Lagrangian vortex loops method for hydrodynamic loads computation in 3D incompressible flows

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ABSTRACT

Lagrangian vortex loops method (LVLM) is considered. Main features of this method are the following. The vorticity in the flow domain representation as a system of closed vortex loops of the same circulation. So the vorticity motion is simulated as its movement along the streamlines of velocity field, that corresponds to neglecting of the viscosity influence in the flow domain, however its effect is considered semi-empirically through procedures implemented for vortex loops reconnection and smoothing.

Vortex loops are generated on the body surface and coincide with level-set lines of the double layer potential. In order to reconstruct the potential distribution on the body surface the least-squares procedure is implemented, while the primary value is vortex sheet intensity distribution. This, in turn is based on the boundary condition satisfaction with respect to tangential velocity components. Such approach makes it possible to consider bodies of complicated shape, which is given by triangular surface mesh. For the coefficients of the linear system, which approximates the boundary integral equation, semi-analytical approach is developed, which allows for their calculation with high accuracy even for the low-quality mesh.

For pressure field reconstruction the analogue of the Cauchy – Lagrange integral is used, and integral formulae are used, which allow computation of the hydrodynamic loads acting the body.

Numerical examples are considered for the different types of bodies: cuboid, wing of the finite span. Self-organisation of the vortex loops in the flow makes it possible to simulate such vortex structures as horseshoe vortices after the wing.

The possibility of the generalization of the developed algorithm is discussed for moving bodies.

The advantage of the proposed method is connected with rather small computational cost of the algorithm in comparison to traditional mesh method, while unsteady hydrodynamic loads can be computed with the accuracy, enough for engineering applications.

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