and longitudinal spacing of the vortex street, respectively, mm; \(c_v\), vortex velocity, m/sec; \(\Gamma\), vortex circulation, \(m^2/sec\); \(a\), amplitude of oscillogram of density-gradient pulsations in a wake with a body behind a model; \(a_0\), amplitude of oscillogram of density-gradient pulsations in an unperturbed wake; \(\gamma\), intermittence factor of the vortex street structures; \(T\), duration of continuous vortex street, sec; \(\Sigma T\), total time of recording of vortex convergence process, sec; \(n\), frequency of vortex convergence, 1/sec; \(c\), flow velocity, m/sec; \(\sqrt{\rho_0}\), mean amplitude of pulsations in base pressure of model with a body in its wake, Pa; \(\sqrt{\rho_{00}}\), mean amplitude of pulsations of base pressure of model with an unperturbed wake, Pa; \(P_b\), base pressure of model with a body in its wake, Pa; \(P_{b0}\), base pressure of model with an unperturbed wake, Pa; \(\Delta P\), mean amplitude of pressure pulsations at the forward stagnation point of a cylinder located in the model wake, Pa; \(\Delta P_{00}\), mean amplitude of pressure pulsations at the forward stagnation point of a cylinder located outside the model wake, Pa; \(x_0\), distance between model and a body in its wake corresponding to a resonance increase in pulsation amplitude, mm; \(a\), speed of sound, m/sec; \(M\), Mach number; \(Re = \frac{Lc}{\nu}\), Reynolds number; \(Sh = nH/c\), Strouhal number; \(A = \frac{\sqrt{\rho}}{\sqrt{\rho_0}}\), relative amplitude of base-pressure pulsations of the model; \(A_1 = \frac{\sqrt{\rho}}{\sqrt{\rho_{00}}}\), relative amplitude of pressure pulsations at the forward point of the cylinder; \(\varepsilon = \frac{P_b}{P_{b0}}\), relative base pressure of model.

LITERATURE CITED


D. B. Vafin, A. F. Dregalin, and A. B. Shigapov

Results are presented of a calculation of the heat radiation from a two-phase mixture in Laval nozzles in unidimensional and two-dimensional formulations.

The motion of a two-phase mixture in curved channels such as are present in Laval nozzles is characterized by substantial longitudinal and transverse gradients of the gasdynamic parameters in the transonic and supersonic flow regions. The radiation properties of both the gas phase and the particles of the condensed phase depend on the gasdynamic and thermodynamic characteristics of the medium. As a result, significant optical discontinuities occur both along and across the flow in Laval nozzles. Certain studies conducted in a two-dimensional approximation [1-3] show that errors may result from calculating the radiation from two-phase media in a unidimensional formulation of the problem of radiative heat transfer in the presence of substantial optical discontinuities or without allowance for the actual shape of the radiating volume.

Described below is a method of calculating the heat radiation from two-phase flows in axisymmetrical volumes with smooth diffuse-reflecting and radiating sides of arbitrary form. To describe the radiant energy transfer process, we used two-dimensional equations of the \(P_3\)-approximation of the spherical harmonics method. Calculations in a unidimensional formulation were performed in the \(P_3\)-approximation for an infinite cylinder.

Figure 1 shows the diverging part of the Laval nozzle and the coordinate system for the problem being examined. The region of integration is given by the equation of the generatrix $R = f(x)$, the minimum cross section $R_0$, and the nozzle length $L$.

Using the $P_1$-approximation, we can obtain a system of differential equations in partial derivatives describing radiant energy transfer in the axisymmetrical absorbing and anisotropically scattering volumes:

$$
\frac{\partial q_{\lambda x}(r, x)}{\partial r} + \frac{\partial q_{\lambda x}(r, x)}{\partial x} + \frac{q_{\lambda x}(r, x)}{r} + \alpha_{\lambda}(r, x) c_{\lambda} U_{\lambda}(r, x) = \eta_{\lambda}(r, x),
$$

$$
\frac{\partial U_{\lambda}(r, x)}{\partial r} + 3 K_{1\lambda}(r, x) q_{\lambda x}(r, x) = 0,
$$

$$
\frac{\partial U_{\lambda}(r, x)}{\partial x} + 3 K_{1\lambda}(r, x) q_{\lambda x}(r, x) = 0.
$$

System (1) is supplemented by the following boundary conditions on the symmetry axis

$$
\frac{\partial U_{\lambda}(r, x)}{\partial r} = 0
$$

and on the bounding surfaces

$$
c_{\lambda}(1 - r_w) U_{\lambda}(r, x) + 2 \sin \alpha (1 + r_w) q_{\lambda x}(r, x) - 2 \cos \alpha (1 + r_w) q_{\lambda x}(r, x) = 4 \pi \varepsilon_w I_{\lambda}(T_w) \quad \text{at} \quad r = R,
$$

$$
c_{\lambda}(1 - r_w) U_{\lambda}(r, x) + 2 (1 + r_w) q_{\lambda x}(r, x) = 4 \pi \varepsilon_w I_{\lambda}(T_w) \quad \text{at} \quad x = 0,
$$

$$
c_{\lambda}(1 - r_w) U_{\lambda}(r, x) - 2 (1 + r_w) q_{\lambda x}(r, x) = 4 \pi \varepsilon_w I_{\lambda b}(T_w) \quad \text{at} \quad x = L.
$$

Boundary conditions (3) were obtained in the form of conditions for diffuse-reflecting and radiating nonconcave surfaces in [4].

With the assignment of the temperature field and radiation characteristics of the medium and bounding surfaces, system (1) together with the boundary conditions (2) and (3) unambiguously define the flux density of the spectral radiation $q_{\lambda}(r, x)$.

To construct a difference grid, we connect the position of the boundaries with a curvilinear coordinate system in which the boundaries of the region are the coordinate lines. Then, in the curvilinear system of coordinates $(\xi, \eta)$, the region is a rectangle (Fig. 1).