11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

THE FINITE CELL METHOD FOR FLUID AND FLUID-STRUCTURE INTERACTION PROBLEMS

Dominik Schillinger[1], René R. Hiemstra[2], Ming-Chen Hsu[3] and Vasco Varduhn[1]

[1] Dept. of Civil, Environmental and Geo-Engineering, University of Minnesota, USA
dominik@umn.edu; http://www.tc.umn.edu/~dominik/
[2] Institute for Computational Engineering and Sciences, The University of Texas at Austin, USA
[3] Dept. of Mechanical Engineering, Iowa State University, USA

Key Words: *Embedded domain analysis, finite cell method, fluid mechanics, fluid-structure interaction*

The finite cell method is an embedded domain method, which combines the fictitious domain approach with higher-order finite elements, adaptive integration, and weak enforcement of unfitted essential boundary conditions [1-3]. Its core idea is to use a simple unfitted structured mesh of higher-order basis functions for the approximation of the solution fields, while the geometry is represented by means of adaptive quadrature points. This eliminates the need for boundary conforming meshes that require time-consuming and error-prone mesh generation procedures, and opens the door for a seamless integration of very complex geometric models into finite element analysis. At the same time, the finite cell method achieves full accuracy, i.e. optimal rates of convergence, when the mesh is refined.

Over the last five years, the finite cell method has reached a state of development where it can be considered a mature and complete analysis technology in the context of computational structural mechanics (see e.g. [3-7]). In particular, it constitutes an attractive opportunity in special situations that can be characterized by a combination of the following points:

- We need to deal with very complex geometries in three dimensions and do not want to generate a boundary conforming finite element mesh [3,4].
- The full automation of the discretization process is more important to us than computational efficiency and speed of the analysis [5].
- We want to do patient-specific analysis on the basis of image-based geometric models, e.g. voxel representations obtained from CT scans [6,7].

In this context, the question arises to what extent the concept of the finite cell method can be extended to the numerical solution of fluid mechanics problems where one or more of these points are important issues. In this contribution, we will address this question and talk about the potential of the finite cell method for fluid and fluid-structure interaction problems. We will first discuss the performance of the finite cell method for different mathematical flow models such as Darcy’s law for flow through porous media, Stokes flow and incompressible Navier-Stokes flow at different Reynolds numbers, showing a series of suitable benchmarks (see for example Figure 1). On this basis, we will identify several promising application examples in the areas of patient-specific biomedical flow simulation and ship hydrodynamics, for which we will present first results. We will also talk about limitations of the finite cell method for fluid mechanics applications, in particular with respect to the quadrature based geometry approximation and the accurate representation of boundary layer phenomena.

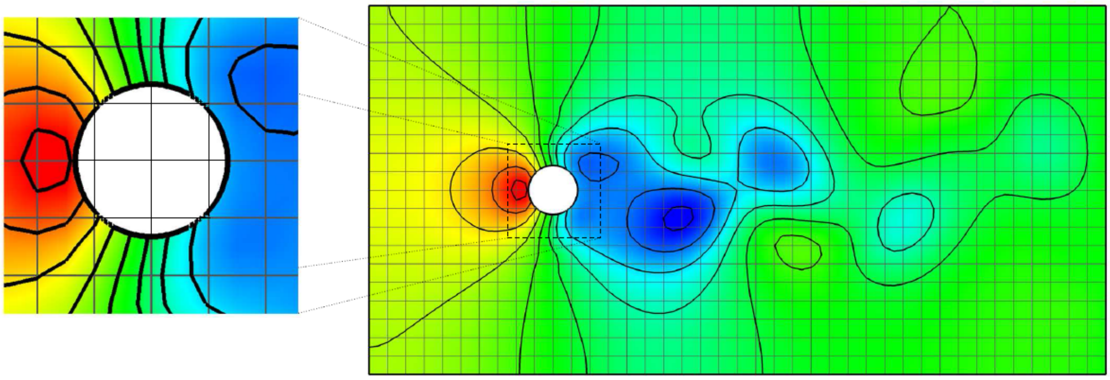

Figure 1: Pressure distribution resulting from a finite cell analysis of the flow around a cylinder. The zoom illustrates the obstacle that is embedded into a structured unfitted mesh. The picture is a snapshot of the steady state and shows the typical phenomenon of vortex shedding behind the cylinder.

REFERENCES

[1] J. Parvizian, A. Düster, E. Rank. Finite cell method. *h*- and *p*-extensions for embedded domain problems in solid mechanics. *Comp Mech* **41**(1), pp. 121-133, 2007.

[2] A. Düster, J. Parvizian, Z. Yang, E. Rank. The finite cell method for three-dimensional problems of solid mechanics. *Comput Meth Appl Mech Eng* **197**(45), pp. 3768-3782, 2008.

[3] D. Schillinger, M. Ruess, N. Zander, Y. Bazilevs, A.Düster, E. Rank. Small and large deformation analysis with the p- and B-spline versions of the Finite Cell Method. *Comp Mech* **50**(4), pp. 445-478, 2012.

[4] M. Ruess, D. Schillinger, Y. Bazilevs, V. Varduhn, E. Rank. Weakly enforced essential boundary conditions for NURBS-embedded and trimmed NURBS geometries on the basis of the finite cell method. *Int J Numer Meth Eng* **95**, pp. 811-846, 2013.

[5] D. Schillinger, L. Dedè, M.A. Scott, J.A. Evans, M.J. Borden, E. Rank, T.J.R. Hughes. An isogeometric design-through-analysis methodology based on adaptive hierarchical refinement of NURBS, immersed boundary methods, and T-spline CAD surfaces. *Comput Meth Appl Mech Eng* **249**, pp. 116-150, 2012.

[6] M. Ruess, D. Tal, N. Trabelsi, Z. Yosibash, E. Rank. The finite cell method for bone simulations: Verification and validation. *Biomech Model Mechanobiol* **11**(3), pp. 425–437, 2012.

[7] Z. Yang, M. Ruess, S. Kollmannsberger, A. Düster, E. Rank. An efficient integration technique for the voxel-based finite cell method. *Int J Numer Meth Eng* **91**(5), pp. 457–471, 2012.