Further, Eqs. (29)-(31) give
\[
\left(\frac{\rho_1^0 \alpha_1 + \rho_2^0 \alpha_2}{m_1 + 1}\right) \left(\frac{\rho F_i}{k_1}\right)^{\frac{1}{n_1}} \delta_1^{2m_1 + 1} \frac{\delta_2^{2m_1 + 1}}{2\pi k_1} = -\frac{q_1 + q_2}{2\pi},
\]

(33)

\[
\left(\frac{\rho_1^0 \alpha_1}{2m_1 + 1}\right) \left(\frac{\rho F_i}{k_1}\right)^{\frac{1}{n_1}} \delta_1^{2m_1 + 1} = -\frac{q_1}{2\pi},
\]

(34)

from which \(\delta_2(t)\) and \(\alpha_2(t)\) are determined.

Note that if pure liquid flows over the rotor surface, Eq. (32) becomes the solution obtained in [4].

It is also possible to use the Rakhmatulin interpenetration model, together with experimental data, to calculate the flow of materials in other mixers, centrifuges, centrifugal diffuser-atomizers, etc.

**NOTATION**

\(V_j\), \(\rho_j\), \(\alpha_j\), velocity, mean density, and concentration (by volume) of the j-th phase; \(\rho_j^0\), true density of the j-th phase; \(\mathbf{T}_j\), liquid stress tensor; \(F_j\), mass force acting on the j-th phase; \(\gamma^{ki}\) and \(\epsilon^{ki}\), stress and strain-rate tensors; \(f_{12}\), phase-interaction force; \(P\), pressure; \(R\), radius of conical rotor channel; \(x^4\), orthogonal coordinates; \(\rho\), density and velocity of mixture; \(\eta\), effective liquid viscosity; \(d\), characteristic dimension of solid particles; \(\omega\), angular velocity of rotor; \(k\), \(k^*\), \(n\), \(m\), \(m_1\), \(k_1^*\), power-law parameters for liquid and mixture; \(\alpha\), semivertex angle of conical channel; \(W\), collective rate of settling of solid particles; \(\Phi_0\), factor determined by the shape of the solid particles; \(q_j\), mass flow rate of j-th phase; \(r = R - R\cos\alpha\), distance from axis of rotor rotation to an arbitrary point; \(\rho_{20}\), bulk density of solid phase.

**LITERATURE CITED**


**CHARACTERISTICS OF FLOW BETWEEN A ROTATING AND A STATIC DISK IN THE PRESENCE OF RADIAL FLOW**

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An improved method is proposed for the calculation of the flow in the gap between a rotating and a static disk in the presence of radial flow. The algorithm of the solution is realized on a Nairi-2 computer.

To solve a number of problems associated with the hydraulic circulation section of a multistage turbine with disk rotors and, in particular, to calculate the axial forces and temperature state of the rotors of a steam turbine, it is necessary to know the radial distribution of the pressure of the medium in the gap between a rotating disk and the corresponding static element (diaphragm, casing). An approximate solution of this problem was obtained in [1] and subsequently refined in [2-4]. In [5], there was further development of the method of calculating the pressure distribution along the disk radius in the presence of radial flow, but the
velocity profile used for the flow in the gap led, under certain conditions, to the appearance of negative values of the flow swirl, which is inconsistent with the physical interpretation of the problem. Consequently, the agreement between the results obtained according to [5] and experimental data is limited [6].

In [6], on the basis of a theoretical analysis and experimental data, a calculation based on similarity theory was proposed. However, this approach requires the availability of data obtained in model experiments.

In a number of works — in particular, [7] — it has been shown by experiment and calculation that in a broad range of radial flow rates the profile of the radial component of the flow velocity is analogous to the velocity profile in a radial diffuser. In the present paper, this analogy is applied to the calculation of the radial pressure distribution in the gap between a rotating and a static disk.

It is assumed that the medium in the gap between the disks is incompressible and that the flow is axisymmetric. In the case when the gap between the disks is narrow, i.e., the width $s$ is considerably less than the length $r_2 - r_1$, the time-averaged turbulent flow in the gap can be described by the equations

$$\frac{1}{r^2} \frac{d}{dr} \int_0^r c_r^2 dz = \frac{1}{r^2} \int_0^r c_z^2 dz = -\frac{s}{\rho} \frac{dp}{dr} + \frac{\tau_{tr}}{\rho}$$

(1)

$$\frac{1}{r^2} \frac{d}{dr} \int_0^r c_z^2 dz = \frac{\tau_{tr}}{\rho}$$

(2)

$$2\pi r \int_0^r c_r dz = q$$

(3)

Following [5], it is assumed that if the relative gap $\bar{s} = s/r_2 \leq 0.1$, the flow between the disks is viscous, i.e., there is no potential nucleus of the flow, and that the boundary layers at the rotating and static disks are of thickness $\delta = \delta' = s/2$. In accordance with the results of [7], the profiles of the azimuthal and radial velocity components are written in the following form: close to the rotating disk,

$$c_\varphi = \omega r \left[ 1 - \left(1 - y \right) \left( \frac{z}{\delta} \right)^{\frac{1}{n}} \right]$$

$$c_r = c_r \left( \frac{z}{\delta} \right)^{\frac{1}{n}}$$

(4)

and close to the wall (static disk),

$$c_\varphi = \omega r y \left( \frac{s - z}{\delta} \right)^{\frac{1}{n}}$$

$$c_r = c_r \left( \frac{s - z}{\delta} \right)^{\frac{1}{n}}$$

(5)

The stress-tensor components and the components of the flow velocity for the tube are related by a power law with index $1/n$ [8]:

close to the disk,

$$\frac{w}{c^*} = A_1 \left( \frac{c_r}{v} \right)^{\frac{1}{n_1}}$$

(4a)

and close to the wall,

$$\frac{u}{c^*} = A_2 \left[ \frac{c^*(s - r)}{v} \right]^{\frac{1}{n_2}}$$

(5a)

Let $\alpha$ denote the ratio of the radial and azimuthal components of the relative velocity and the corresponding stress-tensor components in the boundary layer close to the disk:

$$\alpha = \frac{c_r}{c_\varphi} = \frac{\tau_{tr}}{\tau_{tr}}$$