NUMERICAL 3D PERMEABILITY PREDICTION USING COMPUTATIONAL FLUID DYNAMICS

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Introduction

The idea of predicting the permeability with CFD tools was already presented in [1] and [2]. It was shown that RVE models created with voxel meshes could help decrease computational time and confidently predict permeability. In this paper, based on permeability prediction in braided RVE models, the link to near-net-shape structural parts will be shown.

Simulation set-up

RVE models for triaxial 12k braids were created with the open source software TexGen and were nested to achieve fibre volume contents (VFC) of 35 % and 44 % for a one layer and a three layer unit cell. Afterwards exported STL-surfaces were transferred to OpenFOAM and re-meshed with SnappyHexMesh (cf. Fig. 1). A full-field fluid flow was simulated with a steady state semi implicit pressure induced solver (SIMPLE) and permeabilities of the RVE's were calculated using Darcy's equation and the calculated flow conditions.

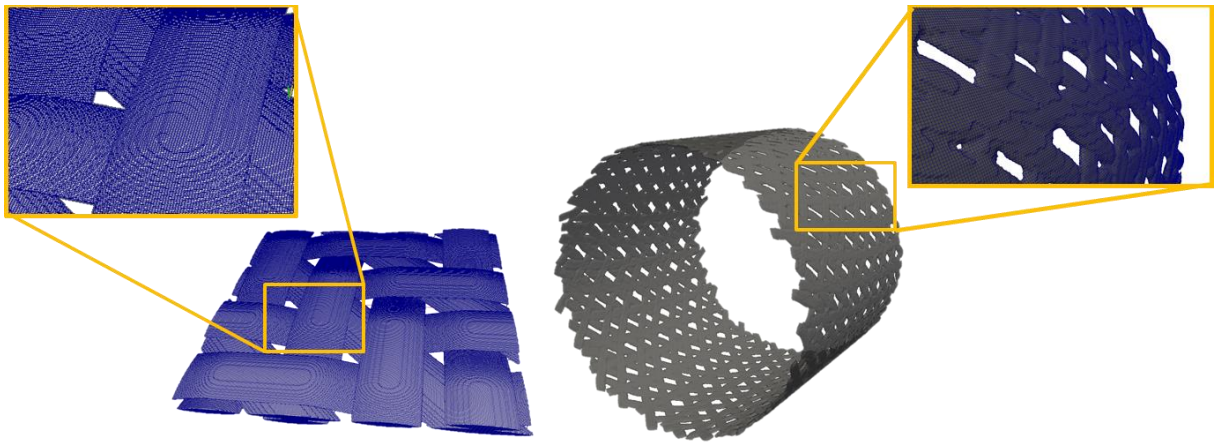

Figure 1: *One layer triaxial 12k braid RVE model (left), 3D near-net-shape triaxial 12k braid model (right)*

The model for the near-net-shape braid was simulated with PAM-FORM and PAM-CRASH (ESI-Group). Afterwards it was transferred to OpenFOAM for re-meshing, calculating flow conditions and determining permeabilities (vide supra).

Results

Simulations were executed with 2 bars of infiltration pressure and a dynamic viscosity of 109 mPas. Results showed stable solutions (cf. Fig. 2) and good agreement with simulations in [1] for braided RVE's. The near-net-shape structure showed lower permeability due to the lower FVC (cf. Table 1), which was necessary for the meshing process in SnappyHexMesh. The computational time for the SIMPLE solver is suitable for the complexity of the mesh, which enables simulations of even bigger geometries. Time for calculating permeability in a post-processing step was 27 s, 60 s and 77 s.

Table 1: *Results for converged values of listed textile geometries*

Textile	Layer [-]	VFC [%]	Permeability K_{xx} [m^2]	Meshing time [min]	Computational time [min]	Cell count [-]
Triax braid RVE	1	35	7.32e-09	14	60	3.4e+06
Triax braid RVE	3	44	6.29e-09	27	120	7.2e+06
Triax braid tube	1	24	9.73e-10	85	62	4.2e+06

Conclusion

Results showed the possibility of using CFD tools like OpenFOAM for permeability prediction of three-dimensional near-net-shape structures, especially of braided structures. It was shown that a steady-state solver reduces computational time to 2 hours for RVE´s and even to 1 hour for complex structures with dimensions of 50 mm x 50 mm x 50 mm, which is crucial for industrial application. The transfer of near-net-shape permeability values to commercial FEM filling tools like PAM-RTM, RTM-WORX or LIMS5 has to be conducted and is present focus of research.

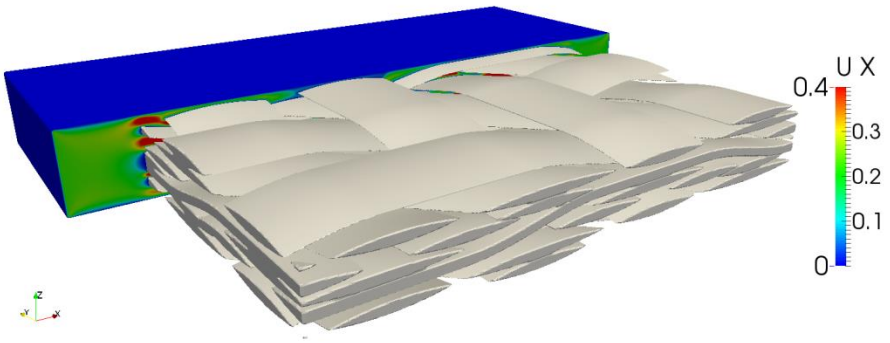

Figure 2: *Viscosity field U_x of three layered triaxial 12k braid (RVE)*

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References

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