Accuracy comparison of different approaches for vortex sheet discretization on the airfoil in vortex particles method

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ABSTRACT

One of the key questions which arise in implementation of meshless Lagrangian vortex particle methods for viscous incompressible flow simulation around the airfoil, is the choice of numerical approach for no-slip boundary condition satisfaction on the camber line of the airfoil. In the simplest case, the airfoil is assumed to be rigid and immovable, so it can be simulated with vortex sheet of unknown intensity. Vorticity after being generated in this vortex sheet becomes part of vortex wake and moves in the flow. The boundary condition according to one of two possible approaches (its satisfaction for normal or tangent components of flow velocity) can be reduced to integral equation of the 1st or 2nd kind [1]. The kernels of such equations have very different properties, in fact.

In the present paper the camber line of the airfoil assumed to be approximated by polygon, which consists of rectilinear segments (panels). The unknown vortex sheet intensity can be approximated by piecewise-constant or piecewise-linear distribution. In the last case, it can be continuous or discontinuous, or continuous everywhere except some specified points that correspond to sharp edges and angle points of the airfoil. Some numerical schemes are considered and estimations of their accuracy in different norms and computational cost are obtained. Two model problems are considered – potential flow simulation around elliptic and Zhukovsky wing airfoils, for which it is possible to construct exact analytic solution in closed form by using conformal mappings theory. Vortex wake influence also should be taken into account correctly. The developed numerical schemes can be used for arbitrary vorticity distribution, which is simulated by separate vortex elements that move in flow region.

For all considered numerical schemes, the necessary analytical formulae are derived for coefficients of the corresponding linear algebraic system that approximates the boundary integral equation.

Another important problem is correct computation of the vortex sheet influence on the vortex wake. It is especially important for flow simulation in boundary layer (in proximity of the airfoil) with high precision. The model problem is considered and the accuracy estimations are obtained for different numerical schemes.

The way of generalization of the obtained results is shown in order to adapt the developed numerical schemes for the general case when the airfoil is movable and/or deformable.

REFERENCES

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