Generation of Artificial Velocity and Scalar Fluctuations based on Divergence-Free Vortex Particles

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ABSTRACT

Formulation of the inlet condition is a well-recognized topic in LES and DNS simulations. The methods for specification of turbulent inlet conditions utilize one of the four following techniques: natural laminar turbulent transition, random uncorrelated oscillations, LES or DNS auxiliary simulation with periodic boundary conditions in a domain in front of the area of interest, synthetic turbulent fields. Overview of existing methods can be found in [1]. The first two techniques are not used nowadays because the first one requires huge computational resources, whereas the second one generates uncorrelated fields which quickly dissipate behind the inlet. The third method is applicable only for flows with a special geometry. Within the last approach the turbulence is artificially generated without a solution of the flow equations. The task is to synthesize a turbulent velocity field V(x ,t) =U(x)+u(x,t), where U(x) is the mean velocity which should be known. The fluctuations u(x,t) need to have a number of properties, which we, according to our experience, list below in the order of their importance:

1). u(x,t) should be spatially and temporally correlated. 2). It needs to have prescribed Reynolds stresses. 3). In addition to the requirement 1, u(x,t) needs to have prescribed integral lengths. 4. u(x,t) should fulfill the continuity constraint 5. In addition to the requirements 1 and 3, u(x,t) should have prescribed correlation functions.

Currently, there is no method, which fulfills all of the above requirements. The authors have recently improved the turbulent spot methods, originally proposed in [2], by formulation of a new turbulent structure based on strict mathematical derivations [3]. These structures are based on a transformed vector potential from which the velocity field is obtained. The structures are called Vortons. They are a kind of typical axisymmetric vortex particles widely used within the vortex particle method (VPM). The vortons allow to fulfill the continuity constraint, not only for isotropic Reynolds stresses, but also for arbitrarily anisotropic ones. The behavior of this structure has been tested on spatially decaying turbulence as well as on channel flow. Both case studies confirm that 1) the adaption length is reduced by application of vortons instead of simplicity-motivated velocity distributions like hat spots and 2) by being able to obey continuity always, the artificial pressure noise is greatly reduced.

REFERENCES

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