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NUMERICAL ANALYSIS OF INFLUENCE OF THICKNESS OF LIQUID FILM ON BOTTOM COVER TO HEAT TRANSFER IN THERMOSYPHON IN CONDITIONS EMERGENCY MODES OF WORK THE RECHARGEABLE BATTERIES OF AIRCRAFTS

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Abstract. Numerical analysis of thermal conditions of a two-phase closed thermosyphon using the software package ANSYS FLUENT has been carried out. Dynamics of change of thickness of the liquid film depending on time impact of heat load are obtained.

1 Introduction

Nowadays, closed two-phase thermosyphons are effective devices using evaporation-condensation cycle [1]. Selecting thermosyphons as a main element of the cooling system of various energy-devices is due to high heat transfer capacity, reliability and ease of manufacturing [1, 2]. Earlier, regularities of heat transfer process in thermosyphons studied mostly experimentally [3-5]. There are studies of influence of the most significant factors in the work conditions and the heat transfer capacity of such systems.

High thermal conductivity is achieved by changing the state of aggregation of coolant. It should be noted that the heat transfer characteristics of the two-phase closed thermosyphon influenced by many factors. One such factor is thickness of liquid layer on bottom cover of thermosyphon [4].

There are mathematical models of physical processes in thermosyphons [6, 7]. But these models describe the work processes of heat transfer systems with fairly significant assumptions on the mechanism of heat transfer. So, for example, [6] adopted a model of the boundary layer flow in the vapor channel, and [7] are considered flow regimes at low speeds blowing vapors of refrigerant from the heated surface and not taken into account a number of processes taking place in the vapor and liquid phase of working fluid.

So far, it has not been studied during unsteady heat transfer in the heat removal through thermosyphons in an emergency operation of technical devices with increase of temperature above permissible levels (e.g., rechargeable batteries).

The aim of this study is mathematical modeling of heat transfer in thermosyphons in comditions emergency modes of work the rechargeable batteries under a heat load (e.g. aircraft).

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2 Physical model

Chart of the closed thermosyphon considered in figure1. It is assumed that the thickness of the liquid film does not vary in height. Also, vapor is considered as an ideal gas. Walls of thermosyphon are insulated.

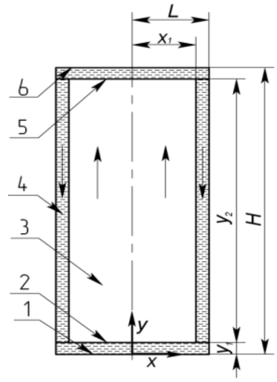

Figure 1. Chart of the closed thermosyphon. 1 – bottom cover; 2 – surface of evaporation; 3 – vapor; 4 – film of liquid; 5 – surface of condensation; 6 – upper cover.

Mathematical modeling was performed using software package Ansys Fluent [8].

Mass rate of evaporation and condensation were calculated by using the formula (7) is used in the description of phase transitions on surface of liquids in a variety of applications (for example, the evaporation of water droplets while moving through the high-temperature gases [9, 10] or by evaporation of flammable liquids in a local heating [11, 12]):

$$w_c = \beta\sqrt{\frac{M}{2\pi RT_w}}\left(P - P_0\right), \tag{1}$$

where P_0 pressure of saturation; T_w – temperature of evaporation surface; R – universal gas constant; M – molecular weight; β– accommodation coefficient.

To verify the mathematical model has been carried out the test calculations (Figure 2). The values obtained were compared with experimental data [4]. Under the experimental conditions [5] the removal of heat from the upper part of thermosyphon carried by heat exchange on the outer surface (y=H) with the coolant condensate. Results of mathematical modeling (Figure 2) show good agreement with experimental data [5].

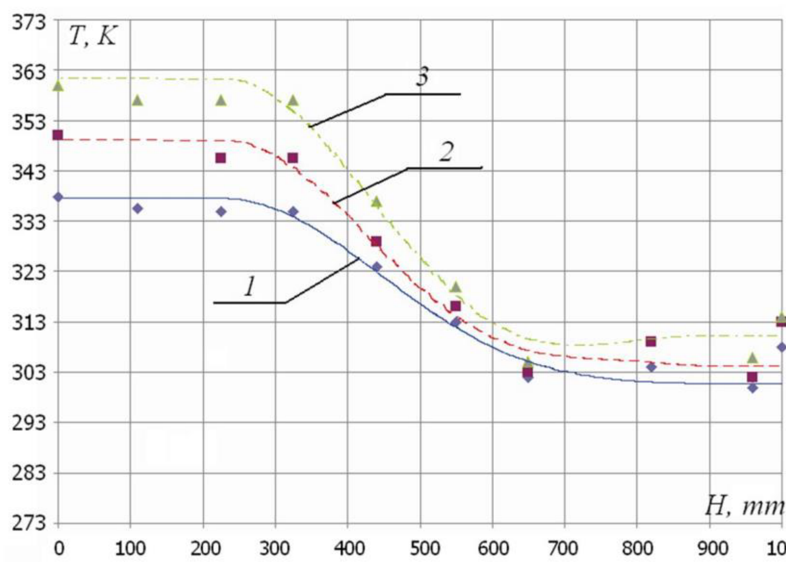

Figure 2. The temperature distribution in the direction *y*. The comparison between numerical results and the experimental. [5]. 1(◆) – Q_h=11,4·10^5 W/m^2, 2(■) – Q_h=16,3·10^5 W/m^2, 3(▲) – Q_h=22,8·10^5 W/m^2.

3 Results and Discussion

Numerical study of thermal processes in the two-phase closed thermosyphon rectangular cross-section with the geometry parameters (Figure 1) has been carried out: the height H = 300 mm, the transverse dimension L = 50 mm. The heat transfer agent is the water. Saturation temperature was assumed 343.15 K.

On bottom cover was set the temperature corresponding to the critical thermal conditions of rechargeable batteries 20NCBN-25-U3 [13]. Operating temperature range of this type of battery is from -60 to +60 ° C [13].

Density of heat flow to the bottom cover thermosyphon adopted in accordance with the operating temperature range of this type of battery: 4,7 ·10^5 W/m^2.

Figure 3 shows, that temperature at bottom cover increases monotonically to 343 K. When the temperature reaches saturation starts boiling of refrigerant, accompanied by absorption of heat of the phase transition and the temperature rise of the bottom cover thermosyphon stops. Crisis of heat transfer occurs when refrigerant has evaporated completely (curves 1-4). This is because when liquid condensate is not fully returned to the heating zone under conditions of modes with the initial film thickness of 5-20 mm. Crisis of heat transfer not occurs under conditions of liquid film on bottom cover with thickness 30mm. In this case temperature at bottom cover corresponds to operating range temperature of batteries an aircraft.

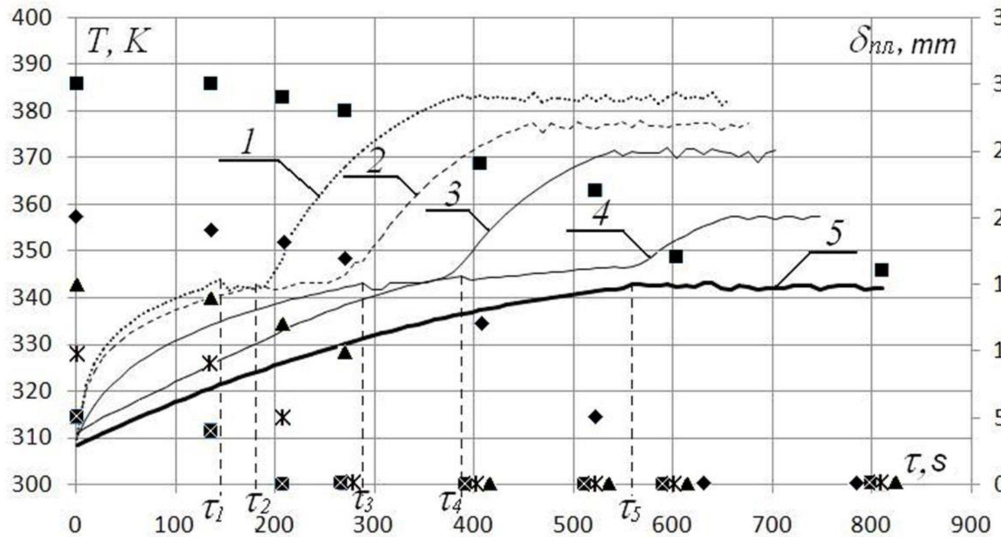

Figure 3. Temperature of surface of bottom cover and liquid film thickness depending on time. 1(■) – 5mm; 2(Ж) – 10mm; 3(▲) – 15mm, 4(◆) – 20mm, 5(⊠) – 30mm.

4 Conclusion

The results of numerical studies characterize temperature on bottom cover of thermosyphon at various conditions and dynamics of change of thickness of the liquid film depending on time impact of heat load.

Flowing condensate film in the heating zone is vaporized faster at temperatures corresponding to critical temperature of battery aircraft equipment and condensate is not returned to bottom cover thermosyphon. The layer thickness of the coolant decreases, and increases the risk of crisis of heat transfer.

The optimum thickness of the liquid film to dissipate heat from the battery in emergency operating mode is 30 mm has been established.

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