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INCREASE OF VORTEX RESOLUTION IN COMPUTATIONAL FLUID MECHANICS BY A COMBINATION OF GRID- AND PARTICLE- BASED METHODS

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Insuffcient 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 when the grid free Lagrangian methods like the Computational Vortex Method (CVM) [1] are applied. The vorticity domain is represented as a set of vortex particles tracked in the Lagrangian way. The CVM has the following advantages: low numerical diffusion, no restrictions with respect to the CFL stability criteria, convenience in results interpretations in terms of vorticity, etc. 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. Taking the fact into account that many disadvantages of CVM can be easily solved within grid based methods and vice versa the authors came to idea to combine both methods to improve the resolution of vortex structures in CFD. The idea 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. The idea requires the development of a new formalism which should contain the procedures describing 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 field of the velocity, obtained by subtraction of filtered velocities from the original ones, is analyzed using λ_{ci} criterion [2]. The vortex particles are placed in regions of high λ_{ci} if the identified vortex structures are smaller than a few grid cells. The two way coupling motion equations are derived from the original Navier Stokes equations using the operator splitting method according to scales. Substitution of the velocity and vorticity decompositions into the vorticity transport equation results in the system of two coupled transport equations with terms having a clear physical interpretation. The first equation in $v-p$ variables is solved using finite volume method with OpenFoam code. The second equation in variables velocity- vorticity is solved with vortex particle method CVM. The boundary conditions are explicitly formulated only for the grid solution. The method principally differs from the hybrid vortex- in- cell method. The aim of this paper is to show the progress in comparison with our previous publications [3] and [4].

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