The Efficiency Comparison of the Vortex Element Method and the Immersed Boundary Method for Numerical Simulation of Airfoil's Hydroelastic Oscillations

Ilia K. Marchevsky*, Victoriya S. Moreva† and Valeria V. Puzikova†

*, † Applied Mathematics dep., Bauman Moscow State Technical University
105005 Moscow, Russia, 2nd Baumanskaya, 5
e-mail: iliamarchevsky@mail.ru , morevavs@rambler.ru, valeria.puzikova@gmail.com

ABSTRACT

Lagrangian meshless Vortex Element Methods [1, 2] are well-known numerical methods which efficiency can be very high when solving coupled aerohydroelastic problems. They allow to simulate both viscous and inviscid incompressible flows in bounded and unbounded domains. Vortex Element Methods for 2D flows are well developed and there are number of approaches for viscosity accounting (e.g., Viscous Vortex Domains method [3]) and for boundary conditions satisfaction. The main advantage of Vortex Element Method is that there is no necessity of mesh constructing and reconstructing when the airfoil moves and the airfoil can be of arbitrary shape. It also provides small numerical viscosity and requires sufficiently small memory and time of computations.

For flow simulation around airfoils with complicated shape or when the Reynolds number is about tens of thousands the number of vortex elements should be very large to provide the necessary accuracy. There are some effective approaches for accuracy improvement [4] as well as number of approaches for computations speedup. First of them are based on the modified mathematical models, the second methods presuppose both parallel computational algorithms and fast approximate multipole methods usage. All these approaches allow to simulate unsteady flows and to solve directly coupled hydroelastic problems even on personal computers.

The other effective method for coupled hydroelastic problems solving which also doesn't require mesh reconstruction is Immersed Boundary Method. Its LS-STAG [5] modification is one of the most accurate algorithms because it provides correct approximation of the governing equations both on rectangular fluid cells and on cut-cells. Because of structured rectangular mesh usage the uniform 5-point stencil inside the flow region and 4 or 3-point 'reduced' stencils at the boundary of the region are used so it is possible to use high-efficiency numerical methods (e.g. Krylov subspaces, multigrid preconditioners etc.) for the corresponding linear systems solving. RANS-based turbulence models have been recently implemented to LS-STAG method, so it can be effectively used for coupled problems solving when the Reynolds number is about tens of thousands.

In the present research the well-known test problem of wind resonance phenomenon simulation is considered. The Vortex Element Method and the LS-STAG method are used for its solving and their comparison is carried out. The obtained results can be useful for scientists and engineers who develop and operate the constructions which structural elements oscillate under hydrodynamic forces.

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