Experimental investigation of pool boiling of water-based Al_2O_3 nanofluid on a copper cylinder

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Abstract. Saturated boiling of nanofluid on a copper cylinder is experimentally studied. The studied nanofluid were prepared using distilled water and Al_2O_3 nanoparticles. The volume concentration of the nanoparticles was equal 3 %. Cylinder diameter was equal 25 mm. The time dependence on the excess temperature at different boiling regimes were obtained. It shown increase of heat transfer coefficient under boiling of nanofluid.

1 Introduction

Studies of the last two decades have shown that nanofluid have unusual transfer properties. In particular, small adds of nanoparticles into carrying liquid can considerably increase its heat conductivity and viscosity [1–2]. This stimulated many thermophysical applications of nanofluid, particularly, aimed at intensification of heat exchange. It has been found that nanofluid have really enhanced coefficients of heat transfer (see, for example, [3, 4] and literature cited therein). The further intention to increase this coefficient stimulated the study of heat transfer of nanofluid during boiling. These works have been performed quite intensely during the last decade. Nevertheless, the obtained results are rather contradictory. For example, in [5] it is noted that adding of nanoparticles does not change heat transport considerably, with an even decrease in the heat transfer coefficient during boiling been seen in [6]. Conversely, in [7–8], this coefficient rose.

Saturated boiling of nanofluid on a cylindrical heater is experimentally studied by researchers in their works [9-10]. The studied nanofluid were prepared using distilled water and iron oxide (II, III) nanoparticles or diamond nanoparticles. The volume concentration of the nanoparticles was changed from 0.05 to 1.0%, their diameters varied from 10 to 100 nm, and the heater diameter was increased from 0.1 to 0.3 mm. It is established that the critical heat flux density in boiling nanofluid depends on the size and material of nanoparticles and on the heater diameter. The critical heat flux density increases with increasing size of nanoparticles and decreases with increasing diameter of the heater.

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In this work, saturated boiling of the nanofluid were prepared using distilled water and Al_2O_3 nanoparticles was experimentally studied. The present work was aimed at studying the influence of nanoparticles on rate of cooling and heat transfer coefficient under boiling of nanofluid on a copper cylinder.

2 Experimental apparatus and procedure

The study of boiling process occurred on the copper cylinder (diameter is 25 mm).

Method of procedure. The cylinder is heated in the furnace to temperature of 350-500ºC. After that it is immersed within studied fluid (distilled water or nanofluid) to the depth of 15-60 mm (see figure 1). Since the surface of the cylinder has a high temperature, when immersed in water formed a vapor film. The studied fluid was heated up saturation point to not spend the warm on heating fluid. Cooldown period occurs at a constant coolant temperature. The value of heat transfer coefficient is constant in the film boiling; that is the boundary condition for steady cooling regimen. Cylinder temperature is measured using thermal couple which mounted into it. The decline rate of the cylinder and the heat transfer coefficient are meant on the score of evidence from the research.

Fig. 1. The scheme of the experimental setup.

Study of boiling was drown using the distilled water, water-based nanofluid and Al_2O_3 nanoparticles. The volume concentration of the nanoparticles in water was equal 3%. Average particle size of Al_2O_3 nanoparticles is 36 nm. Preparation of nanofluid was carried out based on standard two step process. After adding to the base fluid the required amount of nanopowder, the nanofluid was first thoroughly mixed mechanically, and then was placed for the half-hour into an ultrasonic disperser Sapphire to destruct conglomerates of particles. The nanoparticles were purchased from “Advanced Powder Technologies” company LLC (APT) (Tomsk).

3 Results and discussion

The series of five experiments was carry out for distilled water and the nanofluid containing Al_2O_3 nanoparticles.

Boiling regimes in distilled water at different times was shown in figure 2. Unfortunately, addition of nanoparticles leads of decrease in transparency of nanofluid. For this reason the photo of boiling of Al_2O_3 nanofluid are less informative, but the process of boiling are similar.

The dependence of excess temperature θ (the temperature difference between the temperature of cylinder surface and the saturation temperature of the fluid) on time, obtained in the experiment, were shown in figure 3.

Fig. 2. Boiling regimes at different times. Left to right: film boiling, transition boiling, nucleate boiling.

The average (for all replicates) dependences of excess temperature θ on time for the distilled water (dotted line) and Al_2O_3 nanofluid (solid line) were shown in figure 3. In this figure there were boiling conditions, that realized in these experiments and shown in figure 1-2. That is change slope of a curve indicates the changes.

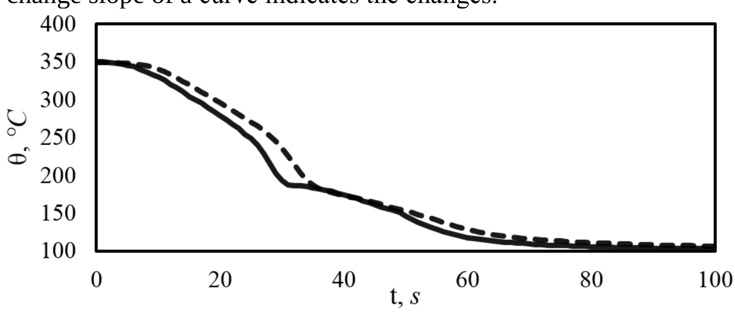

Fig. 3. The dependence of excess temperature on time.

It can be observed that the boiling of distilled water and the nanofluid are identical in order of merit, but they differ quantitatively because it is necessary to notice that:

a) a transition region from film boiling to transition boiling (see figure 4) – set transition in the nanofluid occurs in about 5 seconds earlier then in distilled water and excess temperature θ is at about 10-15ºC higher in the first instance, which is equivalent of increase of heat transfer coefficient of the nanofluid on 7.5-10% in comparison to heat transfer coefficient of distilled water.

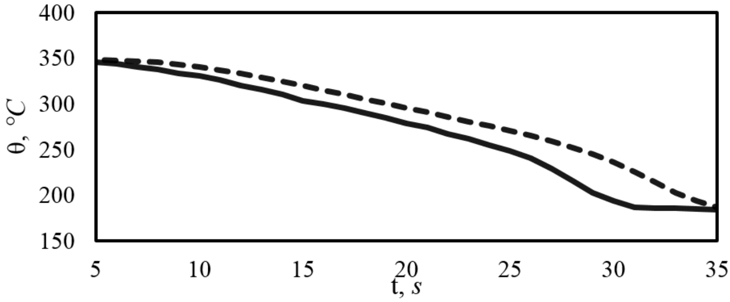

Fig. 4. The dependence of excess temperature on time in the transition region from film boiling to transition boiling.

b) a transition region from transition boiling to nucleate boiling (see figure 5) - set transition in the nanofluid occurs in about 25-30 seconds earlier then in distilled water, which is equivalent of increase in heat transfer coefficient of the nanofluid on 20-40% in comparison to heat transfer coefficient of distilled water.

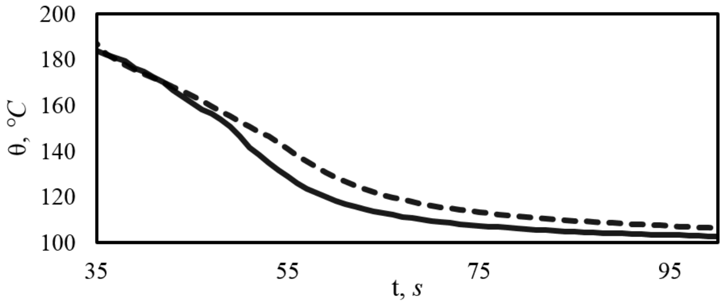

Fig. 5. The dependence of excess temperature on time in the transition region from transition boiling to nucleate boiling. transition boiling to nucleate boiling

4 Conclusions

Based on the experimental results, it may be concluded that using of nanofluid, connected to phase transition, is effectually. Using nanofluids increases the heat transfer coefficient, this can increase the energy efficiency of setups in which the main process is boiling.

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