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INVESTIGATION OF NONSYMMETRIC JET AERODYNAMICS

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Results are presented of experimental data on studying the characteristics of nonsymmetric jets and the influence of modal-constructive parameters on their development.

Axisymmetric and plane-parallel streams with uniform velocity field at the exit are utilized sufficiently extensively in different branches of engineering. The characteristics of such streams are sufficiently well studied at this time and there are engineering methods for their analysis [1, 2].

However, in a number of recent cases, for instance, in pneumatic automation for the development of automatic systems, in the design of gas burner apparatus with a regulatable flame and others in order to intensify the process, great interest has appeared in the production and study of nonsymmetric jet characteristics.

The development and aerodynamic characteristics of nonsymmetric jets differ significantly from the aerodynamic characteristics of axisymmetric and plane-parallel jets. There are no methodology and analysis of such jets at this time. Consequently, experiment remains the single facility for determining the characteristics of nonsymmetric jets.

Nonsymmetric jets are organized by different apparatus (circular, slot, rectangular) by installation of guiding apparatus (vanes) within or at the exit from a nozzle. They can also be obtained by the interaction of jets flowing out at definite angles. The most simple modifications of apparatus that assure organized nonsymmetric jets with different angle of deviation from the geometric axis of the unit are represented in Fig. 1.

Plane-parallel jets with a uniform velocity field are developed in the apparatus (Figs. 1a and b) with a parallel—horizontal arrangement of rotating blades at the exit and their axis agrees with the geometric axis of the apparatus. Under parallel rotation of both blades to one side, the axis of the jet being developed at the exit is shifted. As the blade position changes relative to the apparatus axis, a jet developing with a definite angle of deviation [3] can be organized at the output.

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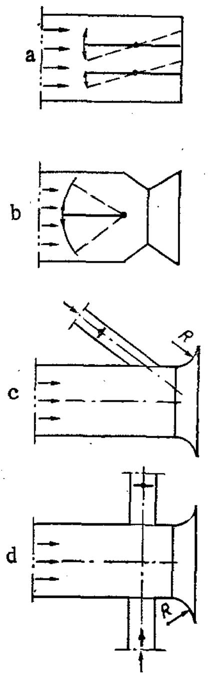

Fig. 1. Construction of apparatus assuring nonsymmetric jets.

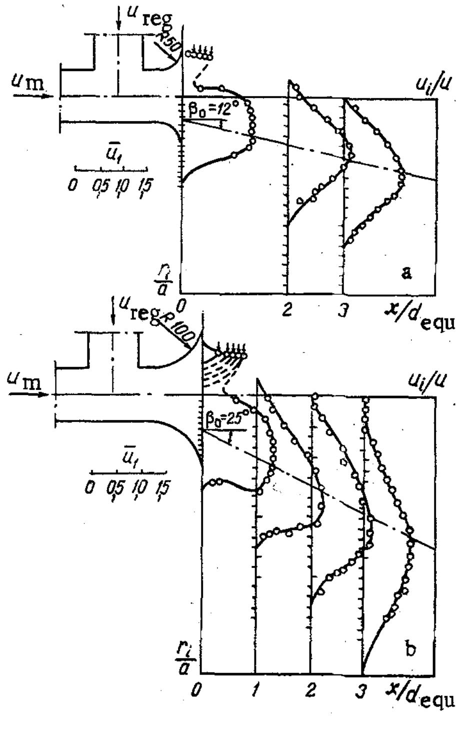

Fig. 2. Field of relative resultant nonsymmetric jet velocities at the exit from apparatus for $\bar{u} \simeq 0.4$; $\bar{R} = 0.5$ to 1.0.

As the ratio of the stream velocities and the angle between them changes in the apparatus (Fig. 1c and d), a stream can be organized at the output that is deflected to one side or the other of the geometric axis of the apparatus, i.e., a nonsymmetric jet is organized whose aerodynamic characteristic depend on the modal and structural parameters. It must be noted that in the apparatus represented (Fig. 1) the shape of the exit part exerts strong influence on the nonsymmetricity of the jet being developed in space. Preliminary tests show that the smoothest nonsymmetric jet (flare) can be organized in the apparatus (Fig. 1d) which is sufficiently simple and has no moving organs at the exit. Because of regulation of delivery

TABLE 1. Investigated Modifications and Modal-Structural Parameters of Apparatus

Rel. radius of curvature of the toroidal diffusor (exit) $R = R/a$	Stream velocity		Velocity at exit $u = u_m + u_{reg}$, m/sec
	main u_m, m/sec	regulating u_{reg}, m/sec	
0,5	14,8	6,6	21,4
	12,1	10,8	22,9
	5,12	14,9	20,22
1,0	14,6	5,97	20,57
	12,0	11,25	23,25
	5,17	14,9	20,07
	15,0	6,0	21,0
1,5	12,05	11,05	23,1
	5,33	15,4	20.73

Remark. The main ($a \times b$) and regulating ($a' \times b'$) channel sections are 100×100 m^2; the angle between the streams (γ) is 90°.

of part of the total stream through the side channels, each of which has an individual gate, the jet deflection can be controlled. For a fully open gate of one of the regulating channels with shape of the exit part in the form of a toroid in the vertical plane, the nonsymmetric stream deflects so that it moves upward or downward along the wall.

The stream characteristics produced for $\gamma = 0$ (one jet) or $\gamma = 180°$ (opposing jets) are investigated sufficiently completely and are utilized extensively in practice [1, 2, 4]. The nonsymmetric jet produced as a result of interaction of the two streams flowing at an angle $\gamma = 90°$ ($\alpha_m = 0$, $\alpha_{reg} = 90°$) has still not been studied. We conducted tests to study the stream characteristics for the mentioned case as the velocity ratio and the shape of the exit part of the apparatus changed. The modal-structural parameters of the apparatus are presented in Table 1.

The velocity and pressure distribution in the flow field of a nonsymmetric jet produced by the apparatus was determined by using a three-channel cylindrical pneumometric probe which had first been calibrated in a uniform plane-parallel stream for different flow modes by means of a Prandtl tube etalon. The experiments were conducted in the self-similar flow domain.

The results of investigating the aerodynamic characteristics of nonsymmetric jets are presented in Figs. 2-4 for different $\bar{u}$ and $\bar{R}$.

Presented in Fig. 2 are the velocity field distributions at different distances from the mouth of the apparatus for $\bar{u} \approx 0.4$ and $\bar{R}$ variable. It is seen from the figure that an increase in $\bar{R}$ from 0.5 to 1.0 results in an increase in the nonsymmetricity of the jet, i.e., β_0 increases and the jet deviates intensively from the apparatus axis (Fig. 2b).

An increase in the inflow from the side opposite to the deflected part of the jet is characteristic for the considered cases. In the second case, when $\bar{R} = 1.0$ (Fig. 2b) the inflow increases significantly and runs in within the apparatus, it here occupies the greater half of the input section of the apparatus. It is interesting that this inflow, no matter what its power, is observed only in the nearest section of the jet ($\bar{X} = 0.0$). Such a phenomenon is intrinsic for all the cases investigated (see Table 1).

The nature of the influence of the parameters $\bar{R}$ and $\bar{u}$ on the nonsymmetry of the jet can be traced in Fig. 3. An increase in $\bar{R}$ from 0.5 to 1.5 results in a growth in the angle of deflection β_0 of the nonsymmetric jet axis of 2.5-4.0 times for $\bar{u}$ a constant (Fig. 3a). The parameter $\bar{u}$ exerts insignificant influence on the angle of deflection β_0 of the nonsymmetric jet axis (Fig. 3b). Results of the experimental data show that $\bar{R}$ has practically no influence on the hydraulic resistance coefficient (Fig. 4a), while $\bar{u}$ exerts substantial influence in all modes (Fig. 4b) although the mean mass flow velocity $\bar{u}$ at the exit remains unchanged (see Table 1). Such growth of the hydraulic resistance coefficient ξ as $\bar{u}$ increases is most often associated with interaction of the main and regulating streams within the apparatus.

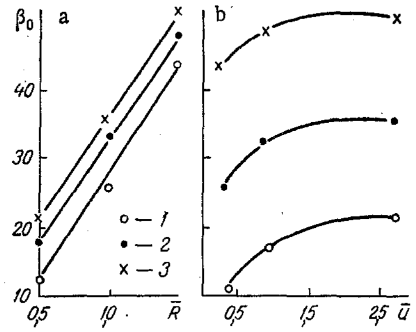

Fig. 3. Influence of $\bar{R}$ and $\bar{u}$ on the angle β_0 of nonsymmetric jet axis deflection: a) 1) $\bar{u} \approx 0.4$; 2) 0.9; 3) 2.9; b) 1) $\bar{R} = 0.5$; 2) 1.0; 3) 1.5.

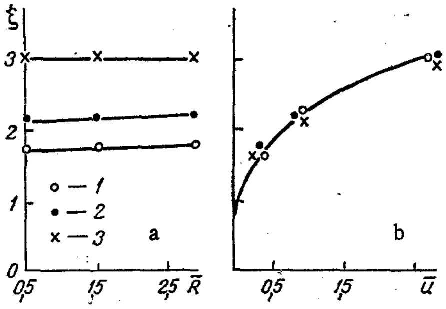

Fig. 4. Influence of $\bar{R}$ and $\bar{u}$ on the hydraulic drag coefficient ξ. Notation the same as in Fig. 3.

NOTATION

$\gamma = \alpha_m + \alpha_{reg}$, angle between the jets, deg; α_m, α_{reg} angles between the jet axes and the horizontal axis of the apparatus, deg; $\bar{u} = u_{reg}/u_m$, velocity ratio; u_m, u_{reg}, velocities of the main and regulating streams, respectively, m/sec; $u = u_m + u_{reg}$, resultant velocity at the exit, m/sec; $\bar{u}_i = u_i/u$, relative velocity at the exit; u_i, running velocity, m/sec; $\bar{R} = R/a$, relative radius; R, radius of curvature of a toroidal diffusor at the exit, mm; a, b, a', b', respectively, the height and width of the main and regulating channels, mm; β_0, angle of nonsymmetric jet axis deflection from the geometric axis of the apparatus, deg; $\bar{X} = x/d_{equ}$ is the relative distance; x, distance from the apparatus mouth to the section under consideration, mm; d_{equ}, equivalent diameter of the exit section of the apparatus; ξ, hydraulic resistance coefficient; and r_i, running height, mm.

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