Instabilities and Bifurcations in the Wakes

Valentin A. Gushchin and Pavel V. Matyushin*

Institute for Computer Aided Design of the Russian Academy of Sciences (ICAD RAS)
19/18, 2nd Brestskaya str., Moscow 123056, Russia
e-mail: gushchin@icad.org.ru, pmatyushin@mail.ru, web page: http://www.icad.org.ru

ABSTRACT

The homogeneous and stratified viscous fluid flows around a sphere and a circular cylinder have been investigated in the wide range of Reynolds *Re* and Froude *Fr* numbers by means of the direct numerical simulation (DNS) and the visualization of the 3D vortex structures in the wake (where $Re = U \cdot d/\nu$, $Fr = U/(N \cdot d)$, d is the sphere diameter, N is a buoyancy frequency). For DNS the explicit numerical method SMIF (second-order accuracy in space, minimum scheme viscosity and dispersion, monotonous) has been used [1]. For the visualization of the 3D vortex structures in the fluid flows the isosurfaces of β have been drawing, where β is the imaginary part of the complex-conjugate eigen-values of the velocity gradient tensor.

Homogeneous viscous fluid. A circular cylinder wake. At $Re > 191$ there is a periodicity of the flow along the circular cylinder axis. At $191 < Re \leq 300$ and $300 \leq Re \leq 400$ the periodicity scales are equal to $3.5d \leq \lambda \leq 4d$ (mode A) and $0.8d \leq \lambda \leq 1.0d$ (mode B) correspondingly. *Owing to our investigations* it was found that the values of the maximum phase difference along the circular cylinder axis are approximately equal to 0.1-0.2 *T* (for mode A) and 0.015-0.030 *T* (for mode B), where the time *T* is the period of the flow [2].

Homogeneous viscous fluid. A sphere wake. The following classification of the 3D flow regimes can be obtained from the published papers: 1) $200 < Re \leq 270$ – a steady double-thread wake; 2) $270 < Re < 300$ - a double-thread with waves; 3) $300 < Re < 420$ – a procession of the vortex loops (facing upwards); 4) $420 < Re < 800$ – a procession of the vortex loops with the rotation of the shear layer; 5) $800 < Re < 3.7 \cdot 10^5$ - a procession of the vortex loops with the shear layer instability; 6) $Re > 3.7 \cdot 10^5$ - the turbulent boundary layer. *Owing to our investigations* the detailed formation mechanisms of vortices (FMV) in the sphere wake have been described for $200 \leq Re \leq 1000$ [3]. In particular it was shown that the detailed FMV for $270 < Re \leq 290$, $290 < Re \leq 320$ and $320 < Re \leq 400$ are different.

At $5 \cdot 10^4 \leq Re \leq 4 \cdot 10^5$ the monotonous reduction of the time-averaged total drag coefficient has been observed (from value 0.455 to 0.155) due to the laminar-turbulent transition in the boundary layer. It was shown that this drag crisis manifests itself to us through the formation of the separated bubbles within the boundary layer (near the primary separation line).

Stratified viscous fluid. A sphere wake. The clear understanding of the continuous transformation of the 3D vortex structure around a sphere with decreasing of *Fr* has been obtained at $Re < 500$ [4].

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