SOME TEST DATA ON THE PROPERTIES OF LIQUID FILMS

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Data are shown pertaining to the properties of thin films of various liquid substances on cylindrical surfaces under various thermal conditions.

An experimental study was made under isothermal and under nonisothermal conditions, pertaining to certain properties of liquid films forming on a circular rod in a transverse high-velocity and even transsonic stream (120-320 m/sec) of a gaseous liquid dispersion.

In the test apparatus for this experiment, compressed air was fed to a nozzle where liquid was injected and the generated free jet was made to flow transversely past a circular rod. The air temperature was held within the 22-28°C range, the temperature of the liquid was held within the 20-23°C range, and the mass concentration of the liquid in the mixture was varied from 0.05 to 0.30.

Water, a 20% solution of potassium carbonate, and a 40% solution of ethyl alcohol were used in the isothermal tests. Carbon steel, stainless steel, nichrome, copper, brass, aluminum, and graphite rods 1.8 to 8.0 mm in diameter were used, their surfaces cleaned and then washed with a degreasing solvent before the experiment. The film thickness was measured on the rod surface, at a point 90° above the stagnation line, by the contact method with a micrometer needle and a cathode-ray oscillograph: the deflecting plates of the latter and the needle both in series with the film and the rod. As soon as the needle touches the liquid film, the circuit of the deflecting plates closes and the sine wave on the oscillograph screen becomes characteristically distorted. As the needle moves further, it finally touches the rod and, as a result of a much reduced circuit resistance, the sine wave becomes almost entirely straight. The difference between the micrometer readings at these two needle positions corresponds to the maximum film thickness.

Observations have shown that, under all conditions, on the rod surface in a high-velocity stream there forms a stable liquid film with small-scale surface irregularities at which droplets continuously precipitate and separate. In the wake region there forms a short unstable shroud. Equilibrium between these two mass transfer processes is reached at a definite film thickness and depends, according to the measurements, on the gas velocity, on the surface (rod) material, and on the properties of the liquid — it remains conservative with respect to the liquid concentration and to the rod diameter. Results of the film thickness measurements are shown in Fig. 1 for water under isothermal conditions. The tests with solutions of ethyl alcohol and potassium carbonate were performed using stainless steel rods. The film was respectively about 30% thinner and 20-25% thicker than a water film.

The nonisothermal tests were performed differently in that only a nichrome rod 1.8 mm in diameter and 19 mm long was used. Heat was generated at the rod surface by passing a low-voltage alternating electric current through the rod. In each test the air velocity at the nozzle exit was 315-320 m/sec, the thermal flux density was 10^7 W/m^2, and the mean rod temperature was 1300°C. The temperature was determined by a measurement of the rod elongation during heating, with a micrometer connected to the oscillograph as before. The following liquids were used in this test: water, kerosene, solar oil, and a 40% solution of ethyl alcohol.

The behavior of a film in the heat transfer tests did not differ from its behavior in the isothermal tests. Despite the high rod temperature, neither formation of vapor bubbles at the heat transfer surface (in the film) nor breakdown of the film (at above 0.1 mass concentrations of liquid in the mixture) was noted in any

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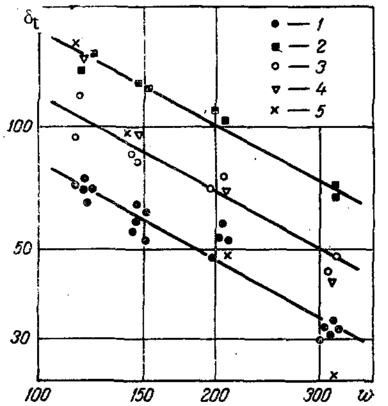

Fig. 1

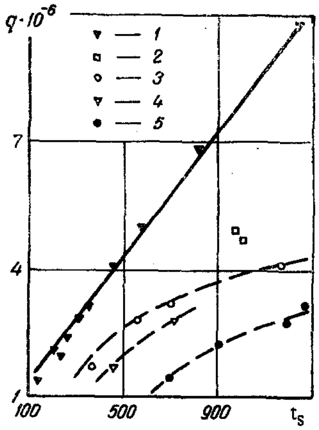

Fig. 2

Fig. 1. Thickness of water film δ (μm) as a function of the gas–liquid stream velocity w (m/sec), at various surfaces: carbon steel and stainless steel 2.0-7.8 mm in diameter (1), graphite 6.0 mm and copper 5.9 mm (2), brass 4.0 and 8.0 mm (3), aluminum 6.0 mm (4) nichrome 1.8 mm (5).

Fig. 2. Thermal flux density q (W/m^2) through a liquid film, as a function of the surface temperature t_s (°C): water (1), solution of ethyl alcohol (2), kerosene (3), oil (4), dry air (5).

of the tests. Heat emission from the rod and evaporation of liquid from the surface were not accompanied by any critical modes. The rod temperatures and the thermal flux densities are shown in Fig. 2.

The thickness of the water film was measured at rod temperatures up to 800°C. The results were the same as shown in Fig. 1.

Thus, it has been established experimentally that large thermal fluxes pass through a thin liquid film when the rate of mass transfer at its surface is high. Owing to the high thermal conductance of a thin film, it becomes unnecessary to dissipate the heat at the solid–liquid interface. For this reason, vapor bubbles do not appear even when the temperature at the heat transfer surface is high.