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LETTER TO THE EDITORS

EFFECT OF VARYING GRAVITATIONAL FIELD ON CONDENSATION OVER VERTICAL PLATES

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NOMENCLATURE

- A, constant $4\mu k(T_d - T_0)/\rho^2 \Delta H$;
- a, gravitational acceleration at the leading edge of the plate;
- b, parameter in the representative variation of gravity;
- g, gravitational acceleration;
- h, local heat-transfer coefficient;
- h_m, average heat-transfer coefficient;
- k, thermal conductivity;
- L, length of the plate;
- Nu_x, local Nusselt number for varying gravitational field;
- $\bar{N}u_x$, local Nusselt number when $g = a$;
- Nu_{av}, average Nusselt number for varying field;
- $\bar{N}u_{av}$, average Nusselt number for constant field, $g = a$;
- T_d, T_0, constant temperatures at the surface of film and wall respectively;
- U, average velocity of condensate in the film;
- x, co-ordinate parallel to the plate and measured from the leading edge where condensation starts.

THE CONVENTIONAL film condensation equations are integrated with the usual assumptions [3] following an analysis on free convection by Lemlich [1] and Catton [2]. With the average velocity in the film given by $U = \dfrac{\rho g \beta^2}{3\mu}$ which is derived for a fully developed (non-acceleration) flow, the film thickness β is solved, as

$$\beta = \frac{A^{\frac{1}{4}}\left(\int_0^x g^{\frac{1}{3}}\, dx\right)^{\frac{1}{4}}}{g^{\frac{1}{3}}}. \tag{1}$$

From this, the following equations are derived for linear and exponential variations of gravitational field.

$$\frac{Nu_x}{\bar{N}u_x} = \frac{4}{3}\left[\frac{b}{a}x \Big/ 1 - \left(1 + \frac{bx}{a}\right)^{-\frac{4}{3}}\right]^{\frac{1}{4}} \tag{2}$$

$$\frac{Nu_x}{\bar{N}u_x} = \exp\left(\frac{bx}{3}\right)\left[\frac{bx}{3} \Big/ \exp\left(\frac{bx}{3}\right) - 1\right]^{\frac{1}{4}} \tag{3}$$

$$\frac{Nu_{av}}{\bar{N}u_{av}} = 1 + \tfrac{1}{7}bL. \tag{4}$$

The following conclusions are drawn from the above equations.

(i) From equation (2), the increase in Nusselt number is dependent on $(b/a)\,x$ and is small compared to the increase in acceleration.

(ii) For exponential variation of gravity, equation (3) shows the increase in Nusselt number or heat transfer coefficient to be strongly dependent on b, i.e. independent of the acceleration at leading edge. The ratio of average heat transfer coefficients varies linearly with L for bL less than 1. If $bL = 1$, 14 per cent increase in average transfer factor can be achieved.

(iii) From equation (1) it may be shown that a maximum value of β exists at $bx = 0{\cdot}86$ for $g = a \exp(bx)$. Hence local heat transfer coefficients increase after $bx = 0{\cdot}86$ which is not visualised for uniform gravitational field. This gives an insight into the opposing processes of condensation and gravitation. The effect of a linear variation in gravity is to decrease the film though the controlling factor is the condensation process.

However, when the field changes non-uniformly (as an exponential variation) the processes oppose each other up to $bx = 0{\cdot}86$. Up to this point, the effects of variations in gravity are similar to those for a linear variation, but after this point the gravitational field controls the heat transfer rate.

REFERENCES

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