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BRIEF COMMUNICATION

EFFECT OF SURFACE ROUGHNESS ON THE REWETTING PROCESS

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INTRODUCTION

Among the many variables which affect the rewetting process, the role of surface roughness has received relatively little attention. The surface roughness of the wall may affect the heat transfer distribution in the region of the propagating rewetting front and probably also the rewetting temperature.† However, whether or not it may significantly affect the rewetting velocity itself is still not clear.

A rough surface, as compared to a smoother one, has a larger surface area and generally a greater number of active sites from which nucleation can start. These factors usually produce a higher heat transfer rate in the nucleate boiling region. This has been confirmed by many experiments, but there seems to exist a critical roughness size above which the effect becomes asymptotic (Kurihara & Myers 1960).

Experimental studies on top-flooding processes showed that the surface condition could change rewetting rates. Piggott & Porthouse (1973) and Yu *et al.* (1977) reported that during their early test runs, rewetting velocities showed progressive improvement with time, but then subsequently remained consistent. These investigators concluded that the effect was due to initial surface oxidation.

Contrary to this, the results of Lee *et al.* (1982) showed that the rewetting rate progressively deteriorated during the first few days of the experiment after a new test-section was installed (following the initial cleaning procedure). Subsequently, the rewetting rate remained practically constant.

The effect must be due to a "deposit" on the surface of the test-sections. The deposit affects the rewetting results in two ways: firstly, it alters the thermal properties of the test-section surface; and secondly, the number of active nucleation sites on the surface. Since the effects of both of these are difficult to predict, it is not possible to predict how they would affect the rewetting rate itself.

Piggott & Porthouse (1973) artificially changed the nature of the surfaces of two relatively short test-sections (0.20 and 0.225 m) by shot blasting and silver plating. They concluded that the shot blasting increased the rewetting velocity by a factor of 3 while silver plating halved the rewetting velocity, and that the increase is due to the increase in the number of active nucleation sites in the heating surface.

Presented herein are the experimental results on the role of surface roughness solely in the process of the rewetting of hot surfaces by falling film and by bottom flooding.

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†The apparent rewetting temperature in the present paper is defined as the temperature of the intersection of the tangent to the temperature–time trace at the beginning of the steepest portion of the fall. This definition was also used by other workers (e.g. Piggott & Porthouse 1973) and corresponds to the definition of "upstream wall temperature" unaffected by axial conduction, as used by Yu *et al.* (1977).

EXPERIMENTAL APPARATUS AND PROCEDURE

The details of the rewetting test loop used in the study are essentially the same as those reported by Lee *et al.* (1982). The main experimental loop consisted of two sections, one fixed to the laboratory floor and the other on a pivotable mounting which allows experiments to be carried out on test-sections of circular or annular cross-section of up to 4 m in length, at any angle between the vertical and horizontal.

The fixed section consists of a water demineralizer, preheater, main supply boiler and three different size flowmeters. The movable section consists of a by-pass circuit, the test-section, a pair of quick acting valves to divert the coolant flow to or away from the test-section, a condenser and a reverse tank for the coolant. Test-sections may have removable outer jackets, thermocouples spot-welded along the inner wall of the test-sections. The loop had other usual peripherals including a high-speed data acquisition system and a 150 kVA power supply.

For the falling film ("unconfined") flooding experiment, the loop was modified so that coolant could be injected along the outside surface of circular test tubes, through a special coolant injection nozzle assembly. The test-sections for the falling film experiment were made of S.S. 304 tubings with outside and inside diameters of 15.9 and 13.5 mm, respectively. Six chromel–alumel thermocouples were spot-welded onto the inside wall surface. To avoid or minimize bowing of the test-sections due to asymmetric thermal expansion and/or contraction during the test, tension of about 500 N was applied between the ends of the test-section.

The outer tube of the annular test-sections used for the bottom ("confined") flooding experiment was made of tempered glass tubing having an inside diameter of 40.4 mm. The core tubes were the same test-sections used in the falling film experiment.

Surface roughness was created by sand blasting (roughness of 1.7 μm, r.m.s.) and by mechanical knurling (roughness of 6.4 μm, r.m.s.). The roughness of the polished test-section was 0.38 μm, r.m.s.

The procedures for tests and data reduction are similar to those reported by Lee *et al.* (1982).

RESULTS AND DISCUSSIONS

Figure 1 illustrates the effect of surface roughness on rewetting velocity in both the falling film and bottom flooding experiments, respectively. It can be summarized that at high coolant injection rates, the surface roughness affects the rewetting velocity to a certain extent, especially at high initial

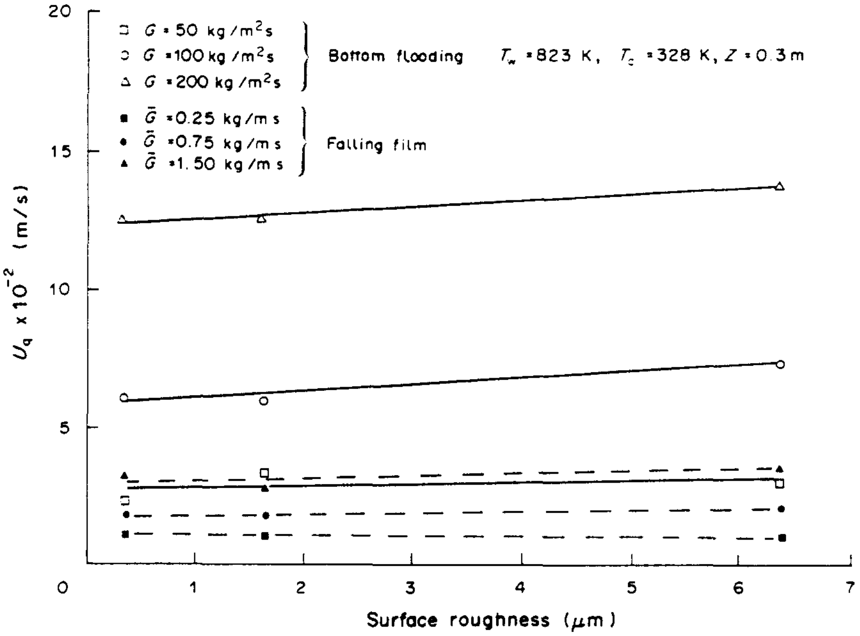

Figure 1. Rewetting velocity.

wall temperatures with large coolant subcooling. However, the increase by a factor of 2 or 3 reported by Piggott & Porthouse (1973) was never observed in our experiments. Otherwise, the effect is seen to be almost negligible.

The trends seen in figure 1 should preferably be looked at from the viewpoint of the heat transfer processes involved during the rewetting transient; i.e. in terms of the two conveniently deducible parameters which bring about the rewetting phenomena: the distribution of heat transfer coefficients and the rewetting temperature.

Rewetting temperature

The deduced rewetting temperature at different coolant mass flow rates for the three test-sections of differing surface roughness has shown that only at very high initial wall temperatures with relatively small coolant mass flow rates, is the effect of surface roughness noticeable in both modes of flooding; the larger the value of surface roughness, the lower the rewetting temperature, implying that, other parameters being equal, this would result in higher rewetting velocity, as already seen in figure 1. Otherwise, the effect of surface roughness on the rewetting temperature seems to be negligible.

The effect of the surface roughness at different values of the initial coolant subcooling was also seen to be negligibly small in both flooding modes.

Heat transfer coefficient distribution

The surface heat flux distributions deduced from the temperature–time traces obtained during the rewetting processes, for both falling film and bottom flooding experiments, are shown in figures 2 and 3, respectively.

It has been shown by Lee *et al.* (1982) that the mechanism of rewetting in falling film (unconfined) is quite different from that of bottom flooding (confined). This is clearly seen in figures 2 and 3.

In both cases, the surface heat flux distribution, and therefore the heat transfer coefficient distribution, in the "wet region" are significantly affected by the surface roughness. However, in the "dry region", the effect of surface roughness was not noticeable for bottom flooding.

The qualitative effect of surface roughness on the rewetting velocity can be deduced from the information shown in figures 2 and 3, through one- or two-dimensional analyses available in the literature. These analyses imply that the lower the rewetting temperature and/or the higher the effective average heat transfer coefficient, the smaller the resulting rewetting velocity.

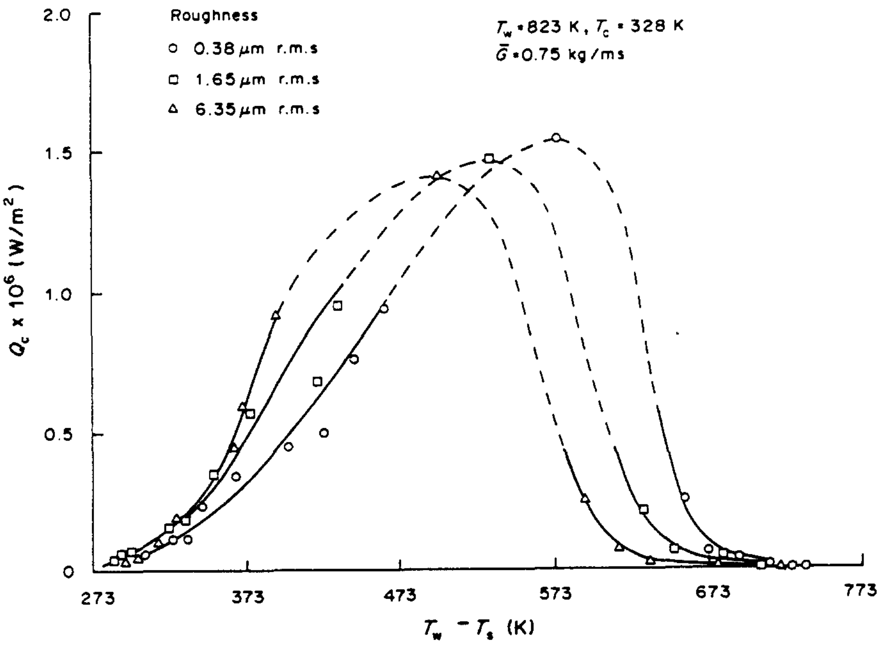

Figure 2. Surface heat flux distribution, falling film.

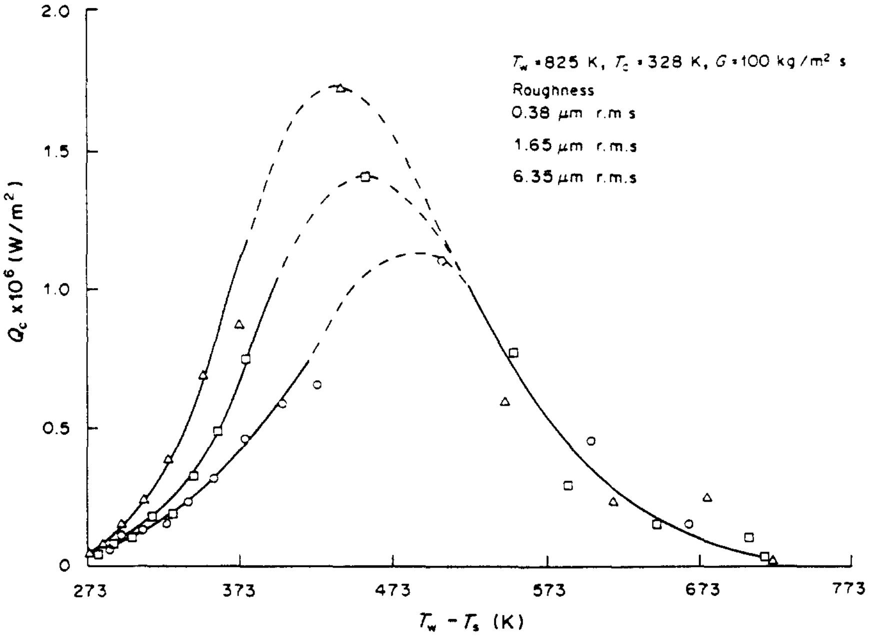

Figure 3. Surface heat flux distribution, bottom flooding.

In falling film rewetting processes, larger surface roughness results in low rewetting temperatures but with smaller average heat transfer coefficients. These opposing effects seem to have almost balanced each other out—the effect of surface roughness on the rewetting velocity was seen to be hardly noticeable, as shown in figure 1.

In bottom flooding rewetting processes, since the two-phase flow heat transfer coefficients behind the rewetting front ("wet region") can hardly affect the rewetting process in confined flooding cases (Kim & Lee 1982), and the effect of surface roughness on the heat transfer coefficient distribution in the "dry region" seems to be very small, it may be deduced that the effect of the surface roughness must be insignificant, except for cases of very high initial wall temperature. This is again clearly demonstrated in figure 1.

CONCLUSIONS

The present experimental results showed that the effect of surface roughness on the rewetting velocity is very small for both falling film and bottom flooding.

NOMENCLATURE

G = Coolant mass flow rate, kg/m s
$\bar{G}$ = Coolant mass flow rate, kg/m^2 s
Q_c = Surface heat flux, W/m^2
T_c = Coolant inlet temperature, K
T_q = Rewetting temperature, K
T_s = Coolant saturation temperature, K
T_w = Channel initial wall temperature, K
U_q = Rewetting velocity, m/s
Z = Axial distance from the inlet, m

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