Investigation of Boiling Heat Transfer of Binary Mixture from Vertical Tube Embedded in Porous Media

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Ethanol–water binary mixtures with 7 different mole fractions of ethanol ranging from 0 to 1 were adopted as testing liquids in the experiment. The vertical heating tube was inserted in porous matrix composed of five well sorted glass beads whose diameters range from 0.5 to 4.3 mm. Due to the effect of composition, the trend of combination of vapor bubbles was reduced, resulting in the increase of peak heat flux of binary mixture. With the increase of ethanol mole fraction, 0.5 mm diameter bead had lower value of peak heat flux, while for pure liquid the critical state is difficult to appear. With given diameter of glass bead, there existed an optimum value of mole fraction of ethanol, which was decreased with the increase of bead diameter. A dimensionless heat transfer coefficient was predicted through the introduction of a dimensionless parameter of porous matrix, which agreed with the experimental results satisfactorily.

Keywords: binary mixture, dimensionless heat transfer coefficient, porous media.

INTRODUCTION

Multicomponent fluids and their heat transfer characteristics have received attention due to the intensively concern over energy efficiency and environment effect, especially for the thermal design of air conditioner and refrigeration system[1]. Nucleate pool boiling of liquid mixture is distinct from single component boiling in that their heat transfer coefficients can be considerably lower than those of an equivalent pure fluid with the same physical properties as the actual mixtures[2]. When porous media are added, the mechanism of boiling heat transfer becomes extraordinarily complex. Up to now, this research area was seldom investigated. In the present article, the effect of porous medium combined with the effect of composition of binary mixtures on the boiling characteristics was focused and investigated experimentally and theoretically.

EXPERIMENTAL APPARATUS AND PROCEDURE

Apparatus
A schematic sketch of the experimental setup is given in Fig.1, 2 and in more detail in Ref.[3]. The cylindrical vessel is made of stainless steel, well insulated with 30 mm thick glass wool. The vertical heater is a 150 mm long copper tube in which a ceramic rod wrapped with nichrome wire is inserted. The heat flux is calculated from the voltage difference and the electric current through the heater of the test section. Alumel–chromel thermocouples are installed on the inner surface of the test section and in the bulk liquid to measure their temperatures.

Procedure
After cleaned with distilled water and acetone and dried with drying apparatus, soda-lime glass spheres with average diameters of 0.5, 1.16, 2.5, 3.5, 4.3 mm respectively were piled in the cylindrical vessel.
Hailong Mo et al. Investigation of Boiling Heat Transfer of Binary Mixture from Vertical Tube Embedded to the height equal to that of the vertical heater. Ethanol–water binary mixtures (whose mole fractions of ethanol $X_1 = 0, 0.06, 0.172, 0.245, 0.323, 0.403, 1$) were added to the height 30 mm higher than that of the porous layer to prevent the effect of low level of liquid free surface on boiling. The inner surface of cylindrical vessel and the outer surface of vertical heater were cleaned with distilled water and acetone to prevent the effect of cleanliness of surface and impurity left in the vessel. Before starting experiment, the liquid were degassed for a long time to ensure that the uncondensable gas was all removed.

EXPERIMENTAL RESULTS AND ANALYSIS

Boiling Point Temperature of Binary Mixture

The boiling point temperatures of binary mixtures with different mole fractions of ethanol were measured at each beginning of experiment when the binary mixtures reached saturation boiling at one atmospheric pressure. The results were compared with the data obtained from Ref. [2], the maximum deviation was 1.42%, see Fig.3.

Effect of Bead Diameter on Boiling of Binary Mixture at Given $x_1$

It could be seen from Fig.4 that the heat transfer coefficient of binary mixture increased with the increment of bead diameter at given mole fraction of ethanol, which indicated that the resistance in vapor passage decreased with increase of bead diameter. At low mole fraction of ethanol, the heat transfer coefficient of binary mixture approached that of the distilled water ($X_1 = 0$), while at high mole fraction of ethanol, the heat transfer coefficient of binary mixture approached that of the pure ethanol ($X_1 = 1$). Concerning the effect of bead diameter on boiling heat transfer, that of the 2.5 mm diameter bead should be noticed. With the increase of mole fraction of ethanol, its heat transfer coefficient increased gradually. When $X_1 = 0.172$, in the range of $q < 12$