Experimental and Numerical Study of the Thermal Performance of Water-Stainless Steel Heat Pipes Operating in Mid- Level Temperature

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Abstract

Thermal performance of water-stainless steel screen mesh wick heat pipes was investigated in this study. Three screen mesh wick heat pipes were fabricated and tested all different inclinations, and their thermal conductance in different modes were compared (experimental, calculated and numerical). The different mesh numbers can bring different meanings in terms of both liquid flow resistance and capillary pumping. The aim was to analyze the thermal behavior in the permanent and transient regime for each power when operated with the power step and power cycles in mid-level temperature, for use in several industrial and aerospace applications when those levels of temperature are required. The calculated thermal conductances based on the thermal resistance analysis were used to be compared with the obtained experimental thermal conductances. An adjustment factor was calculated with the objective of being used in the results of the calculated thermal conductances to bring them closer to the actual results that were obtained experimentally with the water-stainless heat pipes. The numerical approaches undertaken in analysing the transient thermal performance was used the multifluid model where two different fluid zone were created to represent vapour flow in the middle and liquid flow in the porous wick. The predicted surface temperatures with varying heat inputs (25 W - 125 W) from the numerical model and experimental tests were used for thermal conductance (numerical and experimental) were compared with calculated thermal conductance.

Keywords: heat pipe, experimental heat pipe, simulation, thermal performance.

Introduction

Heat pipes are passive heat transfer devices that can successfully transfer large amounts of heat. The robust and simple tubular structure with no moving parts makes the heat pipe a perfect choice for different applications such as industrial or aerospace. Heat pipe technology for industrial applications has been widely used on heat recovery system, with an increasing development for thermal control of electronic equipment and heat exchangers performance augmentation [1-4]. The heat was applied to the evaporator by a controlled electric heater, being used the testing power step, the heat source was applied to each heat pipe to observe, at first, the start-up effect. Once the temperatures for the start-up power have reached stability, power was changed according to the testing profile, following the sequence to temperature stabilization.

Discussion and Results

With the tests performed for the power cycles of 25, 50, 75, 100 and 125 W it was possible to verify the temperatures along the heat pipes to obtain the temperature profile for operating at 0° (Figure 1a). The experimental results may raise possible variations, which came from heat pipe manufacturing standpoint and it affects heat pipe operation. Considering that the heat pipes were manually manufactured, an adjustment factor was taken into consideration for the thermal conductance results in such a way that it could result in a more accurate analysis in a way to put into consideration these possible variations. The adjustment factor is defined as follows

$$Factor = \frac{G_E}{G_{global}} \tag{1}$$

$$G_{global} = \alpha \frac{Q}{T_e - T_a} \quad \text{where } 0.8 \leq \alpha \leq 3.0 \tag{2}$$

The calculated thermal conductance used in this study for each power applied to the heat pipe can be defined as

$$G_C = \frac{1}{R_T} * Factor \tag{3}$$

Figure 1b presents the results of the thermal conductance obtained from Eq. (3) for a better analysis of the heat pipes thermal operation.

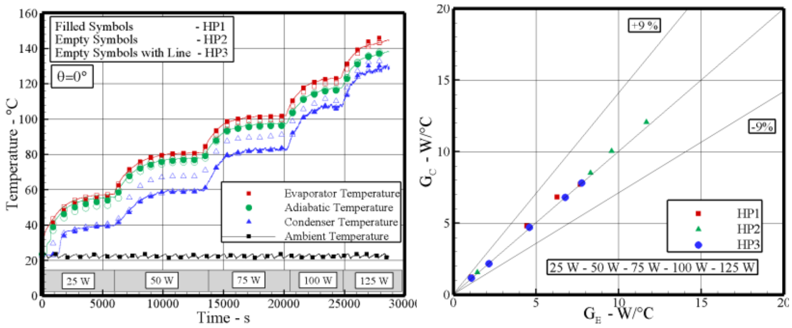

Figure 1. (a) Temperature profiles, (b) Thermal Conductance for HP1, HP2 and HP3

Conclusions

The results show a good correlation between the experimental, calculated and numerical results. The proposed calculated thermal conductance and thermal conductance numerical, correctly predicted the increase in thermal conductance with the increase in the heat input and the same has been validated experimentally. The highest experimental thermal conductance was obtained by HP2 of 12 W/°C The heat pipe HP2 showed better thermal performance due to smaller pore size, lower porosity and permeability and higher capillary pressure. The theoretical thermal conductance presented results of approximately 9,6 W/°C for the HP1, 15.5 W/°C for the HP2 and 23 W/°C for the HP3.

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