Research of wetting on micro- and nano-scale coating

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Abstract. Surfaces with porous coatings are used to improve heat transfer during boiling and transportation of liquid to the drained areas [1]. Effectiveness of coatings will depend on their wetting. The aim of the work is to study the characteristics of wetting. Wetting angle and capillary rise liquid height are measured for surfaces with micro arc oxidation coating, microporous sintered coating and coated with aluminum oxide nanoparticles (Al₂O₃) in work.

1. Introduction
Wetting is used everywhere in nature. Lotus leaf has a unique property-drops roll down from its surface at an extremely small angle of inclination, in consequence of the relief features: combination of microstructure and wax coating creates a superhydrophobicity of the sheet [1]. Relevance of wetting study on different coatings is determined by fact that the effectiveness of many devices depends on its quality.
Currently, widely used method of heat exchange intensification is creation of microporous coating on the surface, which improves reliability and efficiency of heat exchangers. For example, nano and microporous coatings reduce the thermal resistance of a weakly inclined composite thermostabilizer [2]. Porous materials can be appreciated by measuring their permeability, that is, ability of a liquid to pass through a porous material under the action of an applied pressure gradient [3]. The permeability depends on wetting and particles diameter [4]. Increased particle diameter in 8 times allows to increases permeability coefficient by an order [5]. The study of wetting characteristics, namely contact angle and the capillary rise liquid height will allow to develop coatings with the properties that are necessary in various energy sectors.

2. Object of research
The wetting angle and the height capillary rise of liquid were measured for surfaces with micro arc oxidation, the microporous sintered coating and with a coating of nanoparticles with agglomerates and coated nanoparticles (figure 1). Peculiarity of the studied coatings is that they have structural heterogeneity [6]. Sintered coatings and coating obtained by micro arc oxidation have been pre-cleaned by degreaser.
Working fluid is water. In the case of a nanoparticles coating, two samples on a nickel substrate were selected. Colloidal liquid consisting of water and aluminum oxide nanoparticles (figure 2) was applied and dried on samples [7].
3. Methods of measuring

3.1 Wetting angle measuring
Static wetting angle is measured by method of lying drop (figure 3). Wetting angle measurements were made for all samples in three different points, as in the first approximation (figure 5). Ten measurements of wetting angle on the left and right side of the drop were did for each point. Chosen drop volume was 0,0041 cm³ in order to compare results with known data.
3.2 Height capillary rise measuring

![Diagram](image)

**Figure 4. Methods of measuring of height capillary rise: a - Immersion of the sample in a liquid, b - Applying a drop on a vertical surface**

The height of capillary rise was measured for microporous coatings and surface with micro arc oxidation by immersion method (figure 4-a) (for greater measurement accuracy) and for the coating of nanoparticles by method applying a drop (figure 4-b).

4. Results of measurements

4.1 Results of measurements of wetting angle

Contact angle is influenced by various factors. In paper influence of coating was considered. Contact angel was measured for each drop with a diameter of 2mm. The average wetting angle is equal 70 to 90 degrees, with deviation 5 degrees for surface with micro arc oxidation (figure 5- b), 40-70 degrees, with deviation 5 degrees for a surface coated with nanoparticles and their agglomerates (figure 5- a). Wetting angles are close to zero for coating only from nanoparticles and microporous sintered coating. Formation of the bubble depends on contact angle. Increased wetting angle (wettability deterioration) allows to reduce temperature corresponding to the beginning of boiling and increases heat transfer. Improvement of wettability facilitates the flow of fluid in the zone of intensive evaporation and increase CHF [8].
4.2 Results of measuring of height capillary rise

Capillary rise height of liquid was up to 2.4 and 36 mm for samples with micro arc oxidation coating and microporous coating, respectively. High capillary rise was maximal for microporous sintered coating due to highest porosity and permeability. The height capillary rise was not less than 4mm in the case of a surface coated with nanoparticles (figure 6). The rise height was close to zero for the coating from nanoparticles and their agglomerates. However, this results depend on optimal size of agglomerates. This effect will be investigated in further. It is important that the maximum height capillary rise was maintained over time, that will characterize the high long-term strength of the coating.
Permeability can be estimated using Darcy’s law, at a water temperature of 20°C and a drop radius of 1mm (Figure 7). It is possible to estimate the coefficient of permeability, knowing the following parameters: G is the volumetric flow rate, µ is the liquid viscosity, ΔP is the pressure drop across the length of the sample L [3]. Obtained data for three coatings show that capillary rise liquid height increases if the permeability coefficient of the layer was grew.

5. Conclusion

The highest capillary rise liquid height is obtained on a sample with a microporous sintered coating, and the lowest – on coating obtained by micro arc oxidation. The biggest wetting angle is obtained on coating obtained by micro arc oxidation, and the smallest - with a microporous sintered coating. Microporous sintered coating is effective in the boiling, but it is difficult to produce and apply, for example, in microchannels [9,10]. Coatings from nanoparticles can use in the microchannel. It is necessary to investigate agglomerates of nanoparticles and estimate optimal sizes. Optimal size of agglomerates can be estimated by measuring wetting angle. It is important that the maximum height capillary rise was maintained over time, that will characterize the high long-term strength of the coating.

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