

Session: Bluff body flows

Scale-Resolving Simulation of Turbulent Flows Using Immersed Boundary Method on Unstructured Meshes

Ilya Abalakin, Alexey Duben, Tatiana Kozubskaya, Natalya Zhdanova

Keldysh Institute of Applied Mathematics of RAS, Russia

The usage of scale-resolving approaches facilitates more accurate prediction of characteristics and better understanding of flow physics in simulation of complex problems. The drawback is that in addition to high computational costs these methods demand large highly-skilled human effort for appropriate computational (body-fitted, BF) mesh design, especially when complex geometric configurations are considered. This follows from scale-resolving approach requirements but is also caused by certain features of numerical schemes and other computational aspects. Increasing the geometry detalization results in rapidly growing time expenses for mesh building. Moreover, this amplifies the probability of errors. That's why object geometry optimization while using scale-resolving approaches becomes a strongly time-consuming task in the sense of human hours. In view of these problems, the immersed boundary (IB) method looks quite promising. This approach allows one to simulate the flow over the solid body without boundary conforming meshes.

We exploit the IB techniques based on Brinkmann penalization [1]. A similar approach was presented for incompressible flows on octree meshes in [2] and on unstructured meshes in [3]. In this work we combine the two approaches: body-conforming for main or simple geometry parts of the configuration, where it is important to provide high accuracy simulation of the boundary layers over a surface, and the IB method for modelling remaining elements.

The numerical algorithm implemented in our in-house code NOISEtte realizes the recent modification [4] of hybrid RANS-LES DES approach. It is adjusted for joint use with the IB method. We use the EBR (Edge-Based Reconstruction) schemes, which provide higher accuracy on unstructured meshes thanks to quasi-1D reconstruction of variables along extended edge-oriented stencils [5]. To treat high gradients and shocks we develop the WENO-extension of EBR schemes [6]. In order to gain the best accuracy – stability – computational cost ratio we develop an adjustable hybrid numerical algorithm that takes into account local characteristics of flow and mesh.

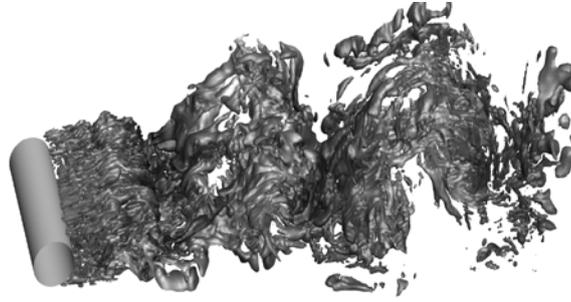


Fig. 1. Visualization of the flow over circular cylinder simulated by IB approach.

We validate our resulting algorithm by simulating turbulent compressible flows over the circular cylinder with $Re=3900$ and tandem of square cylinders with $Re=180000$ on unstructured meshes. Visualization of the first problem flow simulated using the IB method is demonstrated in Fig. 1. The validation is based on comparing the results with those computed using classical BF approach and corresponding experimental data. Mesh resolution requirements and other numerical aspects of flow simulation near bodies modelled by the IB method will be discussed.

We use the developed method to simulate the transonic turbulent flow over a cavity with the installed deflector of complex geometry [7] where the deflector is described by the IB techniques while the cavity – using the usual BF approach.

The work is supported by the Russian Science Foundation (Project 16-11-10350).

References

- [1] Angot Ph., Bruneau C.-H. and Fabrie P., *Numer. Math.*, 81, 497–520 (1991).
- [2] Vasilyev, O.V. and Kevlahan N.K.-R., *SIAM J. Sci. Comput.*, 26(6), 1894–1915 (2005).
- [3] Bergmann M., Iollo A., *J. Comput. Phys.*, 230(2), 329–348, (2011).
- [4] Shur M., Spalart P., Strelets M., Travin A., *Flow Turbul. Combust.*, 95(4), 709–737, (2015).
- [5] Bakhvalov P., Abalakin I., Kozubskaya T., *Int. J. Numer. Methods Fluids*, 81(6), 331–356 (2016).
- [6] Bakhvalov P., Kozubskaya T., *Comput. Fluids*, 157, 312–324 (2017).
- [6] Abalakin I., Zhdanova N., Kozubskaya T., *Math. Models Comput. Simulat.*, 8(3), 219–230 (2016).
- [7] Duben A., Zhdanova N., Kozubskaya T., *Fluid Dynamics*, 52(4), 561–571 (2017).