DISTRIBUTION OF STATIC PRESSURE AND HYDRODYNAMIC RESISTANCE IN A PLANE CHANNEL WITH SEMICYLINDRICAL CORRIDOR-RANKED PROJECTIONS

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Experimental results are given for the mean hydrodynamic resistance of a channel and the distribution of the resistance over a row of projections with air flow for Re = (1.5-170)·10^3, $(s_1/d) = 1.27$, $(s_2/d) = 5.33$, 3.04, 2.13.

Intensification of heat transfer in power plants is directly linked to the efficiency of the heat-transfer surface. Broad investigation of flow and heat-transfer processes in channels of the membrane heating surfaces presumes not only study of the local heat transfer but also determining the conditions of formation of the hydrodynamic flow along the membrane surface and the loss in pressure head in contraction and expansion of the flow in the intertube space. In a plane channel with semicylindrical projections modeling the surface of a membrane heat exchanger, the hydrodynamic resistance is determined by the character of the flow. The acceleration and deceleration of the flow, breakaway and addition phenomena, the formation of vortex zones with return flow — all of these factors influence the formation of the flow structure, the level of heat transfer, and significantly the magnitude of the hydrodynamic energy losses.

In a channel of variable cross section, the static-pressure distribution of the flow is related to the change in velocity variation and the presence of irreversible energy losses Δp, so that the real (measurable) pressure difference is

$$p_2 - p_1 = (p_2 - p_1)_{id} + \Delta p = (\rho/2)(w_1^2 - w_2^2) + \Delta p, \tag{1}$$

where $(p_2 - p_1)_{id}$ is the change in static pressure for ideal flow. The irreversible energy losses consist of the frictional losses at the plane and cylindrical surfaces and the profile losses.

The irreversible energy losses of the flow may be calculated from the experimental static-pressure distribution in a channel of variable cross section. Measurements are made using pressure samples taken from the side wall of the channel, using the experimental apparatus described in [1]. Pressure sampling is through a hole of diameter 0.5 mm, and the excess pressure is measured by a standard micromanometer with an inclined tube, with subsequent conversion to absolute pressure. The experiment is conducted with a corridor configuration of semicylindrical projections in a plane channel, with an air flow. The transverse spacing is $(s_1/d) = 1.27$, and the longitudinal spacings are $(s_2/d) = 5.33$, 3.04, and 2.13.

Experimental data on the static-pressure distribution are shown in Fig. 1. As an example, the pressure distribution is given for the maximum longitudinal spacing $(s_2/d) = 5.33$. In analyzing Fig. 1, it may be noted that the minimum value of the experimental static pressure is in the narrow cross section between the projections, p_{min}. Upstream and downstream, there are maximum reduced pressure $p_{i max}$ and $p_{(i-1)max}$.

In accordance with Eq. (1)

$$\begin{aligned} p_{(i-1)\max} - p_{\min} &= (\rho/2)(w_{\min}^2 - w_{(i-1)}^2) + \Delta p_1, \\ p_{\min} - p_{i\max} &= -(\rho/2)(w_{\min}^2 - w_{(i-1)}^2) + \Delta p_2. \end{aligned} \tag{2}$$

It follows from Eq. (2) that the total irreversible pressure losses of each row of projections are: $\Delta p = \Delta p_1 + \Delta p_2 = p_{(i-1)max} - p_{i max}$.

Various factors affect the resistance of the whole channel with projections: the Reynolds number Re, the transverse and longitudinal spacings, the number of pairs of projections. With

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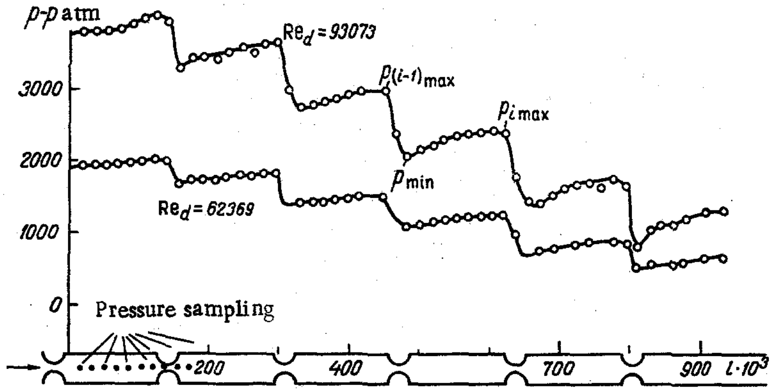

Fig. 1. Characteristic static-pressure distribution in a plane channel with semicylindrical projections, $(s_2/d) = 5.33$. l, m.

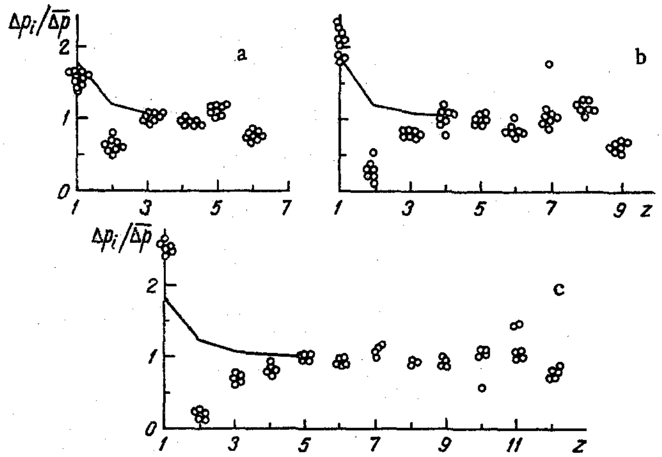

Fig. 2. Pressure-loss distribution over the rows of projections: a) $(s_2/d) = 5.33$; b) 3.04; c) 2.13.

a small number of rows, the energy losses in the first and last pairs of projections in the flow have a pronounced influence on the overall resistance. With a small number of projections in a plane channel, this factor may play a significant role. The ratio of the pressure losses for various rows of projections to the mean pressure drop over the row in the channel $c_z = (\Delta p_i/\overline{\Delta p})$ is shown in Fig. 2, from which it is evident that the first row of projections is characterized by considerable deviation of the pressure losses from the mean. With decrease inthe longitudinal spacing, c_z increases: $c_z = (\Delta p_1/\overline{\Delta p})_{5.33} = 1.5$; $c_z = (\Delta p_1/\overline{\Delta p})_{3.04} = 2.0$; $c_z = (\Delta p_1/\overline{\Delta p})_{2.13} = 2.5$. Analogous results for the first row of a corridor-type bundle were given in [2]. This result may be explained in that the flow around the first row of projections is in conditions of a reduced level of turbulence (a grid with small cells is established at the input).

For the second row, c_z drops strongly and becomes considerably less than one: for the given spacings, $c_z = 0.2$, 0.25, and 0.6, respectively. According to the data of [2], $c_z = 1.2$ for the second row of a smooth-tube bundle.

For the third and subsequent rows, c_z approaches unity both for a membrane surface and for a smooth-tube bundle (Fig. 2). Thus, for a plane channel with semicylindrical projections, as for a smooth-tube bundle, stabilization of the hydrodynamic resistance sets in after 3-4 rows.

For the last row of projections, decrease in c_z is characteristic. This may be explained in that there is more complete recovery of the pressure in the output measuring chamber of the experimental apparatus, since there are no subsequent rows of projections.

Experimental data on the hydrodynamic resistance are shown in Fig. 3 in the form of a dependence of the Euler number on the reynolds number; Eu is determined from the mean pres-

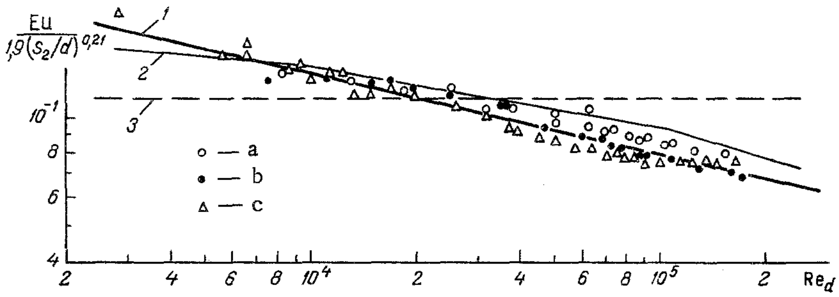

Fig. 3. Generalization of the experimental data on hydrodynamic resistance: 1) calculation from Eq. (3); 2) data of [2]; 3) data of [3]; a-c) as in Fig. 2.

sure drop in one row in a plane channel. The experimental points are satisfactorily described by a dependence of the form

$$\mathrm{Eu} = 1.9\,\mathrm{Re}_d^{-0,22}(s_2/d)^{0,21}. \tag{3}$$

It is evident from the formula that Eu for a single row decreases with decrease in the longitudinal spacing.

Curves from [2, 3] obtained for corridor-type smooth-tube and membrane bundles with transverse spacing $(s_1/d) = 1.52$ are also shown in Fig. 3. It was found in [3] that Eu depends on the transverse and longitudinal spacings, and is not related to Re. This discrepancy in the results may be explained by the influence of asymmetry of the flow, which is present when $(s_1/d) = 1.27$ [4].

NOTATION

$\mathrm{Re}_d = \bar{w}_y d/\nu$, Reynolds number; $\bar{w}_y$, mean velocity in narrow cross section, m/sec; d, diameter of semicylindrical projection, m; ν, kinematic viscosity, m^2/sec; p, static pressure, Pa; Δp, static-pressure difference, Pa; (s_1/d), (s_2/d), transverse and longitudinal relative spacings; c_z, correction to the change in Δp over a row; $\mathrm{Eu} = \Delta p/\rho \bar{w}_y^2$, Euler number; ρ, air density, kg/m^3.

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