THE EFFECT OF AN APERTURE ON THE DRAG OF A BODY UNDER FLOW SEPARATION CONDITIONS

(VLIIANIE OTVERSTIIA NA SOPROTIVLENIE TELA, OBTEKAEMOGO S OTRYVOM STRUI)

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M.I.GUREVICH
(Moscow)

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It seems at first sight that if an aperture is made in the surface of a body under flow separation conditions, the drag coefficient of the body will necessarily decrease. In fact, depending upon the shape of the body, the drag coefficient of the body with the addition of an aperture can be greater, less than, or equal to the drag coefficient of the body without an aperture. We demonstrate this effect by an example.

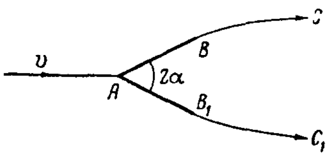

Fig. 1

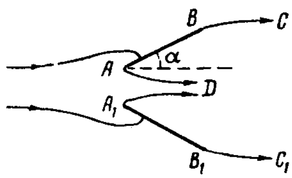

Fig. 2

We consider (Fig. 1) the plane symmetric problem of a wedge in a stream of ideal, incompressible, weightless fluid, that is, the problem that was solved – as is well known – by Bobylev [1]. If we produce an aperture in the tip of the wedge, a jet flows into the aperture (Fig.2). This problem was solved by Bonder [2]. However, it is also obtained as a limiting case of the problem of a gliding plate with a ground-plane, when the thickness of the stream is in finite. This problem was solved by S.A. Chaplygin (see the literature on the problem in [3]). In particula , Bonder obtained an original result: in the case $\alpha = \frac{1}{2}\pi$, that is, in the case of a flat plate with an aperture (Fig.3) the drag coefficient of the plate is equal to $C_x = 2\pi/(4 + \pi)$ independent of the width of the aperture. M.Iu. Tseitlin (see [3]) generalized Bonder's result to the case of oblique flow against a flat plate with an aperture, provided that the jet ADA_1 did not intersect the free surfaces BC or B_1C_1 . Thus the case of the flat plate itself represents exactly the

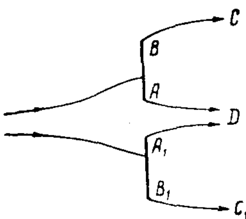

Fig. 3

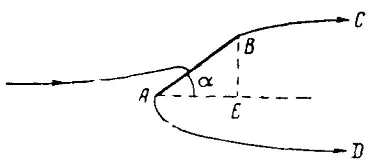

Fig. 4

case in which an aperture in the body does not change the drag coefficient. It would have been possible, using Bonder's solution (Bonder himself calculated the case $\alpha = 120°$), to carry out explicit calculation of the drag coefficient for the obstacle BAA_1B_1 (that is the wedge with an aperture). However this is unnecessary for revealing the indicated effect. It is evident that with variation of the relative width of the aperture the drag coefficient changes monotonously and continuously. We consider the limiting case when the width of the aperture AA_1 is infinite. This is just the case of oblique free-streamline flow past an isolated plate that was studied by Rayleigh [4] (Fig.4). The coefficient of the drag X of such a plate, referred to the projection of the plate in the direction perpendicular to the oncoming stream, as is well known, is

$$C_x = \frac{2X}{\rho BEv^2} = \frac{2\pi \sin \alpha}{4 + \pi \sin \alpha} \qquad (1)$$

The drag coefficient for a wedge has a somewhat more complicated form. Explicit calculation of it was carried out by Bobylev himself. We simply remark that for the drag coefficient of an infinitely thin wedge it is possible to calculate from the equations of Bobylev the value $4\alpha/\pi$, which is less than the drag coefficient according to Rayleigh, which is

$$C_x \approx \pi\alpha / 2$$

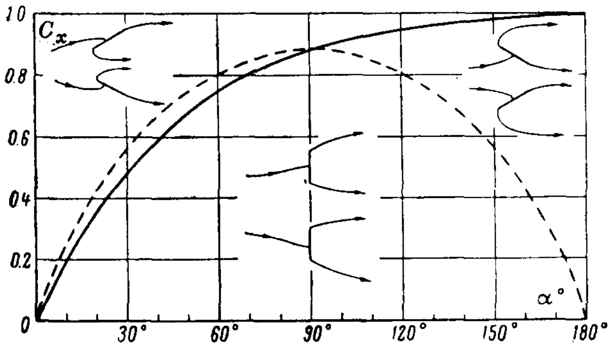

Fig. 5

Fig.5 shows the values of the drag coefficient according to Rayleigh, that is, the drag coefficient of a wedge with an infinitely wide aperture (dashed curve), and the drag coefficient of the solid wedge (solid curve) for an arbitrary angle α.

From an examination of Fig.5 we can draw the conclusion that when the sharp edge of the wedge is directed against the oncoming stream an aperture increases the drag coefficient, and when the wedge is arranged with its base against the flow an aperture reduces the drag coefficient.

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