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Dynamic Stall Simulation with Direct-Forcing Immersed Boundary Method

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Extended Abstract

To predict fluid-structure interactions accurately, a variety of computational methods have been proposed. The most common method to simulate the flow with a complicated solid boundary is to use a body-fitted technique with grids fitting and clustering along the complex boundary. The immersed boundary method is becoming popular since 1972 due to its capability to handle simulations for a moving complex boundary with lower computational cost and memory requirements than the conventional body-fitted method. This method can be categorized as a continuous forcing method in which a forcing term is added to the continuous Navier-Stokes equations before they are discretized. The direct-forcing immersed boundary method (DFIB) is one of the immersed boundary methods. This method uses a virtual forcing term determined by the difference between the interpolated velocities at the boundary points and the desired boundary velocities. The DFIB method with both virtual force and heat source is developed by [1] to solve Navier-Stokes and the associated energy transport equations to study some thermal flow problems caused by a moving rigid solid object within.

The present study is the extended version of [1] for arbitrary geometries. We use point-in-polygon (PIP) to exclude the solid geometry from the fluid. In computational geometry, the PIP problem asks whether a given point in the plane lies inside, outside, or on the boundary of a polygon. It is a special case of point location problems and finds applications in areas that deal with processing geometrical data.

A stall is a reduction in the lift coefficient generated by a foil as angle of attack increases. This occurs when the critical angle of attack of the foil is exceeded. Dynamic stall is a non-linear unsteady aerodynamic effect that occurs when airfoils rapidly change the angle of attack. The rapid change can cause a strong vortex to be shed from the leading edge of the aerofoil, and travel backwards above the wing. The vortex, containing high-velocity airflows, briefly increases the lift produced by the wing.

In the present study a dynamic stall case on a NACA 0012 is considered. The Reynolds number is $1.35*10^5$. The mean angle of attack is 10^o and the amplitude of ocillation is 15^o. The reduced frequency is set to 0.1. Lift and drag coefficients are compared with the former studies and they show that the DFIB method can simulated the flow over a airfoil in the stall case well. Some differences are seen at the maximum (25^o) and the minumum (-5^o) angles; but at the others angles the values are very close.

References

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