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RESEARCH OF THE FLAT SUBSONIC JET DISCHARGING FROM A LOCAL SLOT ON A SURFACE

Introduction. In various pertinent art subsonic and supersonic gas streams are used. Many researchers were engaged in their studying. Now some free turbulence theories are known: Prandtl, Taylor, Reighardt, Marttkoly [1]. In these theories free boundless plane-parallel and axisymmetric jets flowing from a narrow aperture into flooded space are examined. As free turbulence is the elementary turbulence case, the least dependent from viscosity, influence its studying can serve as preliminary step for studying of turbulent streams in general. So, on the basis of free Prandtl turbulence theory three problems of free incompressible liquid flooded jets distribution are solved (Tolmin), current laws in a trace behind a streamline body for flat (Schlikhting) and axisymmetric (Sven) case are developed.

In technical applications the developed theories of characteristics calculation of the subsonic and supersonic jets flowing in channels are of interest. In the process equipment for jet milling the duct system, ejectors, nozzles, accelerating tubes for supplying and dispersal of the energy carrier and material particles two-phase flows which are crushed in the mill chamber at counter flow collision are used. Despite of known jet mill advantages - rotating details and milling bodies absence, low noise level during operation, reliability, rather small sizes and high ready product dispersion and impurities absence in it, - they have several drawbacks restricting their active operation for especially thin and pure products getting. One of main drawbacks of these is the increased deterioration of mill design elements, in particular accelerating tubes deterioration.

For law research of mill accelerating tube deterioration due to influence on them of a material moving in a air flow it is necessary to consider gasdynamic wall jet characteristics. Using wall jet properties, protection devices for power devices and technologies can be developed in various engineering fields.

The purpose of this work is to investigate the characteristics of the air jet flowing from a local slot into flooded space on a plate surface.

In experimental Tolmin's works characteristics of the jet flowing from a narrow slot into infinite space were investigated (see fig. 1), thus use of one experimental constant enabled to bring their results into good correspondence with the theory.

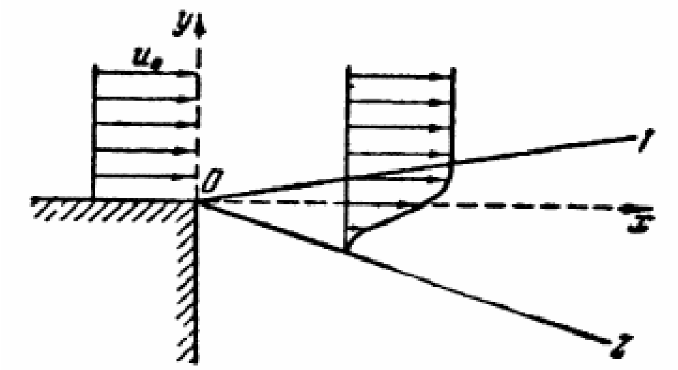

Fig. 1. The flowing of a free jet from a slot in infinite space

The main part. Based on the jets flowing theory the method for calculating of jet characteristics flowing from a narrow slot on a plate is developed, and experimental verification of the received results is carried out.

As the initial data the following initial parameters are set: initial pressure and temperature of air P0, T0. Consider that surrounding slipstream stream is stationary, i.e. Wв = 0.

For calculation of velocity on the certain distance from a slot, it is necessary to know air velocity on an exit from flat nozzle, its form and an air jet type which is formed by it. In the same way it is possible to consider, how velocity changes in each jet profile.

On the central axis of a flat air jet, air velocity is calculated as follows: $w_m = K \cdot w_0 \sqrt{\frac{b_0}{x}}$, where wm - velocity on an jet axis (m/s); x - distance from a jet pole to a point in which velocity is determined (м); b0 - half of the slit-shaped nozzle height (м); w0 - velocity on a slot output (m/s), К - the coefficient, was accepted К= 3,8. To calculate the velocity in other points of a flat jet it is used Tolmin's turbulence theory. He has been investigated velocity distribution in the free flow formed at the flowing through a narrow straight slot. The formula for velocity calculation is given by: $\frac{w}{w_m} = F'(\varphi)$, where $\varphi = \frac{y}{0{,}09x}$. Function $F(\varphi)$ was determined by introducing the dependent variable $z = \ln F(\varphi)$. More detailed calculations are presented in work [1].

The received theoretical characteristics of a jet were compared to experimental data. Two techniques for a jet velocity calculation on the basis of experimental data are considered [2, 3].

To calculate the velocity of the gas moving in jet, it is possible to use the isentropic formulas which realized parametrical relation between pressure and the velocity of a flow using the related velocity λ [2]: $\frac{p}{p^*} = \left(1 - \frac{k-1}{k+1}\lambda^2\right)^{\frac{k}{k-1}}$, where p - static flow pressure, p* - full pressure, k - adiabatic index. Hence $\lambda = \sqrt{\left(1 - \left(\frac{p}{p*}\right)^{\frac{k-1}{k}}\right)\frac{k+1}{k-1}}$. Taking into account $a = \sqrt{\frac{kp}{\rho}}$, and the related velocity $\lambda = \frac{w}{a}$, we finally obtain the formula for the gas flow velocity calculating in the flow:

$$w=\lambda\cdot a=\sqrt{\left(1-\left(\frac{p}{p^*}\right)^{\frac{k-1}{k}}\right)\frac{k+1}{k-1}}\cdot\sqrt{\frac{kp}{\rho}}\,. \quad (1)$$

Also to calculate the velocity change along the length of the tube it is possible to use the model obtained for elementary jet, i.e. one-dimensional flow model (a method 2). The gas velocity is founded from the Bernoulli equation, written for elementary jet [3] $p+\frac{\rho w^2}{2}=p^*$. Hence

$$W=\sqrt{\frac{2(p^*-p)}{\rho}}\,. \quad (2)$$

The air density is calculated by the formula $\rho\cong\frac{B_0}{R\cdot T_0}$[kg / m3], where R = 287,3 Дж/(кг·К) is a specific gas constant of air, B_0 - atmospheric pressure, T_0 - temperature.

To determine the velocity of the flow moving with subsonic velocity, it is necessary to measure static and full pressure in the same point of a flow. However for best accuracy calculations it is necessary to measure not each pressure, but a difference of full and static pressure (p* - p) [Па].

Researches were carried out on flat model of a wall jet flowing on a plate. The installation scheme is shown on fig. 1. The flat model consists of a receiver (1) through which air is supplied in the line model; the working surface (2) equipped by flat nozzle with adjustable section (3), and also adjusting linings (4) whereby control is exercised over the supply of air to the nozzle. In the given experiments flat nozzle is a slot in the sizes 20×5,5 mm.

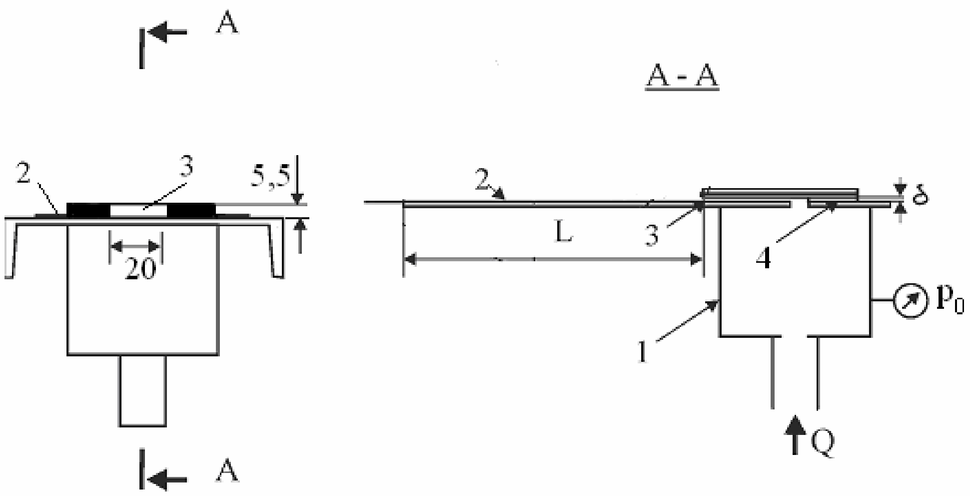

Fig. 2. The installation scheme for tests of flat wall jet model: 1 - a receiver; 2 - a working surface; 3 – adjustable nozzle section; 4 - adjusting linings

The experiment course has consisted in the following. Installation was connected to an air source. After opening of shut-off valve on the tank battery from a receiver (1) air was supplied to the model nozzle through adjustable section (3). Then the selected modes on air pressure upon an input in flat nozzle p = 0,05 МПа, initial velocity of a flow w0 = 54 m/s are set, the efficiency of the device was tested on operating modes. For measurement of full and static pressure difference Pitot - Prandtl tube is used. Differences of pressure p* - p in various flow points were measured and fixed.

Researches were carried out under following medium conditions: atmospheric pressure of 760 mm mercury and temperature 4°C. Measurements of flow pressures were made in points at a distance from a slot x = 40; 55; 70; 100; 120; 140; 160; 180; 200; 220; 250; 270 and 290 mm. Thus the first 5 sections are in an initial jet zone, following three – in a transitive site and the last 5 - in the basic jet zone.

There were investigated the velocity distributions calculated by different techniques and described by final formulas (1) and (2) accordingly which were compared to theoretical jet characteristics. The result analysis has shown, that sizes of the jets velocity calculated by different techniques, accordingly under formulas (1) and (2) are close enough. Therefore further calculation results by the first technique are related, and they were used in the further analysis. On fig. 3 results of experimental and theoretical jet velocity definition in the chosen points on the central axis of a jet are shown.

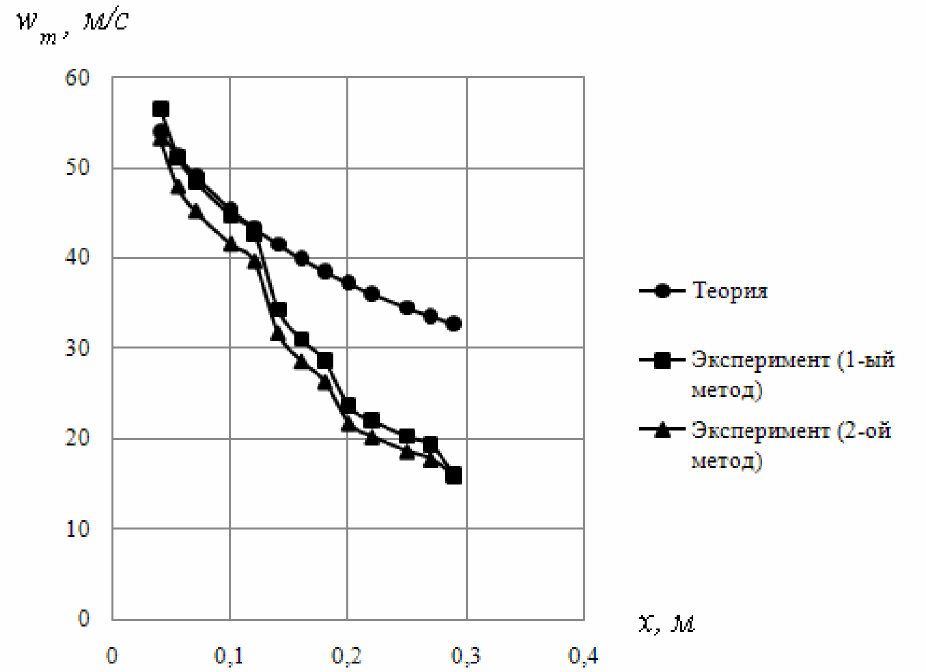

Fig. 3 Velocities distribution along the central jet axis at a level of a plate at measurement at P_0=0,05 MPa.

The results of experimental investigations coincide with the theoretical data on an initial site, i.e. at x = 40 - 120 mm. Further difference in a jet velocity is accounted for the jets spreading phenomenon on a plate since at experimental researches the local jet limited below by a plate was examined causing reduce its energy. In theoretical calculations the boundless jet was examined.

Results of dimensionless velocity calculations in a jet sections were compared when instead of absolute velocity its relation to velocity on a jet axis was postponed, and instead of distance from a jet axis it's considered its relation to distance from an axis to a point where velocity is equal to half axial one. In dimensionless coordinates velocity structures of a flat jet appear affine (see fig. 4). Distinction in levels of velocities distribution in sections is explained by different boundary conditions of theoretical calculations and experimental results.

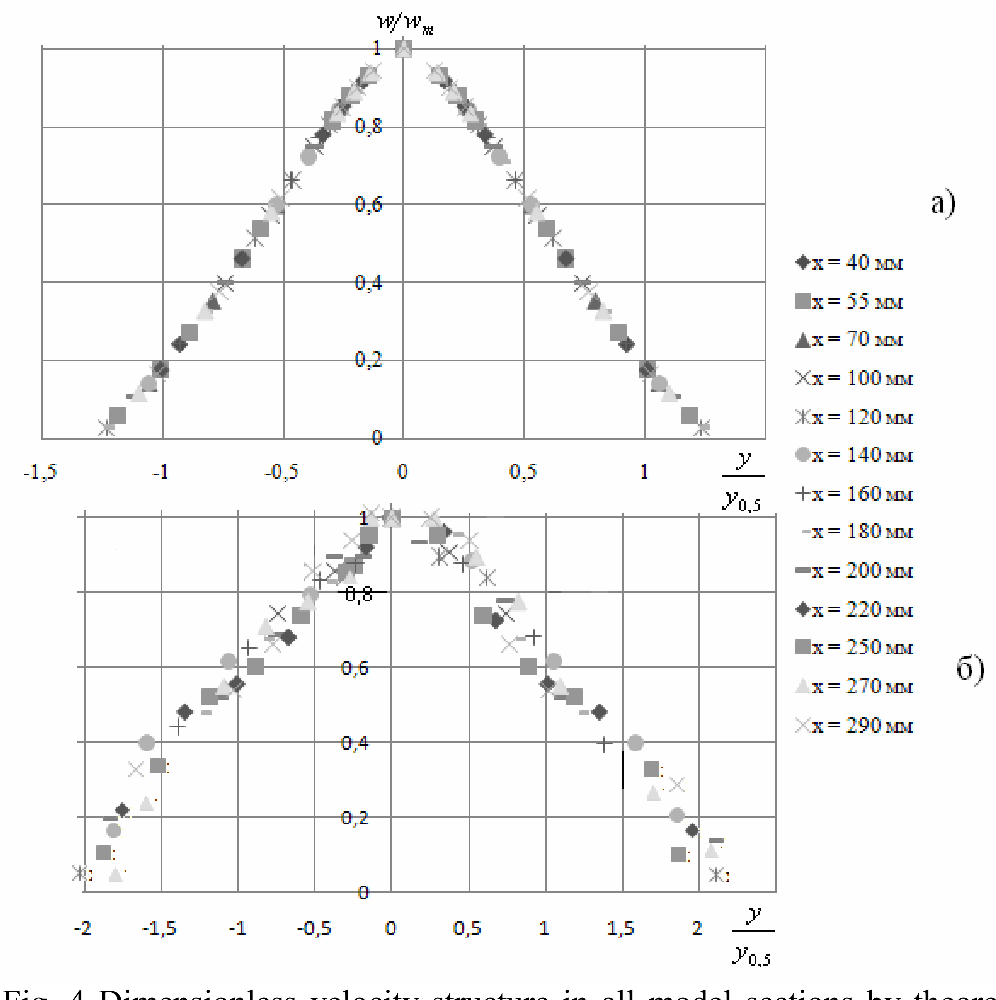

Fig. 4 Dimensionless velocity structure in all model sections by theoretical (a) and experimental (б) calculations

Conclusions. In the study of the wall jet flowing from a local slot into flooded space on a plate, a jet character on initial and basic sites has been revealed. Experimental data on an axis of an initial site are in the good consensus with the theoretical characteristics of a jet received on the basis of the Tolmin's turbulence theory. Characteristics differences of the jet flowing from a narrow crack in infinite space and on a plate are disclosed. It is proved affinity of a dimensionless velocity structure of the jet flowing from a narrow slot, received by calculation and experimental method.

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