CHARACTERISTICS OF THE PROPAGATION OF FREE ANNULAR TURBULENT JETS

I. L. Povkh, E. M. Levin, and Yu. V. Suslin

UDC 532.522.2

Experimental data are presented relating to the propagation of an axially symmetric submerged jet flowing from an annular nozzle formed by two coaxial cylinders.

Free jets flowing from nozzles with annular cross sections formed by two coaxial cylinders are often encountered in technology. Jet flows of this kind are formed, for example, behind axial fans.

According to [1, 2] the aerodynamics of a hollow jet flowing from an annular nozzle obeys the ordinary laws of a free axially symmetric continuous jet over most of the region, the momentum of the hollow jet (like that of the continuous jet) being the same in all cross sections and equal to that in the initial cross section. According to other authors [3, 4] the characteristics of free annular jets differ substantially from those of a continuous circular jet.

In this paper we shall consider the results of an experimental examination of the propagation characteristics in the main region of flow of a free jet flowing from an annular nozzle formed by two coaxial cylinders. In the experimental investigations, air was blown by a fan into a damping chamber and then through the test nozzle into the atmosphere. In order to obtain an annular jet, we used nozzles of diameter 50 and 200 mm with interchangeable linings having relative diameters $\bar{d} = d/D$ of 0.53, 0.6, 0.7, 0.8, and 0.85.

The rate of flow at the exit from the nozzle, u_0, lay between 40 and 50 m/sec, and the velocity distribution was practically uniform. The intensity of turbulence in the initial section of the jet was no greater than 1-2% in every case.

The results of velocity measurements on the jet axis are shown in Fig. 1; the distance from the initial section of the jet is given in effective diameters of the annular nozzle $\bar{x} = x/\sqrt{F_0}$ (F_0 is the area of the annular outlet cross section of the nozzle). The curves of $\bar{u}_m(\bar{x})$ given in Fig. 1 indicate that the relative diameter of the lining has a considerable influence on the laws governing the propagation of the annular jets.

In engineers' calculations the well-known formula of Abramovich [5] has become widely accepted for determining the change in velocity on the axis of an axially symmetric jet in the principal region of flow:

$$\bar{u}_m = \frac{C}{c(\bar{x} - \bar{x}_0)} .$$

The empirical constant c characterizes the change in the transverse dimensions of the jet and depends on the initial outflow conditions [6]. The coefficient C, for a jet with a uniform velocity field in the initial section, propagating in a region with a constant static pressure (momentum along the jet constant), depends solely on the shape of the dimensionless velocity profile in the principal region. Because of this, for identical initial outflow conditions the slope of the $\bar{u}^{-1}(\bar{x})$ straight lines is constant for continuous circular jets.

In the case of annular jets, the slope of the $\bar{u}_m^{-1}(\bar{x})$ straight lines varies with the relative diameter of the inner portion d (Fig. 1). The dimensionless velocity profile (Fig. 2) and the slope of the lines of

M. M. Fedorov Institute of Mining Engineering and Technical Cybernetics, Donetsk. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 21, No. 2, pp. 238-241, August, 1971. Original article submitted November 16, 1970.

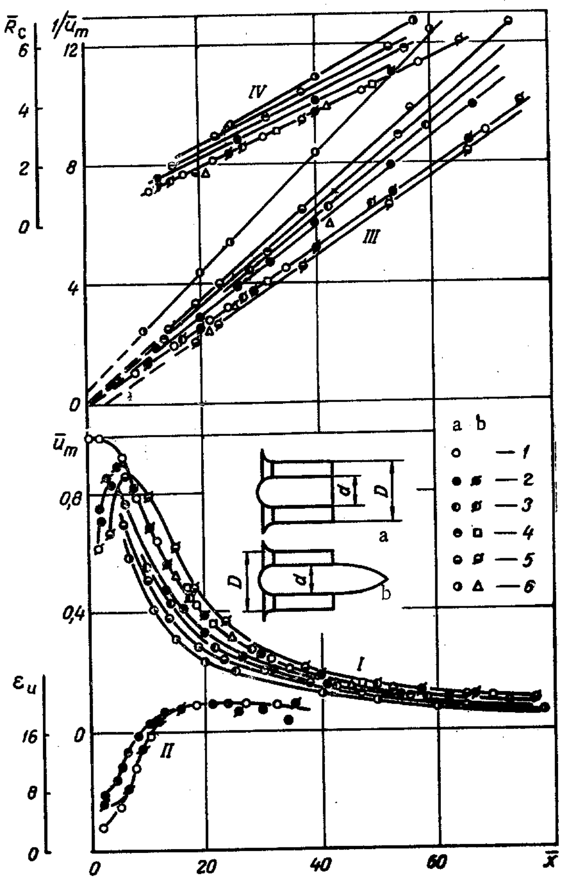

Fig. 1. Influence of the relative diameter d of the lining of the annular nozzle on the average velocity $\bar{u}_m$ along the axis of the jet (I), the reciprocal velocity $\bar{u}_m^{-1}$ (II), and the turbulence intensity ε_u, % (III), as well as on the lines of equal velocity $\bar{R}_c$ (IV) for u = 0.5 u_m: a) without a deflector; b) with a deflector; 1) for $\bar{d}$ = 0; 2) 0.53; 3) 0.6; 4) 0.7; 5) 0.8; 6) 0.85.

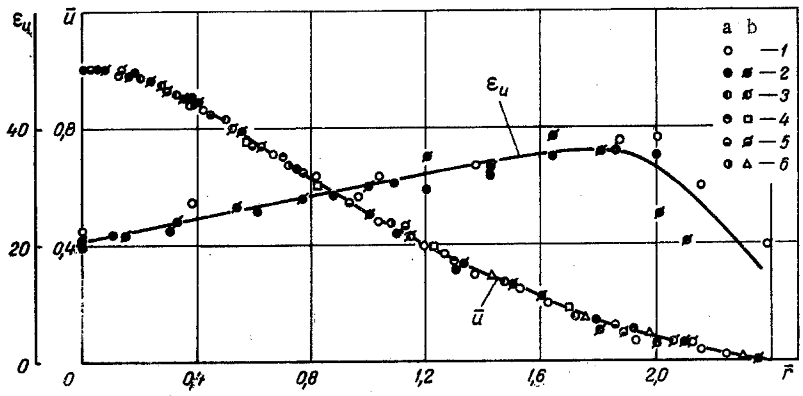

Fig. 2. Dimensionless mean velocity profile and profile of turbulence intensity ε_u, % in the main region of the annular jet for various lining diameters: a) without a deflector; b) with a deflector; 1) for d = 0; 2) 0.53; 3) 0.6; 4) 0.7; 5) 0.8; 6) 0.85.

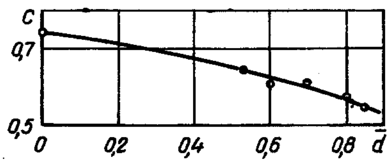

Fig. 3. Change in the coefficient C in annular jets as a function of the relative diameter of the inner portion of the nozzle $\bar{d}$.

equal velocities $\bar{R}_c(\bar{x})$ (Fig. 1) remain practically constant as d varies up to 0.85. Nor is there any change in the distribution of turbulence intensity in the principal region (Figs. 1 and 2).

There is another factor which almost entirely accounts for the changes taking place in the characteristics of annular jets when $\bar{d}$ changes over the range just indicated. In the initial section of the annular jet, there is a break-away (stall) region at a low pressure behind the inner portion of the nozzle. Hence the momentum in the main region of the jet is smaller than in the initial section. This reduction in momentum is the more considerable, the greater the relative diameter of the inner portion of the nozzle, as may be seen from the dependence of the coefficient C on the relative diameter of the inner portion $\bar{d}$ (Fig. 3).

Particularly significant in this respect are the results of measurements in jets flowing from annular nozzles with a deflector placed behind the inner portion (Fig. 1). By analogy with the flow pattern behind a streamlined solid of revolution placed in an unbounded uniform flow [7], the insertion of a deflection removes the break-away (stall) zone and reduces the loss of momentum.

It follows from the curves presented (Figs. 1 and 2) that the laws governing the changes taking place in the velocity of an annular jet in the presence of a deflector are similar to the corresponding laws pertaining to a continuous circular jet, except that, for large $\overline{d}$, there is an appreciable change in the pole distance $\overline{x}_0$.

NOTATION

x	is the distance from the outlet section of the nozzle to the section of jet under consideration;
r	is the distance from the axis of the jet;
u	is the longitudinal component of the average air velocity in the jet;
u_m	is the velocity on the jet axis;
u_0	is the velocity at the outlet from the nozzle;
ε_u	is the turbulence intensity referred to the local average velocity ($\varepsilon_u = \sqrt{\overline{u'^2}}/u$);
C, c	are empirical jet constants;
D	is the diameter of the outlet section of the nozzle;
d	is the diameter of the inner portion of the nozzle;
F_0	is the area of the jet in the initial section;
R_c	is the radius of the jet cross section corresponding to $u = 0.5u_m$;
x_0	is the distance to the pole of the jet;

$\overline{u}_m = u_m/u_0$;
$\overline{u} = u/u_m$;
$\overline{x} = x/\sqrt{F_0}$;
$\overline{x}_0 = x_0/\sqrt{F_0}$;
$\overline{r} = r/R_c$;
$\overline{R}_c = R_c/\sqrt{F_0}$.

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