8. V. M. Borishanskii, in: Heat Transfer and Aerohydrodynamics [in Russian], Vol. 28, Mashgiz, Moscow (1955).
9. S. S. Kutateladze, Fundamentals of the Theory of Heat Exchange [in Russian], Nauka, Novosibirsk (1970).

PROBLEM OF CONSIDERING THE EFFECT OF SUPERHEATING OF VAPOR ON INTENSE CONDENSATION PROCESS OF VAPOR FLOW ON A PLATE

I. G. Shekriladze

UDC 536.423.4

The effect of superheating of vapor on the intense condensation process of vapor flow on a plate is analyzed.

In the analysis of the process of film condensation of moving vapor the elucidation of the role of such secondary factors as the superheating of the vapor, the impurity of the noncondensing gas, etc., is of certain interest. The numerical solutions given in [1] are devoted to the effect of these factors on the intensity of heat transfer in the case of an isothermal plate.

The object of the present investigation is to analyze the effect of superheating of vapor on the heat transfer from a moving vapor to a plate under conditions of intense condensation at constant heat flux.

As is well known [2, 3], near the front edge of the plate the velocity profiles in the vapor phase under conditions of sufficiently intense condensation at constant heat flux correspond with a good accuracy to the asymptotic profile of Meredith and Griffith for a boundary layer with homogeneous suction [4]. The consideration of the effect of superheating of the vapor under such conditions amounts to the analysis of the temperature field in the dynamic boundary layer of Meredith and Griffith with certain assumptions.

If the compressibility of the vapor and the heat release due to friction are neglected, then the equations for the boundary layer for plane motion are written in the following well-known form:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0,$$

$$\rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = \mu\frac{\partial^2 u}{\partial y^2}, \tag{1}$$

$$\rho C_p\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = \lambda\frac{\partial^2 T}{\partial y^2}.$$

We shall assume that the condition of constancy of heat flux at the wall (q = const) corresponds to homogeneous suction of the boundary layer $v = -v_0 =$ const [4],* where in the notation used here v_0 is a positive quantity. System (1) is accordingly simplified:

*This condition is satisfied rigorously for the condensation of the saturated vapor when the heat flux is completely determined by the condensed mass. In the case of superheated vapor this assumption will be strictly correct only in the case when the heat flux caused by the superheating of the vapor will be constant over the length of the plate.

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 30, No. 4, pp. 598-600, April, 1976. Original article submitted January 9, 1974.

This material is protected by copyright registered in the name of Plenum Publishing Corporation, 227 West 17th Street, New York, N.Y. 10011. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission of the publisher. A copy of this article is available from the publisher for $7.50.

$$v = -v_0 = \text{const},$$

$$u = F(y),$$

$$\frac{d^2T}{dy^2} + \frac{\rho C_p v_0}{\lambda} \frac{dT}{dy} = 0. \tag{2}$$

For the analysis of the temperature field in the vapor phase the following thermal conditions are specified:

$$T = T_s \text{ for } y = 0,^* \quad T = T_v \text{ for } y = \infty. \tag{3}$$

Applying the well-known methods of solving an ordinary differential equation with constant coefficients, for the temperature field we obtain

$$T = T_v - (T_v - T_s) \exp\left(-\frac{\rho C_p v_0}{\lambda} y\right). \tag{4}$$

The heat flux from the superheated vapor to the surface of separation of the phases is

$$q = -\lambda \left.\frac{dT}{dy}\right|_{y=0} = \rho C_p \Delta T_v v_0. \tag{5}$$

Thus, the heat flux from the superheated vapor under the investigated conditions is completely determined by the enthalpy of superheating of the condensing vapor and is constant along the length of the plate, which confirms the validity of the assumption v_0 = const.

The velocity v_0 itself, which is an unknown quantity because of the presence of superheating of the vapor, will according to the obtained solution be equal to

$$v_0 = \frac{q}{\rho(r + C_p \Delta T_v)}. \tag{6}$$

Thus, the effect of superheating of vapor under the investigated condensation conditions is equivalent to an increase of the latent heat of condensation by the amount of the enthalpy of the superheating of the vapor. A change of this quantity under conditions of intense condensation of vapor of an ordinary liquid on the plate does not effect the magnitude of the heat-transfer coefficient determined from the saturation temperature of the vapor [2, 3]. Therefore, in the investigated cases the effect of superheating appears only in the amount of condensed vapor.

NOTATION

x, longitudinal coordinate; y, transverse coordinate; u, longitudinal velocity component; $v = -v_0$, transverse velocity component; ρ, vapor density; λ, thermal conductivity of a gas; r, latent heat of condensation; T_v, vapor temperature at a distance from a plate; T_s, saturation temperature; ΔT_v, temperature drop between the interface and superheated vapor, $\Delta T_v = T_v - T_s$; q, heat flux.

LITERATURE CITED

1. W. J. Minkowich and E. M. Sparrow, Intern. J. Heat Mass Transfer, 12, No. 2, 147-154 (1969).
2. I. G. Shekriladze, Soobshch. Akad. Nauk GruzSSR, 35, No. 3, 619-626 (1964).
3. J. G. Shekriladze and V. J. Gomelauri, Intern. J. Heat Mass Transfer, 9, 581-591 (1966).
4. H. Schlichting, Boundary Layer Theory, 6th ed. McGraw-Hill (1968).

*The thermal boundary conditions specified for the condensation process (q = const) for the vapor phase can serve only as a basis for taking the dynamic conditions $v = -v_0$ = const. The thermal boundary condition of the vapor boundary layer is determined by the temperature of the surface of separation of the phases which leads to the condition of isothermality of the surface of cooling of the vapor.