recorded at 5 second intervals for one hour by means of sensors. Data from the sensors were transmitted through the measuring panel to the software AMR WinControl from AHLBORN installed in the notebook. The measured values were out of the program AMR WinControl from AHLBORN exported to Microsoft Excel, where the values were then processed and analyzed. The actual determination of the performance of the heat pipe is based on the difference of input and output temperatures of the cooling water passing through the cooling device positioned on the condensing section of the heat pipe.

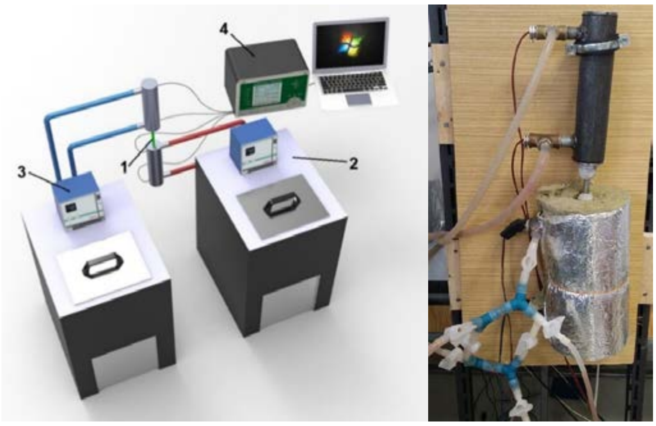

Fig. 4 The scheme of experimental setup (1-Heat pipe, 2-Heating circulators, 3- Refrigerated circulator, 4-Data logger)

5. Results and discussion

Inlet temperature in the heated part of the heat pipe device greatly impacts the performance. The value of power was growing with increasing value of the operating temperature. The performance data of individual samples heat pipes were highest at a temperature gradient 90/20 °C. In general, the tested heat pipes began to work effectively in different temperature. This is due to the pressure difference inside the pipes.

The results in Tab. 1 and 2 show that using $FeCl_3$ and $CuSO_4$ nano-fluids reaching peak output of pipe with a 1% concentration. Its output grew approximately linearly with increasing temperature. The heat pipes work effectively at lower temperatures. In the case of samples with other concentrations, the heat pipes started to work effectively between 70 and 80 ° C. The lowest performance was measured for 3% concentration of the nano-fluid. This could be due not only to different strengths, but also a way of filling and sealing of heat pipe in which may have been deflated respectively aspiration of air.

Table 1: *Power dependence on temperature and the concentration of the $FeCl_3$ nano-fluid*

$FeCl_3$	40°C	50°C	60°C	70°C	80°C	90°C
1%	46 W	59 W	180 W	250 W	326 W	382 W
2%	14 W	41 W	148 W	213 W	285 W	359 W
3%	9 W	12 W	42 W	96 W	187 W	240 W
4%	20 W	95 W	147 W	198 W	260 W	315 W
5%	25 W	94 W	155 W	221 W	288 W	351 W

Table 2: *Power dependence on temperature and the concentration of the $CuSO_4$ nano-fluid*

$CuSO_4$	40°C	50°C	60°C	70°C	80°C	90°C
1%	15 W	37 W	53 W	201 W	342 W	431 W
2%	5 W	1 W	10 W	39 W	164 W	246 W
3%	20 W	22 W	22 W	39 W	261 W	368 W
4%	14 W	34 W	125 W	255 W	313 W	376 W
5%	34 W	62 W	101 W	182 W	300 W	405 W

6. Conclusions

Currently, only a few publications present nano-fluids and this research topic has considerable potential. Nano-fluid seems to be as interesting alternative working substance that can easily and efficiently achieve performance increase heat pipe. The article deals with nano-fluids ferric chloride and cooper sulphate at concentrations of from 1% to 5% and describes the method for producing stainless steel gravitational heat pipes that have been made for this test. The achieved results show the increase of heat pipe performance by about 5% in comparison to other working fluid (water, ethanol). In order to observe more accurate results it is necessary to improve the filling process and insure uniform pressure and the same amount of working medium in all samples.

Acknowledgement

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