HEAT TRANSFER AND LOCAL CHARACTERISTICS FOR GASOIL BOILING IN A LARGE VOLUME

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Measurements have been made on the heat-transfer coefficients, vaporization-center concentration, bubble frequency, and detachment diameters. The amount of heat transported by the vapor bubbles has been determined.

Most measurements on heat transfer and boiling physics have been made with one-component liquids; relatively few measurements have been made on binary mixtures, and those with multicomponent ones are extremely limited. Experimental checks are required on the use of existing models with multicomponent liquids because they are based on measurements for one-component ones.

Measurements are required on the integral and local characteristics to elucidate the physical laws in multicomponent mixture boiling.

Here we give measurements on boiling in atmospheric gasoil (diesel fraction) under conditions of natural convection.

Apparatus and Methods. The working vessel was a stainless-steel tube of inside diameter 54 mm fitted with two windows for photography and illumination. The lower end was fitted with copper leads, while the upper had a condenser and thermocouples to measure the temperatures of the vapor and liquid.

The working part was a stainless-steel capillary of diameter 1.2 × 0.15 mm and length 17 mm, within which there were two cable thermocouples for measuring the wall temperature, which were insulated from the wall with ceramic. This part was heated by direct current from a stabilized source.

The vessel was surrounded on the outside by guard heaters and thermal insulation. The temperature profiles in the vertical direction were smoothed out by fitting the lower part with an additional heater. The heaters were supplied with alternating current.

We used an SKS-1M-16 cine camera operating at 1500-1600 frames/sec. The temperatures were measured with a digital voltmeter and traveling device. The pressure in the vessel was measured with a standard gauge of class 0.4.

The guard heaters produced a temperature in the gasoil at atmospheric pressure such that all the air was displaced from the vapor volume by the light fractions, which was detected from the production of the first drop of liquid at the end of a cooled glass tube connected through the upper end to the vapor volume, after which the volume was sealed off and heat was applied to the working part.

The bubbles were imaged with a magnification of 25-26 on paper and the edges were traced; the detachment volumes were used to calculate the equivalent diameters. The most likely values for the frequencies and detachment diameters were determined from the distributions for each heat flux.

The maximum relative error in measuring the heat flux was 2.1%, while that for the heat-transfer coefficient was 6.5%, that for the detachment diameter 3.1%, and that for the detachment frequency 0.7%.

Results. The experiments were performed at pressures of 0.1, 0.2, 0.3, and 0.4 MPa with heat fluxes from about $5 \cdot 10^4$ up to $63 \cdot 10^4$ W/m^2. We determined the critical flux at 0.1 MPa, which was $72.5 \cdot 10^4$ W/m^2. With isolated bubbles at P = 0.1 MPa, we used four values of the heat flux in high-speed cine photography.

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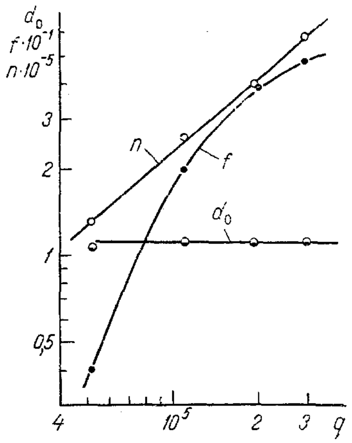

Fig. 1

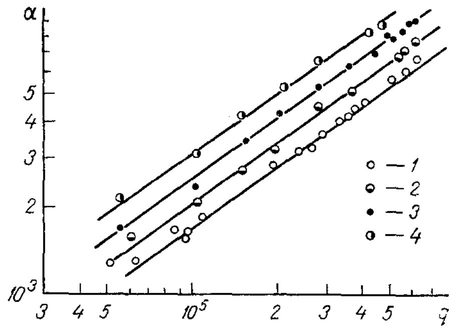

Fig. 2

Fig. 1. Effects of heat flux q (W/m^2) on vaporization-center concentration n ($1/m^2$), frequency f (1/sec), and detachment diameter d_0 (mm).

Fig. 2. Effects of heat flux q (W/m^2) and pressure P (MPa) on the heat-transfer coefficient α ($W/m^2 \cdot K$): 1) P = 0.1; 2) 0.2; 3) 0.3; 4) 0.4.

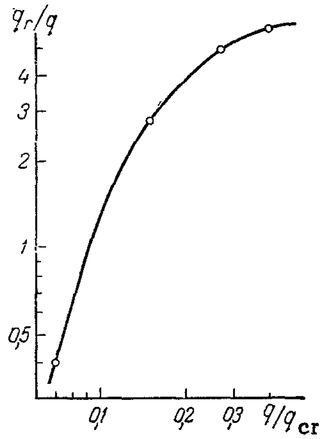

Fig. 3. Effects of relative heat flux on the proportion of the heat q_r/q (%) transported by vapor bubbles.

At each pressure, we detected the occurrence of the first bubbles visually to determine the boiling point T_b (the saturation temperature for a one-component liquid). T_b remained constant as the flux increased up to about q_{cr}. The relation between the boiling point and the vapor pressure is

$$T_b = 686 + 183 \lg P. \tag{1}$$

Figure 1 shows the effects of the heat flux on the local characteristics. The detachment frequency and vaporization-center concentration increase with the flux, while the detachment diameters remain almost constant. Similar relationships have been given [1] for d_0 as a function of q in the boiling of water, carbon tetrachloride, freon 12, and ethanol.

Figure 2 shows the heat-transfer measurements, where the transfer coefficient increases with pressure at a given flux density. The following empirical relationship applies for the ranges used:

$$\alpha = 1.5 q^{0,7} P^{0,48}. \tag{2}$$

In bubble boiling, the heat is transferred from the hot surface at a rate q_r by bubbles, together with the transfer by the liquid. There is a rapid heat transfer at the contact between the base of a bubble and the heater [2-4], but away from this, the hydrodynamic effects of the bubbles (during growth and detachment) have little effect on the heat transfer.

When a one-component liquid boils, the heat is transported away from the hot surface mainly by the vapor in the bubbles [4]. For example, for water at atmospheric pressure and $q = 200 \cdot 10^3$ W/m², the proportion q_r/p of the heat transported by the vapor is about 50%. It is therefore important in elucidating the transfer mechanism to determine the heat transport by the vapor in the boiling of gasoil, which is a multicomponent liquid with a relatively low latent heat of evaporation (the overall value for the mixture is taken as 250 kJ/kg).

The amount of heat carried by the bubbles at the instant of detachment can be determined from the local characteristics via

$$q_r = \frac{\pi}{6} \overline{d}_0^3 f r \rho'' n. \quad (3)$$

Figure 3 shows q_r calculated from (3); it clearly increases with the heat flux, although the proportion in the total heat removed is small. For example, q_r/q is about 6% at $q = 0.4q_{cr}$.

The data show that heat transport by the vapor does not make a substantial contribution to the total heat flux in the boiling of gasoil, which is a difference from a one-component liquid.

NOTATION

α, heat-transfer coefficient; q, specific heat flux; q_{cr}, critical heat flux; q_r, specific heat flux transferred by vapor bubbles; T, temperature; P, pressure; d_0, detachment diameter of bubbles; f, frequency of bubble detachment; n, density of nucleation sites; r, latent heat of evaporation; ρ'', vapor density.

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EFFECT OF A MAGNETIC FIELD ON A LIQUID CRYSTAL FILM AND STUDY OF THE FREDERIKS TRANSITION USING MOLECULAR DYNAMICS

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We discuss the results of a molecular-dynamics study of the lattice model of a liquid crystal.

The effect of bounding surfaces and external fields on the properties of liquid crystal films is of significant theoretical interest, and is also important in applications because of the wide use of various magnetooptical and electrooptical effects in liquid crystals. The traditional theoretical methods of dealing with problems of this kind have series difficulties, and therefore computer simulations of the problem are of great interest [1, 2].

Several interesting results were obtained in [3] in a study of the effect of a magnetic field on the phase transition in the lattice model of a liquid crystal by the Monte Carlo method. In particular, it was established that the well-known molecular field theory was in satisfactory agreement with the computer results. In the present paper we study a more complicated situation, which is of greater importance in practice. We consider the case when the liquid-crystal system experiences the competing effect of bounding surfaces and an external

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