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Temporal and Spacial Adaptation Strategies in Aerodynamic Simulation of Bluff Bodies Using Vortex Particle Methods

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Abstract : Fluid dynamic computation of wind caused forces on bluff bodies e.g light flexible civil structures or high incidence of ground approaching airplane wings, is one of the major criteria governing their design. For such structures a significant dynamic response may result, requiring the usage of small scale devices as guide-vanes in bridge design to control these effects. The focus of this paper is on the numerical simulation of the bluff body problem involving multiscale phenomena induced by small scale devices. One of the solution methods for the CFD simulation that is relatively successful in this class of applications is the Vortex Particle Method (VPM). The method is based on a grid free Lagrangian formulation of the Navier-Stokes equations, where the velocity field is modeled by particles representing local vorticity. These vortices are being convected due to the free stream velocity as well as diffused. This representation yields the main advantages of low numerical diffusion, compact discretization as the vorticity is strongly localized, implicitly accounting for the free-space boundary conditions typical for this class of FSI problems, and a natural representation of the vortex creation process inherent in bluff body flows. When the particle resolution reaches the Kolmogorov dissipation length, the method becomes a Direct Numerical Simulation (DNS). However, it is crucial to note that any solution method aims at balancing the computational cost against the accuracy achievable. In the classical VPM method, if the fluid domain is discretized by Np particles, the computational cost is O(Np2). For the coupled FSI problem of interest, for example large structures such as long-span bridges, the aerodynamic behavior may be influenced or even dominated by small structural details such as barriers, handrails or fairings. For such geometrically complex and dimensionally large structures, resolving the complete domain with the conventional VPM particle discretization might become prohibitively expensive to compute even for moderate numbers of particles. It is possible to reduce this cost either by reducing the number of particles or by controlling its local distribution. It is also possible to increase the accuracy of the solution without increasing substantially the global computational cost by computing a correction of the particle-particle interaction in some regions of interest. In this paper different strategies are presented in order to extend the conventional VPM method to reduce the computational cost whilst resolving the required details of the flow. The methods include temporal sub stepping to increase the accuracy of the particles convection in certain regions as well as dynamically re-discretizing the particle map to locally control the global and the local amount of particles. Finally, these methods will be applied on a test case and the improvements in the efficiency as well as the accuracy of the proposed extension to the method are presented. The important benefits in terms of accuracy and computational cost of the combination of these methods will be thus presented as long as their relevant applications.

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