Extension of the LS-STAG Immersed Boundary Method for RANS-based Turbulence Models and its Application for Numerical Simulation in Coupled Hydroelastic Problems

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ABSTRACT

The LS-STAG immersed boundary / level-set method is useful for numerical simulation in coupled hydroelastic problems, since it doesn't require a coincidence of cell edges and boundaries of the computational domain, and allows to solve on the Cartesian mesh problems when domain shape is irregular or it changes in the simulation process due to aeroelastic body motion.

However, the LS-STAG method, as all mesh methods has a significant limitation when simulating flows with high Reynolds number: it requires extremely small space and time steps. It leads to significant increase in computational cost. The traditional method of solving this problem is RANS, LES, DES etc. turbulence models usage.

In this research, the general approach to the application of the LS-STAG method for the numerical solution of RANS equations is suggested by constructing the LS-STAG method extension with the Spallart-Allmaras turbulent model.

A software package is developed for the numerical simulation of the bodies' motion in the viscous incompressible flow by using the LS-STAG method and its modifications. The C++ language and the paradigm of object-oriented programming are used. It allows to modify and to develop the package (for example, by including a mesh for non-Newtonian and turbulent stresses in addition to the staggered meshes "velocity-pressure") much easier in comparison with procedure-oriented programming paradigm.

To verify the software package test problems of flow simulation past various non-moving and moving airfoils have been solved. The Taneda's phenomenon (stabilization of the wake past a rotary circular cylinder), as well as circular airfoil wind resonance phenomenon and wind turbine rotors autorotation were simulated.

REFERENCES

[1] R. Mittal and G. Iaccarino, "Immersed boundary methods", *Annu. Rev. Fluid Mech.*, Vol. *37*, pp. 239–261, (2005).

[2] Y. Cheny and O. Botella, "The LS-STAG method: A new immersed boundary / level-set method for the computation of incompressible viscous flows in complex moving geometries with good conservation properties", *J. Comput. Phys.*, Vol. **229**, pp. 1043–1076, (2010).

[3] P.R. Spalart, "Strategies for turbulence modelling and simulations", *Int. J. Heat and Fluid Flow*, Vol. **21**, pp. 252–263, (2000).

[4] P.R. Spalart and S.R. Allmaras, "A one-equation turbulence model for aerodynamic flows", *Recherche Aerospatiale*, Vol. **1**, pp. 5–21, (1994).

[5] J.T. Klamo, A. Leonard and A. Roshko, "On the maximum amplitude for a freely vibrating cylinder in cross flow", *J. of Fluids and Struct.*, Vol. **21**, pp. 429–434, (2005).

[6] M.M. Zdravkovich, *Flow around circular cylinders*, Oxford University Press, Oxford. 1997.