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BRIEF NOTES

Hydrodynamics characteristic of non-circular cavity flows

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THE PAPER presents experimental investigations of the cavity flows free from the vortex wake. Characteristic properties of such kind of flow have been performed for different ranges of the Fronde and the Reynolds numbers.

IF A HEAVY liquid stream flows around particular simple bodies, e.g. a disk, a cone, a truncated ellipsoid, and gas is supplied to their back part then immediately behind the body the gas cavity is being formed, and thus the so-called cavity flow arises. Behind the cavity a vortex wake is formed which with a small flow velocity can break into a pair of vortical plaits.

For the cavity flow the formula is valid analogous to that of KUTTA-JOUKOWSKI which in the case of forward flow *velocity parallel* to the horizontal plane has the shape

$$Y = \varrho g W - \varrho u \iiint_{t} \Omega_z d\tau,$$

where Y is the resultant force vertical component, ϱ is the liquid density, g is the acceleration of gravity, U is the flow velocity, Ω_z is the velocity rotor component along the horizontal axis normal to the undisturbed flow velocity, W is the volume limited by the wetted surface of body and cavity.

Among the cavity flows one may isolate such a class of flows which are completely free from the vortex wake. Such cavity flows in a heavy liquid were called by us non-circular ones, and the feasibility of constructing such flows was shown by us in the paper [1].

Non-circular cavity flows possess particular properties which distinguish them among the ordinary cavity flows. Let us note two of the most important ones, which are the exact consequences of lack of vortex wake: at non-circular cavity flow 1) the induced resistance is equal to zero, 2) the resultant force vertical component is equal to weight displacement, in other words, the zero buoyancy $Y = \varrho g W$ exists. The latter statement follows from the formula given above.

The case is also of interest when the vortex wake behind a cavitating body although being not completely eliminated has a small intensity. Therewith a system of bound vortices of the opposite signs may correspond to the vortex wake. In this case and with the vortex wake availability the integral in the above formula may be equal to zero.

This flow turned out to be realized, in particular, with the longitudinal streamlining of the body of revolution, close to ellipsoid rotation of elongation 7, the upper and the lateral surfaces of which are embraced by the cavity and the fore-part, the after-part and the lower part are flowed around without discontinuity.

The experimental investigations of such flow properties have been performed in conditions which are characterized by a range of changing the Froude number

$$7 \leqslant \mathrm{Fr} = \frac{U}{\sqrt{gd}} \leqslant 12.5$$

and a range of changing the Reynolds number

$$3.8 \cdot 10^6 \leqslant \mathrm{Re} = \frac{UL}{\nu} \leqslant 6 \cdot 10^6,$$

where d is the diameter of the middle section of the body, L is the length of the body.

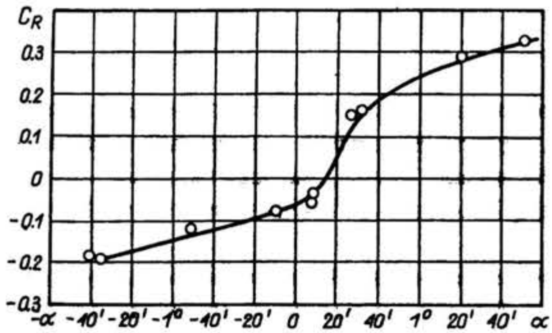

FIG. 1.

Figure 1 shows the experimentally obtained dependence of the buoyancy coefficient

$$C_R = \frac{Y - \varrho g W}{\varrho g W}$$

on the angle of attack α which forms in the vertical plane an axis of the body with the flow velocity direction. The angle of attack is regarded to be a positive one with the body fore-part situated higher than the body after-part.

It is clear from the graph that on the investigated cavitating body even with the zero angle of attack the buoyancy loss does not exceed $0.1\varrho g W$ and, consequently, the intensity of the vortex wake behind the cavitating body is small.

Another indication of the flow realized regime approximation to the non-circular cavity flow is the negligibility of the angle of attack value ($\alpha = +0° 20'$) at which the zero buoyancy takes place, i.e. $C_R = 0$.

The given results have been obtained in the experiment when the cavitation number

$$\sigma = \frac{2(P_\infty - P_c)}{\varrho U_\infty},$$

where P_∞ is pressure in undisturbed flow at the depth of the body motion, P_c is pressure in the cavity, with changing the angle of attack α remained constant, in this case $\sigma = 0.108$.

All the results given below have been obtained when a zero buoyancy was provided for the cavitating body.

To maintain the chosen regime of flow with separation it is necessary to supply the cavity with some amount of gas to compensate for its leakage from the cavity into the flow.

With the ordinary cavity flow the main and decisive source of the gas consumption from the cavity are the vortical plaits in the kernels of which due to coming to the surface a considerable pressure drop takes place, and this results in air exhausting from the cavity.

With such a mechanism of carrying gas into the flow, the Froude number significantly affects the value of its consumption, since this number is one of the parameters defining the intensity of the vortical plaits. Proving this fact, Fig. 2 represents graphically the gas

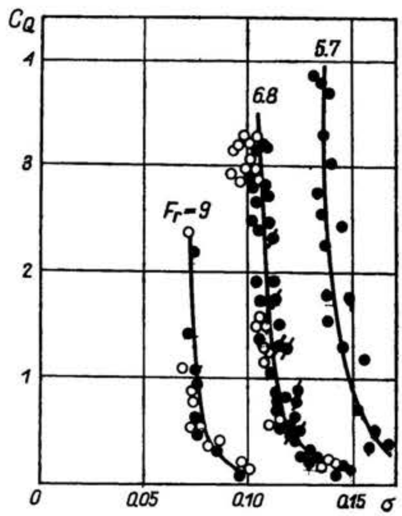

FIG. 2.

consumption dependence upon the Froude number Fr and the cavitation number σ. The value of the gas consumption here and later on is characterized by the coefficient

$$C_Q = \frac{Q}{Ud^2},$$

where Q is the volumetric gas consumption with the pressure equal to that in the cavity.

In non-circular cavity flow a cavity is free of vortex wake and vortical plaits, and, therefore, the most essential cause of the gas consumption from the cavity is eliminated. This leads to the sharp decrease of consumption of gas being carried into the flow.

One may expect the analogous effect produced by the flows close to the non-cir cular cavity flows. Actually in the case investigated, the essential decrease in intensity of the vortex wake leads to the complete lack of vortical plaits.

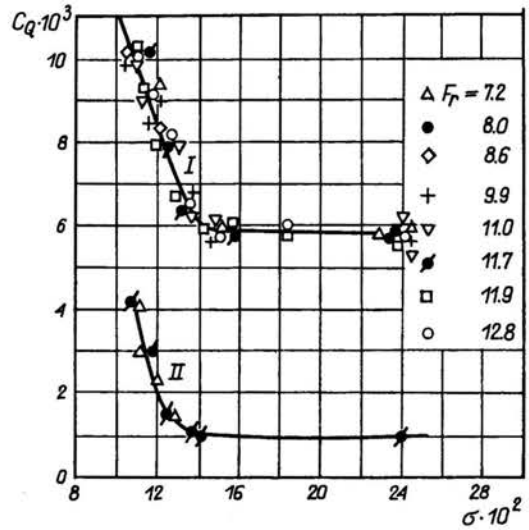
$C_Q \cdot 10^3$
10
8
6
4
2
0
8
12
16
20
24
28
$\sigma \cdot 10^2$
I
II
$F_r = 7.2$
8.0
8.6
9.9
11.0
11.7
11.9
12.8

FIG. 3.

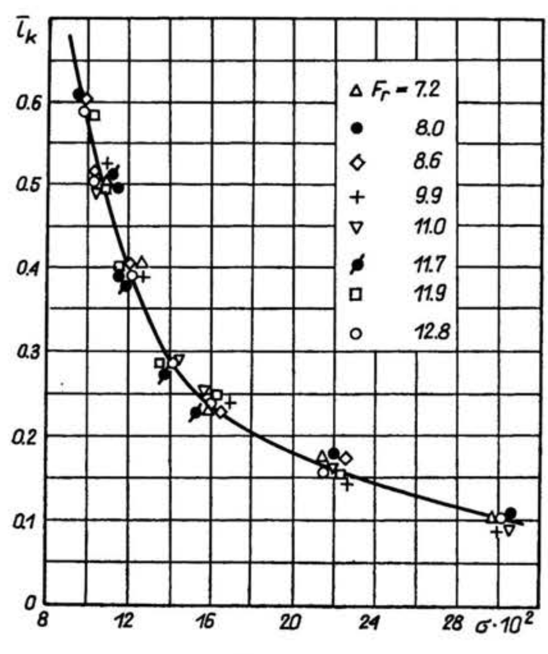
$\bar{l}_k$
0.6
0.5
0.4
0.3
0.2
0.1
0
8
12
16
20
24
28
$\sigma \cdot 10^2$
$F_r = 7.2$
8.0
8.6
9.9
11.0
11.7
11.9
12.8

FIG. 4.

Figure 3 shows the dependence (curve I) of the coefficient of consumption C_Q upon the number of cavitation σ for the body examined; the coefficient of the gas consumption at $F_r = 7$ and $\sigma = 0.108$ is two orders less than the analogous coefficient for the ordinary cavity flow.

Now the value of gas consumption is affected mainly by the local non-stationary flow at the line of the cavity free surface coming into contact with a solid body. By diminishing a clearance between the cavity free surface and the body, one may achieve the most steady flow in the region of the cavity end, and the amount of gas being carried into the flow per time unit can be thereby decreased.

The new dependence of the coefficient C_Q upon the cavitation number σ (shown in Fig. 3, curve II) is the result of changing the body geometry performed in this direction.

We will also note the fact that as may be seen from Fig. 3 the coefficient of the gas consumption with the chosen geometry of a cavitation body depends only upon the cavitation number and does not depend on the Froude number.

This is also one of the most important specific features of the cavity flow, close to the non-circular cavity flow.

Figure 4 represents one more functional dependence which turned out not to be influenced by the Froude number. Here the length of the cavity is laid off on the ordinate axis and is expressed in fractions of the cavitating body length.

This, in its turn, resulted in dependence of the relative resistance on the cavitation number only, without dependence on the Froude number (Fig. 5).

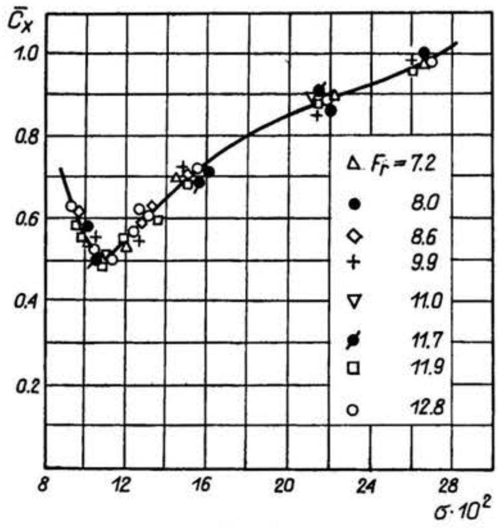

FIG. 5.

Thus, in the case considered, when the essential decrease of the vortex wake intensity is achieved by means of choice of cavity flow scheme and the zero buoyancy is provided, the effect of ponderability on the cavity flow weakens and all the basic hydrodynamic characteristics depend only on the cavitation number and do not depend on the Froude number if the latter lies in the range pointed out above.

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