acteristics. However, the discovery of these defects enables one to concentrate attention on the zones which need particular care during tests and debugging the design.

The reported results show that the preliminary flow visualization in the models of laser pumping loops considerably simplifies the work and makes it possible to avoid mistakes at the stage of developing and designing a laser. The design procedure is very simple and the consumed time and capital outlays are incomparably lower than those related with adapting a loop from the unsuccessfully designed one. In modernizing the available lasers, hydraulic modeling is an effective tool for obtaining the desired result with minimally changing the design.

**NOTATION**

D, inner diameter of the vane array of the rotor; L, length of the vane array along the axis of rotation; U, peripheral velocity of the rotor.

**LITERATURE CITED**


**THE KINETIC MODEL OF PARTICLE TRANSFER IN TURBULENT FLOWS WITH CONSIDERATION OF COLLISIONS**

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The work presents the kinetic model of particle dynamics in turbulent flows taking into consideration inelastic collisions. Transfer coefficients of the dispersed phase in constrained flows are found on the basis of this model.

To describe a particle movement in rarefied dispersed flows (i.e. for low volume concentration of the dispersed phase), greater attention should be paid to the interaction between particles and turbulent pulsations of the carrier flow, since the role of collisions between the particles proper is not essential. The kinetic equation for the probability density function [PDF] of the particle velocity in turbulent flows without taking account of collisions was obtained in [1, 2]. For large particles ($\tau T \gg 1L$) in an isotropic turbulent flow this equation develops into the known Fokker–Planck equation for the Brownian movement [3, 4]. A solution of the equation for the PDF can be constructed with the help of the perturbation method [4-6] widely used in the kinetic theory of gases for the solution of the Boltzmann equation [7, 8]. On the contrary, in the case of the analysis of particle dynamics in sufficiently dense dispersed flows the collisions of particles between themselves play a determining role. An elementary kinetic theory of highly concentrated dispersed systems is formed in [9]. Studies [10, 11] offer the kinetic models of particle transfer in dispersed flows, based on the solution of the Boltzmann equation by the perturbation method and further developing

the Enskog approach for dense gases for the case of inelastic particle collisions. The present work proposes a kinetic model for
describing particles in turbulent flows taking into consideration their interaction during collisions, which generalizes the results

The equation for the PDF of the velocity of large particles disregarding their rotation can be presented in the form

\[ T[F] + J[F, F] = N[F], \]

\[ T[F] = \frac{D}{\tau^2} \frac{\partial^2 F}{\partial v_h \partial v_h} + \frac{1}{\tau} \frac{\partial (v_h - V_h) F}{\partial v_h}, \]

\[ N[F] = \frac{\partial F}{\partial t} + v_h \frac{\partial F}{\partial x_h} + \left( \frac{U_h - V_h}{\tau} + \hat{f}_h \right) \frac{\partial F}{\partial v_h}. \]  

(1)

Here \( T[F] \) is the operator, describing the particle interaction with the carrier turbulent flow; \( J[F, F] \) is the Boltzmann
operator of collisions in the Enskog form [7], and \( N[F] \) is the convective operator, defining the deviation of the probability
density of the particle velocity from the equilibrium Maxwellian distribution.

The integration of Eq. (1) in the velocity space can result in equations for the concentration, mean velocity, and
pulsation energy of the dispersed phase. The equation for the volume concentration of particles has the form

\[ \frac{\partial \varphi}{\partial t} + \frac{\partial q V_h}{\partial x_h} = 0. \]

\[ \varphi = \int F dv, \quad V_i = \int v_i F dv / \varphi. \]  

(2)

Let us write the equation for the dispersed phase movement:

\[ \frac{\partial V_i}{\partial t} + V_h \frac{\partial V_i}{\partial x_h} = \frac{U_i - V_i}{\tau} + \hat{f}_i - \frac{1}{\varphi} \frac{\partial P_{ih}}{\partial x_h}. \]  

(3)

Here \( P_{ij} = P_{ij}^k + P_{ij}^c \) is the total stress tensor in the dispersed phase; \( P_{ij}^k = \varphi(v_i^i'v_j^j) \) are the stresses caused by the kinetic
pulsation movement of particles, and \( P_{ij}^c \) are the stresses, which define the momentum transfer during particle collisions.

The equation of the balance of the particle kinetic pulsation energy has the form:

\[ \frac{\partial q_{kp}}{\partial t} + \frac{\partial q V_h \delta_p}{\partial x_h} = P_{ih} \frac{\partial V_i}{\partial x_h} + \frac{\varphi}{\tau} \left( 3 \frac{D}{\tau} - 2k_p \right) \frac{\partial q_h}{\partial x_h} - Q. \]  

(4)

The first term on the right side of Eq. (4) describes the generation of the dispersed phase pulsation energy from the
mean movement due to the velocity shift. The second term defines the pulsation energy exchange with the turbulent carrier flow.
The third term describes the pulsation energy diffusion transfer. The quantity \( Q \) determines the pulsation energy dissipation due
to particle collisions. The total pulsation energy flux \( q_i = q_i^k + q_i^c \) is combined from the kinetic part \( q_i^k = \varphi(v_i^i'v_h^h')/2 \) and
from the term \( q_i^c \), stipulated by particle collisions.

It should be noted that the division of the stress tensor and pulsation energy flux into the kinetic part and the part
stipulated by collisions is arbitrary and meaningful from the procedural (computational) point of view.

In accordance with the solution of the kinetic equation for dense gases by the Enskog method [7], the integral of
collisions is presented in the form


(5)

where \( J_0[F, F] \) is the Boltzmann collision integral \( (\varphi \rightarrow 0) \); \( J_1[F, F] \) is the contribution of the first terms into the expansion of the
collision integral into the Taylor series in terms of the parameter, proportional to the particle dimension, and \( Y(\varphi) \) is the
quantity which can be interpreted as the ratio of the number of particle collisions in concentrated and rarefied media.

Within the framework of the assumption of a small deviation of particle distribution from equilibrium , the solution of
Eq. (1) with allowance for (5) can be found in the form of a series \( F = F_0 + F_1 + ... \), where the functions \( F_0 \) and \( F_1 \) satisfy the
equations

\[ T[F_0] + Y J_0[F_0, F_0] = 0, \]

\[ T[F_1] + Y (J_0[F_0, F_1] + J_1[F_0, F_0]) = N[F_0] - J_1[F_0, F_0] = L[F_0]. \]  

(6)

(7)