EXPéRIMENTAL INVESTIGATION OF THE EFFECT OF LOW-FREQUENCY FLUCTUATIONS OF THE LIQUID FLOW RATE ON THE MINIMUM IRRIGATION DENSITY IN FILM FLOW

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It is shown that when low-frequency fluctuations (3-7 Hz) are imposed on a stream of liquid being fed to a channel, the minimum irrigation density in the film is reduced by a factor of 2-3 times compared with the case of non-fluctuating flow.

One of the fundamental technical characteristics of film flows and disperse-film flows is the existence of a minimum irrigation density [1]. This characteristic determines the conditions for the wetting of heat transfer surfaces by the liquid and has an important effect on heat transfer to the film, the value of the maximum wall temperature, and the critical heat flux corresponding to the occurrence of a heat transfer crisis of the second type.

A number of papers have dealt with experimental and theoretical investigations of the minimum irrigation density [2-6]. All the authors have mentioned the important effect on the value of the minimum irrigation density of the kinetic energy of the film flow and the surface tension energy at the interface. Different irrigation densities have been noted corresponding to the onset of breakup of the film, and irrigation densities at which dry spots which have formed are eliminated.

This difference, which is explained by the hysteresis of the wetting contact angle, amounts to 450-1200% or more, and depends on the temperature of the liquid at the inlet, the temperature difference at the inlet between the wall and the film, the roughness and cleanliness of the material of the surface being wetted, and the construction of the distributing device.

For improving the wetting of dry surfaces by irrigation, recommendations have been made to use shaking [4] or vibration of the film equipment, or a brief considerable increase in the irrigation density [5].

It is obvious that all these measures are aimed at increasing the kinetic energy of the film flow to a value which exceeds the energy of the surface tension forces at the interface. At the same time, these methods of improving the wettability are very technologically inefficient, and often reduce the reliability of the equipment.

The present paper presents the results of an investigation of the possibility of increasing the kinetic energy of a wavy film flow by means of artificial perturbations imposed on the liquid stream by a bellows pulsator.

Fig. 1. Experimental loop: 1) experimental channel; 2) thermostat; 3) pump; 4) control valve; 5) electric rotameter; 6) slot distributing device; 7) pulsator; 8) reducer; 9) oscillating crank drive; 10) electric motor; 11) heater; 12) thermal insulation; 13) film thickness probe; 14) electrical bridge; 15) oscillograph; 16) recorder; 17) auxiliary instrument; 18) frequency meter; 19) electric drive for agitator; 20) cooler; 21) industrial heater; 22) agitator.

Fig. 2. Spectral power densities of the film thickness perturbations (Re = 750): 1) free flow of the liquid; 2) \( f_n = 3.8 \) Hz; 3) \( f_n = 5.2 \) Hz; 4) \( f_n = 7.2 \) Hz. \( S(f), \text{mm}^2/\text{sec}; f, \text{Hz}. \)

The investigations were carried out in the experimental loop shown in Fig. 1. Liquid flow rate \( G_0 \) was varied over the range \((0.2-10) \times 10^{-5} \text{m}^3/\text{sec}\), which corresponded to a change in the irrigation density \( \Gamma_0 \) over the range \((0.2-10) \times 10^{-4} \text{m}^2/\text{sec}\). The heat flux density on the heated section was not varied in the course of the experiment, and was kept equal to \( 1.2 \times 10^5 \text{W/m}^2 \).

The frequency of the imposed fluctuations \( f_n \) was varied from 0 to 8.0 Hz. The amplitude of the fluctuation amounted to 0.1 \( G_0 \).

The instantaneous liquid film thicknesses were measured in the course of the experiments by means of a conductometric probe [6]. The moment at which film breakdown occurred was determined visually and by the use of cinephotography.

The investigations were carried out according to the following procedure: a liquid flow rate in the film was established in the absence of superimposed fluctuations and the heat flux density was established also. The liquid flow rate was then gradually reduced up to the moment of formation of a dry patch on the channel surface. (The flow rate corresponding to the onset of rupture of the film was determined.) Subsequently, the flow rate was gradually increased as far as the moment of disappearance of the dry patch from the surface (and the flow rate corresponding to the disappearance of the dry patch was recorded).

The measurements with the superimposition of fluctuations were carried out in this same sequence.

Measurements of the liquid film thickness \( \delta \) were made at the liquid temperature corresponding to the conditions with heat transfer, but these measurements were carried out in the absence of the heat flux.