CAPILLARY STRUCTURES OF HEAT PIPES AND THERMOSYPHONS WITH AREA CHANGING CHARACTERISTICS

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Abstract

The improvement of the physical characteristics of capillary structures is an important technical problem in development of high-performance heat pipes and thermosyphons (HP, TS). Capillary structures from metallic fibres (MFCS), the technology of making of which has been is developed at the Institute for the Problems of Materials Science of NAS of Ukraine [1, 2], possess a number of advantages: the large range of porosity (Θ ≤ 95 %), high permeability, conditioned by the absence of deadlock pores, controlled values of flexibility, durability and plasticity. Researches of two-phase heat exchange under conditions typical of the areas of heating of heat pipes and thermosyphons, allow one to develop such devices with calculated and needed thermophysic characteristics.

Results of researches and discussion

The generalized results of experimental researches of two-phase heat exchange in boiling of water on surfaces with MFCS are presented in Fig. 1. Experimental setup was used the working areas of which are described in [3].

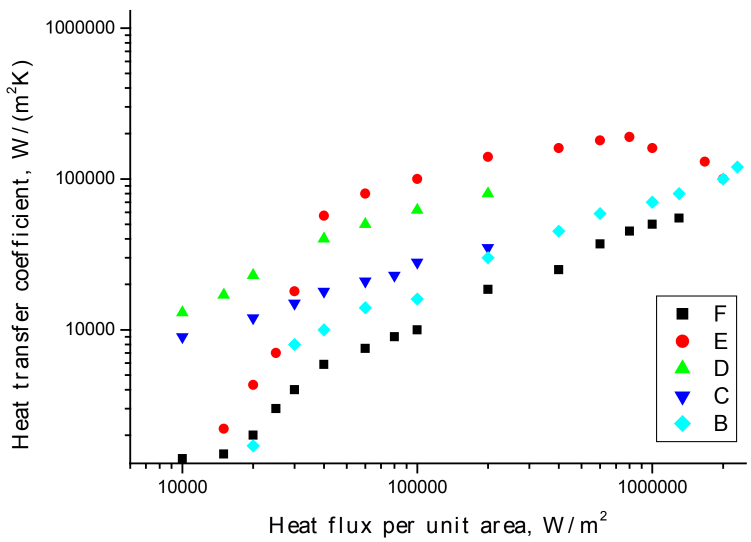

Fig. 1. The generalized results of experimental investigations of two-phase heat transfer intensity in boiling of water on surfaces with MFCS: F – intensity of water boiling on a smooth technical surface; E – same, on a surface with copper MBKC average porosity (Q = 40 %); a mode of "flooding"; D – a mode of "capillary transport» liquids; middle porosity MFCS (Q = 40 %); C – same; high porosity MFCS (Q = 90 %); B – the same, high porosity MFCS (Q = 87 %)

The analysis of data points to the substantial influence of the MFCS characteristios (porosity Θ, heat conductivity λ, thickness δ) on the intensity of heat exchange between the under the above-given conditions. The fact should be mentioned that there is an analogy influence of the characteristics of

MFCS on changes in the coefficients of heat transfer α in both modes of boiling (Fig. 2). Both on flooding «bay» of the area of heating and on its «***replenishment***» by a liquid, the highest intensity is provided by ***medium-porous*** MFCS (Θ = 40-50 %) from highly conductive (copper) fibres, with the thickness of CS δ = 0.5–1.0 mm. For MFCS functioning in the ***HP*** mode (capillary ***replenishment*** of the zone of heating with a liquid), the thickness of CS can be increased (up to 3 mm); in this case the needed value of δ is determined from the results of hydrodynamic calculations.

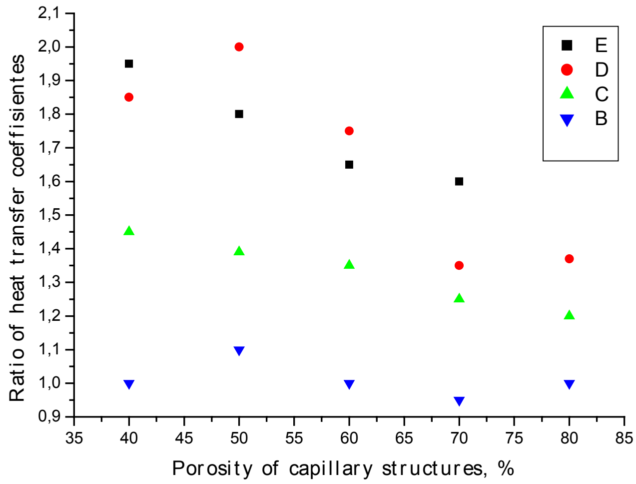

Fig. 2. Comparison of the influence of various transport conditions on boiling heat transfer intensity in the zone of HP-heating ($\alpha_{flooding}$ / $\alpha_{capillary\ transport}$). Thickness of MFCS: E – δ = 0.4 mm; D – 0.8 mm; C – 1.0 mm; B – 2.0 mm

The reasons for the substantial increase in the intensity of two-phase heat extransfer in boiling of ordinary liquids on porous surfaces are explained differently in the literature; our ***semi-empirical*** model, which agrees satisfactorily with experimental data, is expounded in [4].

The characteristics of MFCS exert a substantial influence also on the critical (maximum) values of the heat flux density q_{cr}. The experimental data obtained in the conditions of flooding of the zone of heating by water, are presented in Fig. 3.

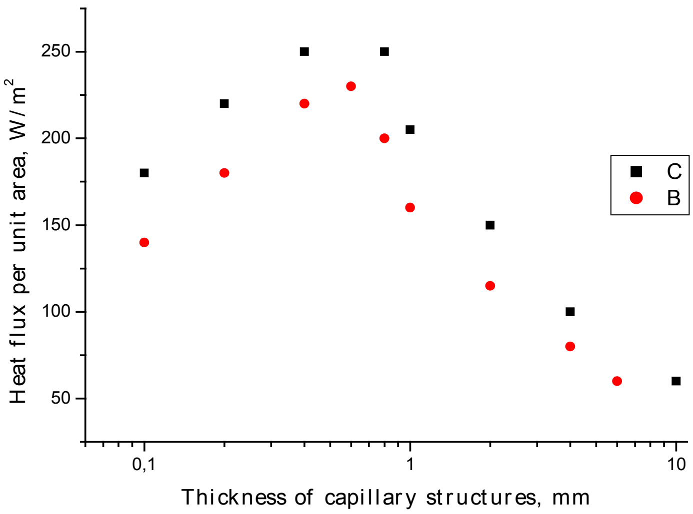

Fig. 3. Influence of the characteristics of copper MFCS on the critical heat flux per unit area in water boiling under the conditions of flooding of a porous surface. Porosity of MFCS: C – Θ = 80 %; B – Θ = 40 %

The highest values of critical heat fluxes q_{cr} were observed with the use of high by porous copper MFCS (Θ = 80–90 %) of thickness δ = 0.4–0.8 mm. The reasons for the increase of q_{cr} on porous surfaces, in our opinion, are the following: 1) the presence of CS hinders rapid coalescence of steam interlayers that appear in the precritical modes of boiling; 2) unlike smooth technical surfaces, on porous surfaces additional centers of vaporization appear at high values of q disposed on factions of CS at some distance from the «bearing» smooth surface.

Unlike the modes of developed boiling, the critical heat fluxes in the case of replenishment substantially depend on the transporting abilities of CS. With an increase in q the amount of liquid that evaporates in the pores of CS increases; at the same time the expenditure of the liquid, transported by CS due to capillary forces is increased insignificantly. At the same time, there appears a temperature difference (gradient) over the length of the zone of heating, which, accordingly, results in the nonisothermicity of the zone and the locality of the heat transfer coefficients. With a further increase in the heat flux density q in the zone of heating drainage of CS takes place, and HP becomes inoperative.

The results obtained served as a basis for creation of MFCS that allowone, depending on the technical terms of development of HP with necessary operating parameters, to use the positive properties of CS that provide both the high values of the intensity of heat exchange (middle porous MFCS) and high values of q_{cr} simultaneously (high-porous MFCS). One of the solutions of the problem is the creation of MFCS with area-variable characteristics, namely, combination of CS of middle and high porosity. The technology of creation of MFCS allows one to successfully solve the technical problems of their construction.

For experimental investigation of «combined» MFCS a number of models were created presented in Fig. 4.

Fig. 4. Samples of MFCS with constants and variables physical characteristics on the heat area

The results of experimental investigations of the specimens developed with boiling of water in the conditions of flooding of CS is presented in Fig. 5 in the form of the dependence $\alpha = f(q)$.

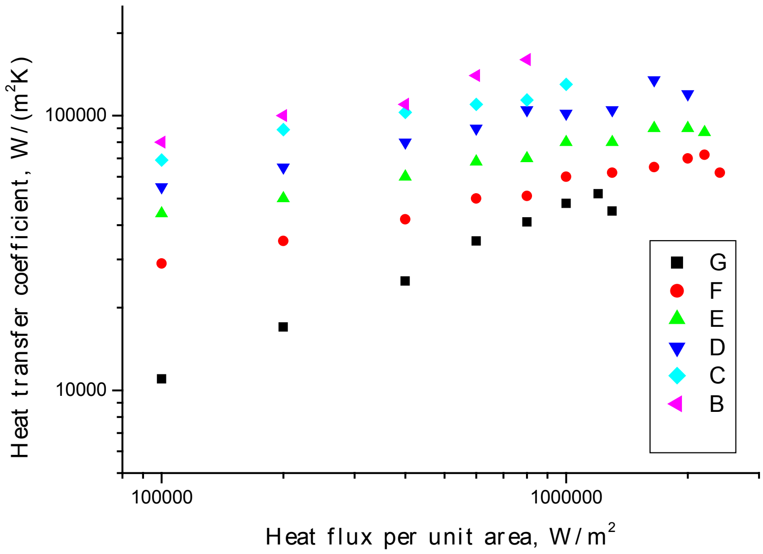

Fig. 5. Data of experimental investigations of MFCS with the physical characteristics variable over the heating area water boiling in the conditions of porous surface flooding. C – water boiling on a smooth technical surface; F – homogeneous copper high porosity MFCS (Q = 90 %); B – homogeneous copper middle porosity MFCS (Q = 50 %); C – nonuniform copper variable porosity MFCS (Q 50 % / (Q 90 % = 0,85); D – (Q 50 % / (Q 90 % = 0,7); E – (Q 50 % / (Q 90 % = 0,5)

The results of investigations confirm the ideas of creation of combined CS. Structures with greater specific area of portions of middle porosity (points 3) provide large values of intensity of heat exchange and smaller critical values of limiting heat flux densities. Structures with a large percentage of high porosity (points 4), accordingly, ensure large values of q_{cr}.

CONCLUSIONS

Thus, creation of capillary structures allows by the purposeful combining of their porosity (on the area of CS), up to a point, to carry out the management by their thermal-physic descriptions. For CS, functioning in the mode of capillary replenishment (transport) of liquid, a presence in the porous structure of middle porous (or little-porous) longitudinal areas-insertions will allow to improve hydrodynamic descriptions of CS, especially at functioning HP in the mode of motion of working liquid against forces of gravitation.

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