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THE STUDY OF FLOW REGIMES AROUND AN OSCILLATING CIRCULAR CYLINDER

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The problem of a viscous incompressible flow around a circular cylinder performing harmonic oscillations is a well known classical fluid mechanics problem. Although it has a long history of research, first studies was made by Stokes [1] in 1851, it still retains the theoretical and practical relevance tooday. Marine and civil engineering, aerospace engineering, robotics - these are just some of the areas in which the problem has a practical application. From a theoretical point of view the study of complex physical mechanisms of vortex formation, structural features of the flow, the analysis of the integral characteristics (such as the hydrodynamic forces acting on the cylinder), the questions of stability and bifurcations of solutions are of the great interest.

Analyzing the recent works devoted to the study of the problem, one can distinguish the following perspective areas of research: structure of the flow regimes around the oscillating circular cylinder, the influence of different flow regimes on the drag force, acting on the cylinder, and phenomenon of a steady streaming . These areas formed the research field of the current work.

The present research consists of two parts presenting different modeling approaches. The first is based on the assimpltotic explanation method combined with the computational bifurcation analysis. The investigations is carried out in the region of small amplitude and high-frequency oscillations of the cylinder. This approach developes Schlichting-Wang [2, 3] asymptotic expansions method in unsteady Stokes boundary layer and in the outer region. The complex flow model is considerd, in which the secondary stationary flow (steady streaming) in the outer region is governed by the full system of Navier-Stokes equations. To solve this problem a computational bifurcation analysis is used. Analysis is performed according to the classical approach (that was presented for example in [4]) for the analysis of one-parameter nonlinear systems. Bifurcation analysis allows to identify several regimes of secondary streaming. The calculated terms of the asymptotic expansion allow to refine the asymptotical estimates of the hydrodynamic forces acting on the cylinder. The resulting formula describes the nonlinear interaction of the harmonics in the boundary layer and takes into account the influence of the different secondary flow regemes.

The second part of present research is devoted to the direct numerical simulation (DNS) of the flow around the oscillating circular cylinder. Two-dimensional and three-dimensional flow models are considered. The simulations are performed in OpenFOAM (CFD) software package using a supercomputer cluster. The periodic flow regimes and the corresponding secondary flows are studied. The influence of the flow regimes stuctures, including three-dimensional coherent structures in boundary layer [5, 6], on the hydrodynamic forces are considered. Numerical simulation allows to make a complete picture of the flow in the region of the small-amplitude, high-frequency oscillations of the cylinder and to evaluate the limits of applicability of the constructed asymptotic theory.

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