Seminar in Applied and Computational Mechanics, Keio University

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Discussion Room 3 in Building #14

Improvement of vortex resolution through application of hybrid methods

by

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Insufficient resolution of vortex structures is one of the key problems in Computational Fluid Dynamics (CFD). First, the turbulent models used in Reynolds Averaged Navier Stokes Equations (RANSE) and Large Eddy Simulations (LES) approaches can be too diffusive. Second, the grid based methods possess rather high numerical diffusion which is proportional to the grid resolution. Both effects result in non- physical flow smoothing making difficult the reproduction of concentrated vortex structures with scales comparable with the cell size. The numerical diffusion can be sufficiently diminished by use of the grid free Computational Vortex Method (CVM). Being developed many decades ago, the CVM is still not became a popular tool in the turbulence research because of the following difficulties: formulation of boundary conditions on solid boundaries, artificial noise typical for all particle methods, viscosity effects modeling, stability problems in three dimensional cases, etc. Many disadvantages of CVM can be easily solved with grid based methods and vice versa. We present the hybrid method (principally different from the vortex-in-cell one) combining CVM and grid based methods to improve the resolution of vortex structures in CFD. The approach is based on the decomposition of vortex structures and velocity field into large scale and small scale parts. The large scale structures are simulated on the grid, whereas the small scale ones are represented through a set of particles within the CVM method. New formalism describes the following effects: generation of new particles from grid based solution, motion of these particles in grid based flow with two-way coupling between vortex particles and background field, mapping of particles back to the grid when their size is growing, diffusion of vortex particles and their disappearance. The generation of fine vortices is based on the idea taken from LES. The two way coupling motion equations are derived from the original Navier Stokes equations using the operator splitting method according to scales. The boundary conditions are explicitly formulated only for the grid solution. Numerical simulations of a few academic cases are presented to illustrate advantages of the hybrid grid- particle method.

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