Heat Transfer during the Boiling of Liquid on Microstructured Surfaces. Part 2: Visualization of Boiling and Critical Heat Fluxes

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Abstract—Results from visualization of boiling process and experimental study of critical heat fluxes on microstructured surfaces are presented. The studied surfaces were obtained using the deforming cutting method and have different design shapes and sizes. Mechanisms of heat transfer enhancement are substantiated. A factor of 4.1 higher value of critical heat flux is obtained.

Keywords: pool boiling, heat transfer enhancement, critical heat flux, visualization

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Nucleate boiling is the main kind of two-phase heat transfer during which heat is transferred from a heated wall to liquid heated to the saturation temperature at the place in which they come in contact with each other. This two-phase transfer process is characterized by significant heat-transfer coefficients due to an intense phase transformation process. The intensity of heat-transfer process is governed by the dynamics with which a steam bubble is generated, grows, and separates from the heated surface.

The following tasks are to be solved in enhancing boiling heat transfer \cite{1–7}. First, it is necessary to achieve the onset of nucleate boiling at a smaller difference of temperatures between the hot wall and liquid and obtain high heat-transfer coefficients in this zone. Second, it is necessary to increase the critical heat flux that identifies the onset of burnout, i.e., to widen the nucleate boiling region.

The first task is solved by applying capillary–porous coatings. However, the use of this approach gives insufficiently high critical heat fluxes. Higher critical fluxes are achieved through the use of microstructured surfaces obtained by subjecting them to mechanical processing or to small-scale deformations of the surface. Such surfaces are used primarily for boiling processes with natural convection \cite{5, 6}. Enhancement of boiling heat transfer on microstructured surfaces is widely used in cooling systems and in heat-transfer equipment \cite{8}.

In \cite{9}, the results from a study of heat transfer during boiling of distilled water on microstructured surfaces obtained using the deforming cutting method were presented. The greatest enhancement of heat transfer was achieved for surfaces with 3D columnar and channel structures: by a factor of 3 to 9. The heat-transfer enhancement ratio obtained for 2D microfins was up to 2.5.

In this work, the results from visualization of boiling on the studied microstructured surfaces are presented and intermediate results from a study of critical heat fluxes are discussed.

METHODS FOR SHAPING BOILING SURFACES

Surfaces obtained using the deforming cutting method (DCM), which implies a combined use of partial cutting and bending of the surface layers of a heat transfer surface \cite{10–14}, can be used as microstructured surfaces for enhancement of boiling processes.

The totality of partially cut and plastically deformed layers, which retained the continuity of their connection with the billet, forms an extended microrelief on the treated surface. The DCM is embodied by using standard metal cutting equipment, including that with numerical program control and is a waste-free and high-efficient process, and allows all geometrical characteristics of the obtained macrorelief to be controlled. Interfin gaps with sizes ranging from a few micrometers to a few millimeters can be obtained. The degree to which this process can be realized in practice depends in the main on the plasticity of material being processed and on the cutting depth to supply ratio. For materials with relative elongation of more than 30\% (the majority of nonferrous metals fall under this category), the height of fins may be up to 7 finning pitches (Fig. 1a), but no more than 4 mm. For materials with relative elongation ranging from 20 to 30\% (this category encompasses the majority of