Image-based isogeometric finite cell analysis of fluid flow through porous media

Clemens V. Verhoosel[*,†], Tuong Hoang[†], Chaozhong Qin[†], Frits de Prenter[†], E. Harald van Brummelen[†], and Herman M.A. Wijshoff[†,‡]

[†] Eindhoven University of Technology
Department of Mechanical Engineering
Energy Technology and Fluid Dynamics group
P.O. Box 513, 5600 MB, Eindhoven, The Netherlands
[*] e-mail: c.v.verhoosel@tue.nl

[‡] Océ Technologies
P.O. Box 101, 5900 MA Venlo, The Netherlands

ABSTRACT

The finite cell method can be used in combination with isogeometric analysis to enable the higher-order discretization of problems on complex volumetric domains, *e.g.* [1]. A particularly interesting application of this immersed simulation technique is image-based analysis, where the geometry is smoothly approximated by segmentation of a B-spline level set approximation of scan data. In this contribution we extend this image-based analysis technique – which we recently successfully applied to the mechanical analysis of miro-CT based trabecular bone models [2] – for the simulation of fluid flows through scan-based porous medium models.

The versatility of isogeometric finite cell simulations for scan-based fluid domains hinges on the robust numerical treatment of various computational aspects. An important aspect is the imposition of no-slip conditions on the interior boundaries. In this contribution we discuss how the geometry tessellation scheme proposed in [2] can be used to construct a parametrization for these boundaries. Since these boundaries are not conforming to the computational grid, the no-slip conditions are imposed weakly by means of Nitsche's method. Ghost-penalty stabilization is employed to avoid the occurrence of spurious pressure oscillations in the vicinity of the interior boundaries [3].

We demonstrate the applicability of the image-based isogeometric finite cell method for the simulation of Stokes flow through a scan-based porous medium. We study the performance of the method in terms of stability, conditioning and accuracy for various velocity-pressure discretization pairs, including Ghost-penalty stabilized equal-order discretizations. We validate our results by comparison with established voxel-based simulation tools for fluid-flows through porous media, and discuss the advantages and disadvantages of the isogeometric finite cell method in the context of scan-based porous media flows.

REFERENCES

[1] Schillinger, D. and Ruess M. The Finite Cell Method: A review in the context of higher-order structural analysis of CAD and image-based geometric models. *Archives of Computational Methods in Engineering*, **22.3** (2015): 391-455.

[2] Verhoosel, C.V. *et al.* Image-based goal-oriented adaptive isogeometric analysis with application to the micro-mechanical modeling of trabecular bone. *Computer Methods in Applied Mechanics and Engineering*, **284** (2015): 138-164.

[3] Hoang, T. *et al.* Mixed Isogeometric Finite Cell Methods for the Stokes problem. *Computer Methods in Applied Mechanics and Engineering*, (2016).