CALCULATION OF THE DIRECTION OF THE AXIS OF A STREAM RESULTING FROM THE MIXING OF TURBULENT JETS

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The possibility is examined of calculating the inclination of the axis of a stream resulting from the mixing of turbulent jets, using a simplified method.

Questions related to the mixing of turbulent gas jets have recently been widely discussed in the liaterature [1]. According to the available experimental data [2–4], the mixing results in a single turbulent stream which, at a certain distance from the point of intersection of the axes of the merging jets, may be regarded as one turbulent jet. In practical applications it is necessary first to have a method of calculating the direction of the axis of this resultant stream from the initial parameters of the mixing jets.

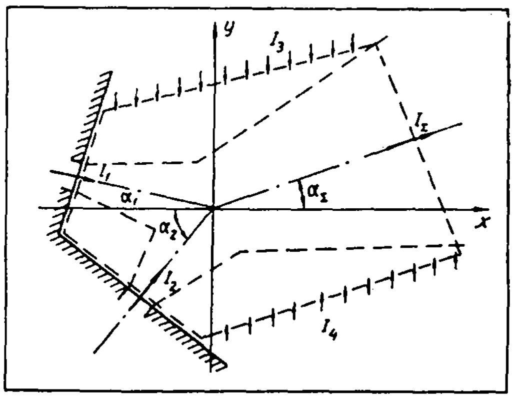

Fig. 1. Diagram of the flow.

A solution to the question of the resultant stream axis direction may be obtained by using the condition of conservation of total momentum in the initial and resultant streams. In doing this, for example, in the case of the mixing of two jets with intersecting axes (Fig. 1), it is necessary, strictly speaking, to take into account, in addition to the momentum of the original jets I_1 and I_2, that of the streams I_3 and I_4 ejected by the jets from the surrounding space. Then the projection of the momentum conservation equation on the axis of coordinates in the general case (without restricting the number of mixing streams) has the form

$$I_{\Sigma j} = \sum_n I_{ij},$$

where i = 1, 2 ... is the ordinal number of the elementary flow, and j = x, y, z designates the axis of the coordinates.

In particular, for the case represented in Fig. 1, taking into account the fact that $\mathrm{tg}\,\alpha_\Sigma = I_{\Sigma y}/I_{\Sigma x}$ we may obtain

$$\mathrm{tg}\,\alpha_\Sigma = \sum_n I_{iy} / \sum_n I_{ix}. \qquad (1)$$

Measurements of static pressure during mixing of turbulent jets [2,3] indicate that the process is nonisobaric. We must therefore understand momentum flow here to be flow of total momentum, allowing for variation both of momentum ρu^2 and also of static pressure p: $I = (p + \rho u^2)\,S$, where S is the flow area at the chosen section.

The need to take into account the momentum of the ejected streams, and also the variation of static pressure in the jet mixing process, makes calculation according to (1) quite onerous. We have verified the possibility of calculating the inclination of the resultant stream by a simplified method, ignoring both the existence of the ejected streams of gas

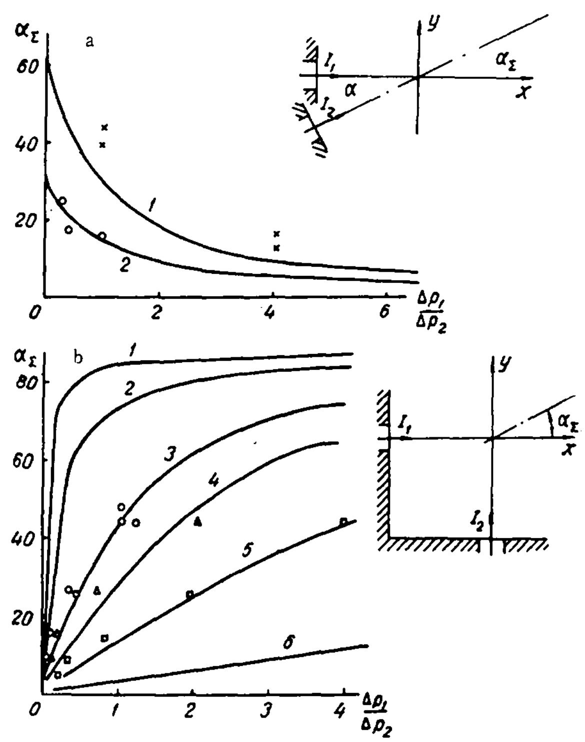

Fig. 2. Comparison of calculation with experimental data: 1) For plane parallel jets [1) for α = 60°; 2) 30°]; b) for axisymmetric jets [1) d_2/d_1 = 4; 2–2; 3–1; 4–0.75; 5–0.5; 6–0.25].

surrounding the mixing jets, and also the variation of static pressure in the mixing region (i.e., in this case we assumed $1 = \rho u^2$).

The calculated curves and the experimental points are shown in Fig. 2a for mixing of two plane parallel air jets discharging from slits of identical size with different pressure drops Δp_1 and Δp_2 [3].

Equation (1) for this case $\alpha_1 = 0$, $\alpha_2 = \alpha$ has the form

$$\operatorname{tg} \alpha_\Sigma = \frac{\sin \alpha}{\cos \alpha + \Delta p_1/\Delta p_2}.$$

In transforming (1), the rate of discharge of the jets was determined by the expression

$$u_i = \varphi \sqrt{\frac{2g}{\rho} \Delta p_i},$$

where the velocity coefficient φ was assumed to be the same for both jets.

Similar results are shown in Fig. 2b for mixing of axisymmetric jets of air, discharging at right angles to one another from cylindrical nozzles of different diameters d_1 and d_2 at different pressure drops Δp_1 and Δp_2. The calculation formula in this case $\alpha_1 = 0$, $\alpha_2 = \pi/2$ takes the form

$$\operatorname{tg} \alpha_\Sigma = \frac{\Delta p_2}{\Delta p_1} \left(\frac{d_2}{d_1} \right)^2.$$

In handling the experimental data, the axis of the resultant stream was determined in all cases according to the maximum total pressure. The results of the comparison, shown in Fig. 2, indicate that for the majority of conditions the present method gives satisfactory agreement between theory and the experimental data, for plane and for axisymmetric jets. Moreover, in certain conditions a substantial divergence of theory from experiment is noticeable, in which event the convenient calculation can be recommended only as an approximation. More rigorous calculations must be made according to the general formula (1), making allowance for the ejected flows and the fact that the process is nonisobaric.

NOTATION

d) nozzle diameter; $g = 9.81$ m/sec^2) acceleration due to gravity; I) momentum flux; p) static pressure; u) stream velocity; S) flow area at chosen section; α_Σ) angle of inclination of axis of resultant stream; ρ) density of gas; φ) velocity coefficient.

REFERENCES

1. L. A. Zalmanzon, Pneumonics [in Russian], Izd. "Nauka," Moscow, 1964.

2. L. A. Zhukova, I. S. Uakarov, and B. G. Khudenko, Izv. vuzov, Aviatsionnaya tekhnika, no. 4, 1964.

3. I. S. Makarov and B. G. Khudenko, IFZh, 8 no. 4, 1965.

4. A. L. Bellin, P. B. Richards, and D. R. Messina, Harvard University NACA, Technical note 2417, Washington, 1951.

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