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An iterative process for the implicit evaluation of forces in the immersed boundary method, using the virtual physical method

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ABSTRACT

The flows around complex and/or moving geometries are present in most applications of fluid mechanics in engineering. However, the numerical simulation of such flows requires, in most situations, sophisticated numerical methods and high computational costs. In this present work, the Immersed Boundary method is used as a viable alternative to represent a complex geometry placed into the flow field. The Immersed Boundary Method has been developed by the Laboratory of Heat and Mass Transfer and Fluid Dynamics (LTCM) of the Federal University of Uberlândia. This technique makes use of two independent domains for the solution of the flows over complex geometries: an Eulerian domain (Cartesian or cylindrical e.g.), which is discretized using the Finite Volume Method over a non-uniform mesh to integrate the Navier-Stokes equations. In this case, a second-order approximation for time and space derivatives is used. Another important remark is that the Lagrangean domain, which represents the immersed boundary, is represented by a superficial unstructured mesh, composed of triangles. Figure 1 gives an idea of both meshes together.

Immersed Boundary (IB) methods reproduce fluid-solid or fluid-fluid interfaces by adding a force source term to Navier-Stokes equations. The way the force field is evaluated characterizes the different Immersed Boundary methods [1]. In this paper a new form of evaluation of the force source term is presented. Here, besides fluid iteration controls, such as convergence criteria in linear systems solvers and maximum divergent, for instance, the solver only advances in time if the L2 norm for the immersed boundary is less than some predefined value. This new way of evaluation of the force term overcomes one of the major shortcomings of the immersed boundary method i.e. the rapid definition of the immersed geometry [2], since the first time-step, guaranteeing a physically more consistent transient period, or even an eventual abrupt change of position of geometry, which is very common in problems like fluid structure interaction (FSI problems).

Some results of canonicals flows (flows over spheres and surface mounted cubes e.g.) obtained with the new procedure, are shown, as well as the comparison of the before and after of the implementation of new force calculation. For the sake of example, Figure 2 (a)-(b), shows the difference between the explicit (common) and implicit evaluation of the flow over a land gear prototype for the first time

step of the simulation. One can clearly see the improvement in implicitation the force source term in figure 2 (b), where no streamline crossed the immersed geometry. As an example of fluid structure interaction, a prototype of a wind turbine is simulated. In such a simulation the turbine prototype is accelerated (from the rest) by the action of the fluid itself. Figure 3 shows the curves of acceleration, the velocity, and the angular dislocation for a few physical seconds of simulation. The in-house parallel code runs on a Beowulf-class cluster, a viable and reliable alternative to solve problems that demand very large computational resources.

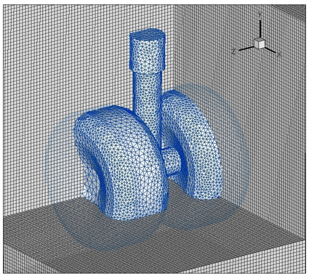

Figure 1: Different types of meshes used in the immersed boundary method.

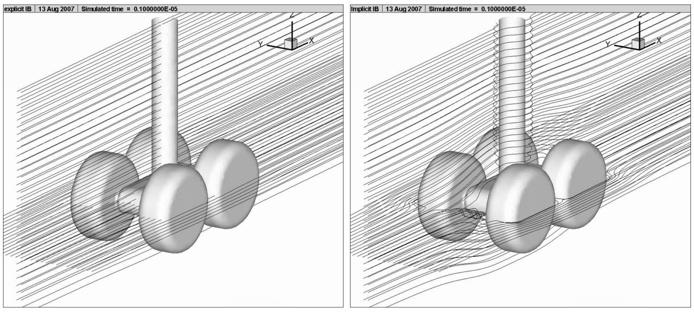

Figure 2: Comparison between the explicit way of forces evaluation in the immersed boundary method with the virtual physical model (a - right), and the implicit way (b - left).

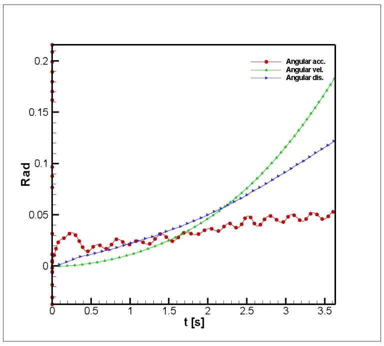

Figure 3: Curves of acceleration, velocity, and angular dislocation for the simulation of a prototype of a wind turbine.

REFERENCES

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