MIXING OF INTERSECTING TURBULENT JETS

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Results are given of an experimental investigation of the flow parameters (velocity, static pressure and temperature fields) of the stream formed by the intersection of two plane-parallel turbulent jets.

In engineering equipment turbulent jets at different temperatures often mix after intersecting at an angle. This paper deals with measurements carried out in equipment of this type. The jets emerged from two vessels, into one of which air was blown directly from the atmosphere, while the other had a preheater. The air was discharged into a space bounded on both sides by parallel walls, which prevented the jets from spreading out in the transverse direction and ensured that a plane-parallel flow structure would result from the mixing process.

Details of the flow regimes investigated are given in the table.

Details of the Flow Regimes Investigated

Regime	Parameters of air supplied to nozzles				Angle of inclination of nozzle, α
	$h_{01}^{*} \cdot 10^{-2}$ N/m^2	$h_{02}^{*} \cdot 10^{-2}$ N/m^2	n	t_{02}	
I-T40	10	10	1	40	30°
II-T40	40	10	0,25	40	
III-T40	4	10	2,5	40	
IV-T70	40	15	3,75	70	60°
V-T70	10	10	1	70	
VI-T70	40	10	0,25	70	

The figure shows the absolute velocity, static pressure and temperature fields for mixing of jets with the same nozzle velocity and an air temperature in the inclined jet of 40°C (regime I-T40).

The velocity vector profile at a section close to the nozzles (x = 10 mm) reveals the presence at this point of two jet flows with a reverse flow zone in between.

The static pressure measurements show reduced pressure at the outer boundaries of the jets. This is associated with the entrainment of air from the surrounding space. In the region of the jet axes the static pressure is above atmospheric, which must be connected with rotation of the entrained flow in the axial direction. In the reverse flow zone reduced pressure is again observed, due to the entrainment of air from this closed region.

Whereas momentum transfer between the jets is revealed in this section only by the presence of a zone of reverse flow, heat transfer from the hot to the cold jet is more clearly expressed. The temperature field in the section with a reverse flow zone (x = 10 mm) shows that in the hot jet heat is not only propagated in the undisturbed flow, but also penetrates through the reverse flow zone into the boundary layer of the cold jet (figure).

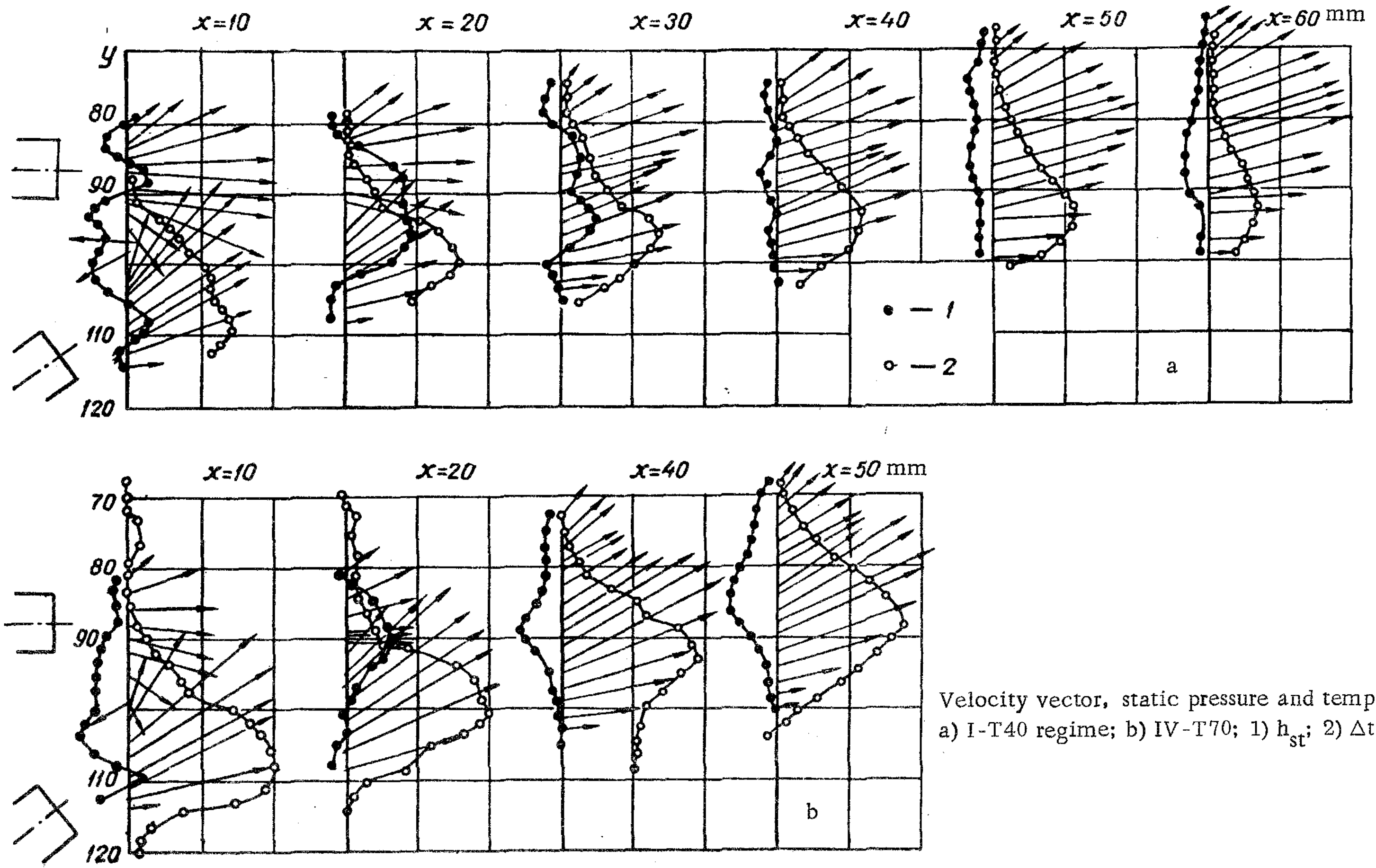
In the next section (x = 20 mm), the intersecting jets still retain their individuality (their velocity vectors intersect), but here there is no zone of reverse flow. The pressure in the central part of the flow is above atmospheric.

In subsequent sections the resultant flow may already be considered as one, even with respect to the velocity fields, although for some time (sections x = 30 and x = 40 mm) traces of separation (two maxima in the velocity field) can still be detected. At a considerable distance (sections x = 50 and x = 60 mm) the resultant flow forms a single stream, with respect to the velocity field, but is skewed in the transverse direction due to the momentum of the inclined jet.

The excess static pressure in the central part of the resultant jet decreases (x = 30 mm) with distance from the nozzles and finally becomes negative (sections x = 40, 50, and 60 mm).

The temperature field shows that heat is gradually propagated over the entire section of the resultant flow; however, in all cases the temperature maximum is located below the velocity maximum, i.e., in the sections investigated heat is propagated preferentially on the side of the flow on which it was introduced by the heated jet.

Thus the heat transfer associated with the intersection of turbulent jets is governed by the process of injection of a hot jet into a cold one. This process extends over the entire mixing length, and the temperature field in the resultant



Velocity vector, static pressure and temperature fields:
a) I-T40 regime; b) IV-T70; 1) h_{st}; 2) Δt(mV).

flow begins to resemble the velocity field (at least their maxima begin to coincide) only at a considerable distance from the section where the velocity field becomes smooth (only one maximum).

Increasing the velocity of the horizontal jet (regime II-T40) does not change the qualitative picture of the process, but leads to an increase in the relative displacement of the velocity and temperature fields. Reducing the velocity of the horizontal jet (regime III-T40), on the other hand, promotes earlier propagation of heat over the entire section of the resultant flow. Even better mixing is achieved if a reduction of the velocity of the horizontal jet is accompanied by an increase in that of the inclinded jet (regime IV-T70, figure). In this case, at the last of the sections investigated (x = 50 mm), a temperature distribution symmetrical about the resultant flow axis is obtained.

The ratio of the velocity heads of the jets at discharge may be represented by the number $n = h^*_{01}/h^*_{02}$. In the experimental range of variation of n, an increase of n led in all cases to earlier mixing of the jets. In this case the skewness of the resultant flow also increased.

An increase in the jet meeting angle led to similar results, but distribution of heat over the entire section of the resultant flow occurs earlier.

NOTATION

h^*_{01}, h^*_{02} – excess total pressure at the exit sections of the horizontal and inclined nozzles, respectively; h_{st} – excess static pressure; $\Delta t_0 = t_{02} - t_{01}$ – temperature difference of the initial jets; α – angle between nozzle axes; x, y – coordinates of measuring point; w – absolute velocity; Δt(mV) – difference between temperatures at measuring point and in vessel receiving, air from the atmosphere; $n = h^*_{02}/h^*_{01}$ – ratio of total pressures.

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