Numerical Simulation of Vortex Interactions Using a Fast Multipole Discrete Particle Method

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ABSTRACT

The discrete vortex method is based on a Lagrangean description of the vorticity transport equation. In order to implement the numerical method one can split the vorticity transport equation into separate diffusive and convective effects. Several formulations can be used to model the diffusive effect, for instance, the random walk method, the core spreading method and the velocity diffusion method. The convection effect can be treated using the material derivative which avoids the solution of a non-linear term; this is the major advantage of the discrete vortex method since each discrete vortex moves with the fluid velocity field. However, the solution of the fluid velocity field requires three contributions which come from the incident flow, the flow perturbation due to the solid body (which is represented by flat panels) and the vortex-vortex interactions. The latter contribution is computationally expensive since the Biot-Savart law is used to compute the induced velocity by all discrete vortices in the vortex cloud. The fast multipole method is a very attractive algorithm used to accelerate the interaction among discrete vortices. It reduces the computational cost of the Biot-Savart law from $O(N^2)$ to $O(N)$. Here, N is the number of discrete vortices for a particular time step. The present fast multipole method algorithm is based on the original ideas of Greengard and Rokhlin, Journal of Computational Physics, 1987, which implemented the method for fast particle interactions. However, new implementation details are developed to further accelerate the solutions of the discrete vortex method. Thus, in the present work, we study the accuracy of the fast multipole method, and later, this study will be used for an analysis of the flow around a cylinder and around a NACA 0012, in different angles of attack, including under stall conditions.

REFERENCES

[1] Greengard, L., and Rokhlin, V., “A Fast Algorithm for Particle Simulations,” Journal of Computational Physics, Vol. 73, 1987, pp. 325–348.

[2] Carrier, J., Greengard, L., and Rokhlin, V., “A Fast Adaptive Multipole Algorithm for Particle Simulations,” SIAM Journal on Scientific and Statistical Computing, Vol. 9, No. 4, 1988, pp. 669–686.