MICROCAVITATION AND DETACHMENT OF A STOKES PARTICLE IN NEAR-WALL SLOW MOTION

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A near-wall slow motion of a solid spherical particle along the wall in a fluid is studied experimentally. In the theoretical study of such motion within the Stokes approximation [1], the following paradox was revealed: no motion of a smooth heavy particle in contact with a plane wall is possible because the particle hydrodynamic drag is infinite and contactless motion is also impossible due to the absence a hydrodynamic lift. In [1], a number of possible factors which could remove this inconsistency were listed: fluid inertia (Magnus force), surface roughness, shear elasticity of the fluid, anomalous viscosity at high pressures or shear rates, cavitation, violation of the no-slip condition on rigid surfaces, disjoining pressure, etc.

The present experimental study motivated by [1] and aimed at clarifying the paradox was preformed for a spherical particle rolling down along an inclined wall of a tube in a quiescent fluid under the action of gravity (see fig). P is the particle weight in a fluid. We used highly viscous fluids, such as silicone and glycerin, and particles with various densities. The particle diameter d ($\geq$ 1 mm) was much greater than the particle surface roughness (not shown in fig.) which, in turn, was much greater than the wall roughness. At fixed d, different particle surface roughnesses were considered. The particle traveled at constant translational velocity u and angular velocity Ω. The inclination angle of the wall α to the horizontal was variable.

It was shown that, for fairly small roughnesses and fairly large α, the particle can travel without contact with the wall under the action of a lift force F_n different from the Magnus force. The gap h between the particle and the wall attained several micrometers. For fairly high roughnesses, the particle traveled in contact with the wall for all values of α. The influence of roughness on particle motion in contact with the wall was considered in [2,3].

In contactless motion of the particle, we observed a cavity (single microbubble) formed directly behind the particle in the particle-wall gap.

The existence of the cavity results in the onset of a lift force F_n according to the following mechanism. Without taking the cavitation into account [1], directly behind the particle in the lubrication layer in the particle–wall gap a negative pressure can arise, while ahead of the particle the pressure is positive. Such pressure distribution gives zero lift force exerted on the particle. When a bubble is formed, that prevents the occurrence of negative pressures, a lift force appears (see fig).

We demonstrated experimentally that contactless motion of the particle depends on static (atmospheric) pressure P_s and surface tension σ for the fluid-air system. These facts also indicate the existence of cavitation and the related lift force. Using the data on the shape of the cavity, we found nondimensional parameters related with P_s and σ and determining nondimensional particle velocities. The existence of such dependencies was verified experimentally.

CONCLUSION

The new hydrodynamic effect was registrered and explained: a slow contactless motion of a spherical particle along a wall with the formation of a particle—wall clearance due to a lift force of cavitation nature.

REFERENCES

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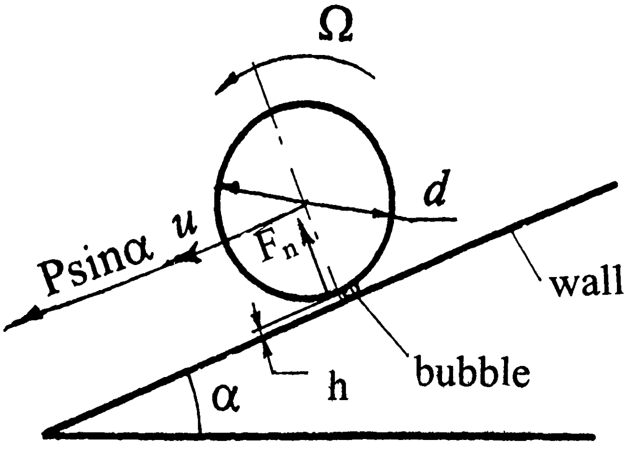

Fig.