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New principle of ventilation

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INTRODUCTION

The new principle of ventilation is based on creating a microclimate in a room (or its section), acting on its thermal-and-humid situation by the air flow resulting from the interaction of two or more incoming jets meeting each other co-axially or at an angle. The change of initial characteristics of jets (impulse, heat and/or moisture content) permits to produce the resulting flow having the necessary direction and predetermined parameters. This principle is especially efficient in a room having a non-stationary thermal-and-humid regime and may be applied in the following cases:

- to localize plots of industrial premises by jet barriers;
- to provide pre-determined parameters of the air in certain parts of a room (e.g. in the zone adjacent to the window and subjected to solar radiation);
- to find an optimal angle for releasing incoming jets of two-sided air-and-thermal curtains;
- to produce a dynamic microclimate;
- to create a responsive (or "tracing") ventilation for accomplishing individual technological operations;
- for an active control of jet processes in diverse fields of engineering.

The problems engendered by interacting jets flowing towards each other co-axially or at an angle have not yet received theoretically founded solutions. This work gives such a result.

THEORETICAL SOLUTION

Let us consider, firstly, the interaction of flat jets of the ideal fluid, directed towards each other, having a common symmetry plane (see Fig. 1).

The jets have initial impulses $\bar{J}_{01}$, $\bar{J}_{02}$, volumetrical discharges L_{01} and L_{02} , velocities $\bar{u}_{01}$, $\bar{u}_{02}$ After the jets have collided in point O , they originate the resulting flow consisting of two jets with impulses $\bar{J}_1$ and $\bar{J}_2$ directed at angle α to the symmetry plane. Because of the symmetry the values of the impulses of the resulting jets are identical $J_1 = J_2 = J$. Each resulting jet consists of two parallel flows spreading at velocities $\bar{u}_1'$, $\bar{u}_2'$ and $\bar{u}_1''$, $\bar{u}_2''$, and having volumetrical discharges $0{,}5\,L_1$ and $0{,}5\,L_2$. The "picture" produced by the interaction of free flat turbulent jets is analogous, since for the field in question, or the formation zone of the resulting jets (Sections 1-1, 2-2, 3-3), the ejection of the surrounding air may be ignored, and one may think that discharges L_{01} and L_{02} of the interacting jets are also being distributed equally to the resulting jets.

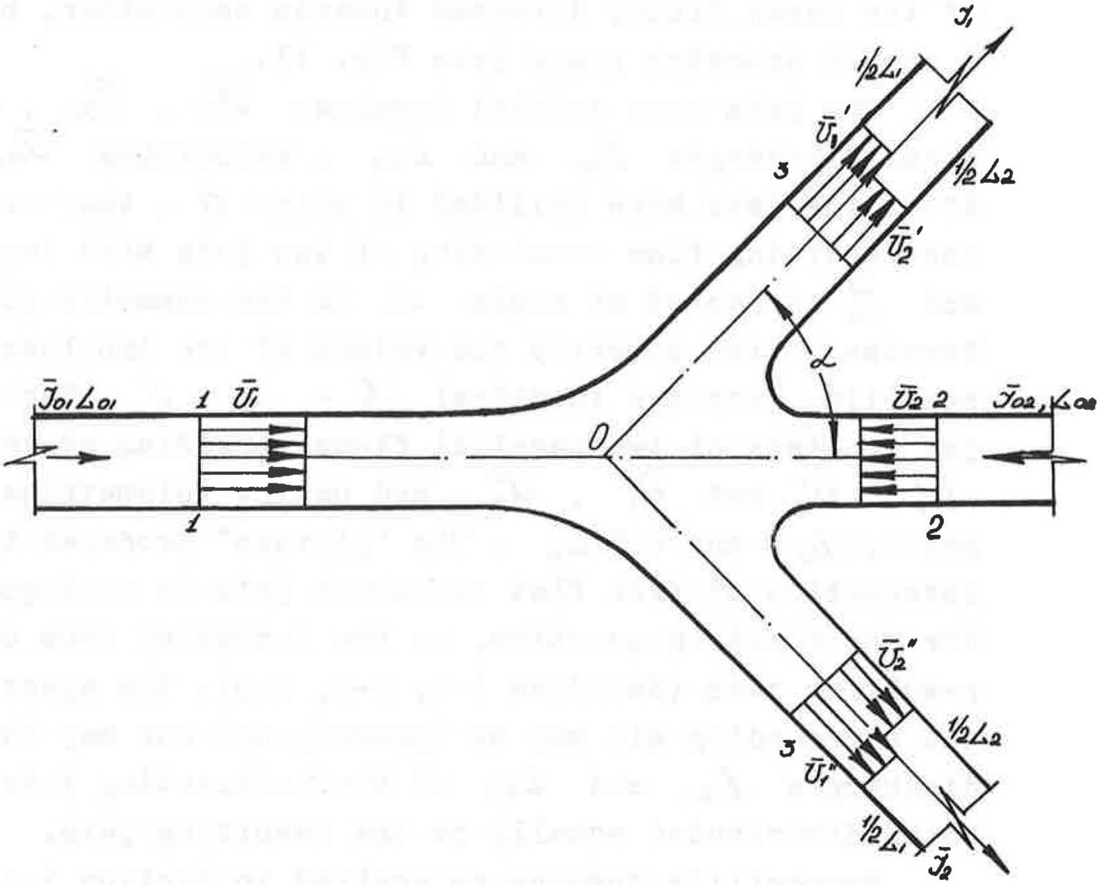
Bernoulli's theorem as applied to Section 1-1, 3-3, and 2-2, 3-3 for every flow suggests for isobaric jets the relations:

$$u_1' = u_1'' = u_1, \qquad u_2' = u_2'' = u_2 \tag{1}$$

Hence, for the impulses' values of the resulting jets one can get:

$$J_1 = J_2 = 0{,}5\rho(L_1 u_1' + L_2 u_2') = \tag{2}$$

$$= 0{,}5\rho(L_1 u_1 + L_2 u_2) = 0{,}5(J_{01} + J_{02}) .$$



$\bar{J}_1$
$1/2\,L_1$
$1/2\,L_2$
$\bar{U}_1'$
$\bar{U}_2'$
3
α
$\bar{J}_{01} L_{01}$
1
$\bar{U}_1$
0
$\bar{U}_2$
2
$\bar{J}_{02}, L_{02}$
1
2
$\bar{U}_2''$
$1/2\,L_2$
3
$\bar{U}_1''$
$1/2\,L_1$
$\bar{J}_2$

Fig. 1

Projecting momentum equations onte the symmetry plane, we shall get:

(3) $$J_{01} - J_{02} + 2J\cos\alpha = 0$$

Hence, taking into account Equation 2, we shall have:

(4) $$\cos\alpha = (J_{01} - J_{02})/(J_{01} + J_{02})$$

The analogous result has been achieved for counter-interacting axially symmetrical jets (see Reference 1). For flat jets the results have been proved experimentally and described in Reference (2).

Now, considering the symmetry plane as a hard wall, and applying the principle of transforming the flows that is applicable to symmetrical jets, we can solve the problem of an oncoming jet running over the plane at the pre-assigned angle α .

From Formulae (2) and (3) it follows that:

(5) $$J'_{01} = J\cos^2\alpha/2 \quad , \quad J'_{02} = J\sin^2\alpha/2$$

where J is the impulse of an oncoming jet,

J'_{01} , J'_{02} are the impulses of a direct jet and opposite one, respectively.

(With respect to Fig. 1: $J'_0 = 1/2\, J_0$).

It follows from Equation (5) that in all angles differing from π there are two oppositely directed oncoming jets being split from the parent one. However, in Reference (3) it has been experimentally proved and stated that at angles $\alpha = \pi/8$ only one direct jet is formed. In this case, it follows from Equation (5) that $J'_{01} \geq 0,96\, J$, $J'_{02} \leq 0,04\, J$. Hence, the smaller value of the opposite jet's impulse was not registered experimentally owing to the inefficient measuring instruments used.

Let us consider the interaction of free flat isobaric jets, directed at angle Θ towards each other, when $\Theta \neq \pi$.

The resulting flow consists of two oppositely directed jets with impulses $\bar{J}_1$ and $\bar{J}_2$ (see Fig. 2). Our experiments aimed at studying flat jets in a hydromodel and the data from Reference (4) have led to the conclusion that the direction of the resulting jet $\bar{J}_1$ coincides with the direction of the vector representing the geometrical sum of the impulses of the interacting jets $\bar{J}_{01} + \bar{J}_{02}$. Whereas the direction of the jet with impulse $\bar{J}_2$ is diametrically opposed. According to the accepted scheme (fig.2) the jet with impulse $\bar{J}_1$ will be further called a direct resulting jet, and the jet with impulse $\bar{J}_2$ will be termed a reversed one. Drawing an analogy with the counter-interaction of coaxial jets ($\theta = \pi$), we suppose that in the small area where they meet (point O is the intersection of the axes of symmetry of the meeting jets) the air discharge from the jets remains constant, so the algebraic sums of the impulses of the interacting and resulting jets are equal:

$$J_{01} + J_{02} = J_1 + J_2 \tag{6}$$

Applying the theorem on a momentum alteration in projections onto the axis of the jet with impulse J_{01} and onto the axis perpendicular to it, we shall have:

$$J_{01} + J_{02} \cos\theta = (J_1 - J_2)\cos\alpha \tag{7}$$

$$J_{02} \sin\theta = (J_1 - J_2)\sin\alpha \tag{8}$$

Equations (6)-(8) give formulae:

- for calculating an angle α of a direct resulting jet with the direction of a jet having impulse J_{01} :

$$tg\,\alpha = J_{02} \sin\theta / (J_{01} + J_{02}\cos\theta) \tag{9}$$

- for finding the impulse value of the direct resulting jet:

$$J_1 = 0.5(J_{01} + J_{02} + J_{02}\sin\theta/\sin\alpha) \tag{10}$$

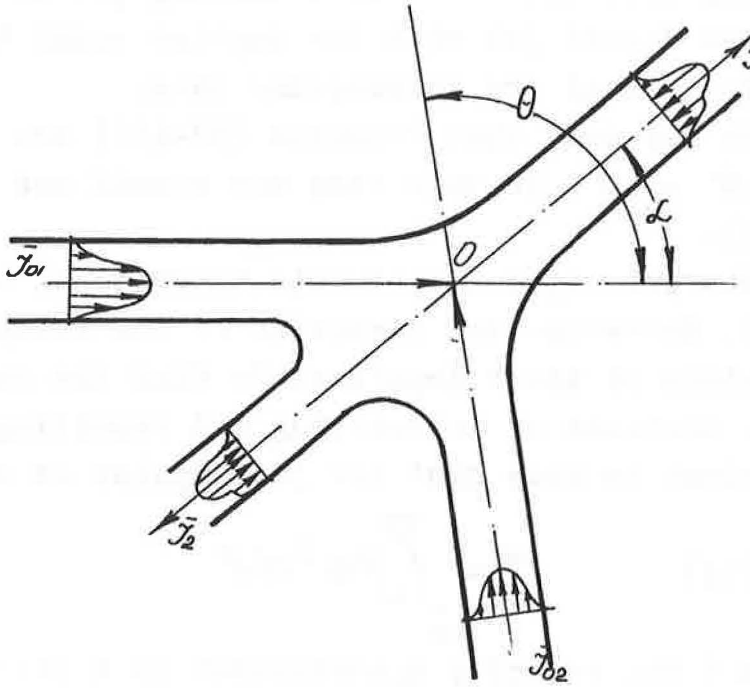


Fig. 2

- for finding the impulse value of the reversed resulting jet:

$$J_2 = 0{,}5(J_{01} + J_{02} - J_{02}\sin\theta/\sin\alpha) \tag{11}$$

In particular, when interacting at an angle α are the jets with identical impulses: $J_{01} = J_{02} = J$, Equations (9)-(11) suggest: $\alpha = \pi/2$, $J_1 = 2J\cos^2\theta/4$, $J_2 = 2J\sin^2\theta/4$, which is in conformity with Equations (5).

When $\theta = 0$, from Equation (9) it follows that $\alpha = 0$, $J_2 = 0$, i.e. the reversed resulting jet is absent, there is only the direct jet with the impulse equal to the sum of the impulses of the interacting jets.

We may note that Formulae (9)-(11) are not applicable when $\theta = \pi$ In this case one should use Equations (2) and (4).

The principal aim of this theoretical examination has been to determine the direction of the resulting jets and the values of their impulses. To find the current velocity in the sections of interacting and resulting jets it is sufficient to know that the jet impulse is equal to:

$$J = \int_0^\infty \rho u^2 dF \tag{12}$$

and that the velocity distribution in a jet section obeys the exponential law:

$$u = u_x \exp[-0{,}5(y/cx)^2] \tag{13}$$

where u and u_x are the velocities in any point, respectively, and on the axis of symmetry of the jet, x and y are the coordinates of a current point, dF is an elementary area with equal velocity values, c is the experimental constant whose probable value is 0,082 (see Reference (5)), ρ is air tightness.

Having determined the values of the impulses of the resulting jets and using Equations (12) and (13), one may find the distribution of velocities in jets' sections, taking as the calculation start of the x coordinate for the resulting jets the meeting place O (Fig. 2). When $\Theta = \pi$, the meeting place of the jets is described in Reference (2).

We have also obtained equations for determining heat-and-moisture contant of the interacting resulting jets that is the subject for an additional report.

CONCLUSION

The theoretical data given in this work permit to evaluate qualitatively and quantitatively the interaction processes of the jets having various initial impulses at different angles of their interaction.

The results received are not only valuable from the theoretical point of view but may also be useful in practice of controlling ventilation processes in rooms as well as in solving problems connected with an active regulation of jet processes in various branches of engineering.

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SUMMARY

The new principle of ventilation is based on creating a microclimate in a room (or its part), modifying its heat-and-moisture situation by air flows formed by two flat interacting incoming jets flowing co-axially or at an angle towards each other, having differing initial impulses. This permits to get a controlled resulting flow of a predetermined direction. The elaborated theoretical equations make it possible to evaluate jets interaction processes qualitatively and quantitatively and can be used for solving practical tasks aimed at an active regulation of jet processes.