The Algorithm for 3D Vortex Sheet Influence Computation in Meshless Vortex Method

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ABSTRACT

Vortex element method (VEM) is very suitable when solving FSI-problems, especially two-way coupled aeroelastic problems, when it is important to simulate unsteady body motion in incompressible flow [1]. Pure Lagrangian modifications of vortex methods don't require mesh generation in the fluid domain and its reconstruction at every time step due to body's motion. Vortex methods need much less computational resources (time of computations, memory and disk space) in comparison with most popular mesh methods.

Flow simulation using VEM requires the solution of two main problems: vortex wake evolution simulation and vorticity flux on the body surface computation, which are solved sequentially, step by step at every time step. In order to simulate vortex wake evolution there are developed number of approaches: vortex wake approximation with vortex filaments, vortex lattices, vortex points (vortons) of different types etc. The vortex fragmenton model for vortex wake simulation is developed by authors and it has been applied to some FSI-problems [2]. As to vorticity flux simulation, one of the most important problems is vortex sheet intensity computation. There are two fundamental approaches, which are based on elimination of the limit values of normal or tangential velocity components on the body surface [3]. These approaches are denoted as 'NVEM' and 'TVEM'.

The accuracy of NVEM approach in some FSI-applications is not enough for practice. In 2D-case TVEM approach allows to obtain much more accurate results, but it requires more precise discretization and integration schemes usage [3]. Such schemes are constructed and investigated by authors for 2D-case [4].

In the present research 3D-case is considered. The discretization scheme for TVEM approach is presented. The body surface is triangulated using arbitrary mesh generator and vortex sheet intensity assumed to be piecewise constant on the cells. TVEM approach includes calculation of two surface integrals: the integral over the 'influence' cell and the integral over the 'control' cell. For arbitrary triangular mesh 'influence' integral can be calculated analytically. Numerical calculation of the 'control' integral using Gaussian points leads to significant errors for neighbor cells. The quadrature formula with analytical singularity integration is derived. Non-singular part is integrated numerically by using Gaussian quadratures. All necessary formulae are obtained in invariant form and can be applied for arbitrary triangular cells.

The original algorithm which is based on the developed approach for vortex influences computation is developed.

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