Adaptive Methods for the simulation of Multiscale Fluid Dynamic Phenomena using Vortex Particle Methods with applications to Civil Structures

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ABSTRACT

Wind effects on long-span bridges and slender buildings constitute a major criterion during the design phase. These effects are very important in certain cases, because they can lead to strong dynamic excitations of the structure and in some cases also to its failure. It is thus necessary to take into account the wind influence by resolving the fluid-structure interaction problem (FSI).

During the design phase the shape optimazation often requires the usage of devices like guide-vanes to enhance a static and passive flow control that is supposed to reduce these phenomena which are responsible for instabilities. Guide-vanes then, along with other small parts of the structure such as handrails and barriers, whose dimensions are much smaller than the cross section of the bridge, are often responsible for smaller scale fluid features like vortices. These features are not negligible because they can largely affect the entire fluid domain and the FSI problem e.g. a small guide vane could change the point of separation of the boundary layer. In order to take into account the effect generated by these entities, it is then necessary to resolve the small scale fluid features.

Vortex Particle Methods (VPM) are successfully employed to study these phenomena. These methods consider a discrete number of mutual interacting vorticity-carrying particles to represent the continuous fluid domain. The boundary conditions are imposed by the Boundary Element Method approach which gives the advantage of a grid free Lagrangian formulation of the incompressible Navier-Stokes equations and a natural representation of the vortex creation process which is inherent in bluff body flows.

This paper presents an adaptive scheme, the aim of which is the resolution of the small scale flow features in some regions. The goal of such an adaptive scheme is to respect a certain balance between the accuracy required for the problem and the computational cost. The desired accuracy is thus obtained by controlling the spatial discretization and the temporal discretization of the problem.

Several adaptation techniques will be herein presented, which will allow a better representation of the FSI problems involving a temporal sub stepping as well as the dynamic rediscretization of the particle map to account for the different flow field scale features. A fundamental study and an application to a real test case will be shown as a proof of efficiency and accuracy.

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