MASS TRANSFER FROM THE SURFACE OF A MOTIONLESS SPHERICAL PARTICLE IN THE WAKE BEHIND A CAVITATING CYLINDER

S. M. Orel and A. D. Molchanov

UDC 66.015.23:532.528

Mass transfer from the surface of a sphere made from benzoic acid in the wake behind a cavitating cylinder is investigated experimentally.

In determining the conditions of operation of rotor apparatus turbulizing a suspension [1], the appearance of cavitation in the turbulizing elements is possible. It is interesting to establish how the cavitation influences the mass transfer from dissolving solid particles in the wake behind the elements.

The aim of the present work is to investigate experimentally the mass transfer from the surface of a motionless spherical particle in the wake behind a cavitating cylinder.

It is known [2-4] that the length of the cavity λ determines to a sufficient extent the structure of cavitation in the cylinder. There are several stages of cavitation, each of which is characterized by a definite length of the cavity [2, 3]:

1) at the beginning of cavitation ($\lambda < 1.3$), the frequency of descent of the eddies from cavitating and noncavitating cylinders is similar ($S = 0.19$);

2) with breakaway of the cavitating eddies ($1.3 < \lambda < 1.6$), the drag of the cylinder is decreased, and the frequency of eddy formation is reduced ($S = 0.15$ at $\lambda = 1.6$);

3) at maximum intensity of cavitation ($\lambda = 3$), a strong wearing property of the surfaces close to the end of the cavity is observed [4] ($S = 0.15$);

4) developed cavitation ($\lambda > 3$) is characterized by the formation of a steady cavity, with a small wearing property.

In the course of the experiments, all the stages of cavitation were achieved.

Investigations were performed on the apparatus described in [5]. The cavitation arose and developed in a cylinder of diameter $2 \cdot 10^{-2}$ m made from aluminum. The cylinder surface was polished to a mirror finish. The length of the cavity was regulated by changing the velocity of flow around the cylinder. A particle of diameter $1 \cdot 10^{-2}$ m was placed behind the cylinder. The particle was made from powdered benzoic acid, by pressing it under a pressure of 10 MPa. The mass-transfer coefficient was determined from the mass loss of the particle.

The experimental results are shown in Fig. 1. It is evident that, with increase in the flow velocity around the cylinder up to the onset of cavitation, mass transfer from the particle surface increases. The spread in the points along the curve is explained by the difference in hydrodynamic conditions at the particle locations, resulting from the breakdown of large eddy formations downstream from the cylinder and, as established earlier [5], it is the large (of the order of the particle diameter) eddies that determine the process of mass transfer from the particle in the wake behind the cylinder.

In the first stage of cavitation, the mass transfer process from the particle is practically unchanged. In the subsequent stages, the mass transfer deteriorates. This is evidently explained by an increase in frequency of the action of large eddies on the frequency because of the reduced frequency of eddy formation in the wake behind the cylinder in these stages of cavitation.

Note also that, in the course of the experiments, no destructive action of cavitation on the samples in the most unfavorable conditions at the end of the cavity ($x/D = 3$) was ob-

Lenin Komsomol Lvov Polytechnic Institute. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 45, No. 6, pp. 922-924, December, 1983. Original article submitted June 9, 1982.

0022-0841/83/4506-1379$07.50

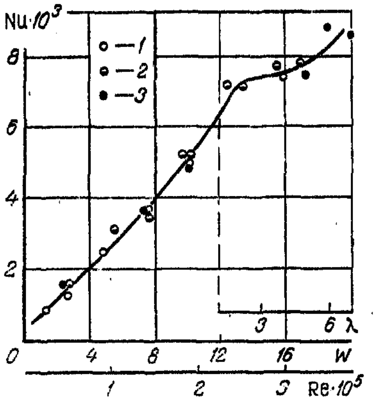

Fig. 1. Experimental data on the solution kinetics of a sphere in the wake behind a cavitating cylinder: 1) x/D = 1.5; 2) 3; 3) 6. w, m/sec.

served even at the stage of maximum intensity when λ = 3. The explanation for this may possibly be that the time required for breakdown of the surface subjected to the activation of cavitation — the so-called "incubation period" — is such that stresses and microcracks leading subsequently to the formation of cavitational erosion appear under the action of the bubbles collapsing at the surface [4]. If the rate of solution is such that, in the course of the "incubation period," the surface is able to dissolve, the action of cavitation on the process of solution is not pronounced.

In conclusion, the data obtained here are compared with the results of [6] on the mass transfer from a wall in conditions of cavitation. Cavitation appeared on projections located upstream. A complex character of the influence of cavitation on the mass transfer from the wall was noted in [6]. In the course of the experiment, cavitation did not always intensify mass transfer. This yet again emphasizes that mass transfer from the surface of a sphere in the immediate wake behind an obstacle is determined primarily by the frequency and dimensions of the eddies descending from it. The cavity arising at a cylinder improved its flow properties, which led to reduction in the frequency of descent of eddies, and this in turn reduced the mass transfer from the sphere surface.

NOTATION

Re = wD/ν, Reynolds number; S = nD/w, frequency of pulsation behind the cavity; λ = *l*D, relative length of the cavity; w, velocity of the flow arriving at the cylinder; *l*, cavity length; D, cylinder diameter; x/D, distance from the center of the cylinder to the center of the particle; n, frequency of eddy descent from the cylinder; ν, kinematic viscosity of the liquid.

LITERATURE CITED

1. P. A. Onatskii, Flow Apparatus with Rotor Mixing Devices [in Russian], TsINTIKhimneftemash, Moscow (1979), Ser. KhM-1.
2. I. Varga, D. Shebesht'en, K. K. Shal'nev, et al., "Correlation of hydrodynamic and acoustic parameters of cavitation," in: Unsteady Water Flows with High Velocities [in Russian], Nauka, Moscow (1973), pp. 449-457.
3. K. K. Shal'nev, "Kinematic structure of breakaway cavitation of a circular profile," Dokl. Akad. Nauk SSSR, 97, No. 5, 785-788 (1954).
4. S. P. Kozyrev, Hydroabrasive Wear of Metals with Cavitation [in Russian], Mashinostroenie, Moscow (1971).
5. G. A. Aksel'rud, A. D. Molchanov, and S. M. Orel, "Mass transfer from the surface of a motionless spherical particle in a turbulent medium behind smooth and rough cylinders," Zh. Prikl. Khim., 55, No. 7, 1606-1610 (1982).
6. V. P. Popov, L. K. Gleb, and L. Ya. Mikharskii, "Influence of cavitation on the convective mass transfer," in: Heat and Mass Transfer in Phase and Chemical Transformations [in Russian], Nauka i Tekhnika, Minsk (1968), pp. 195-201.