Fluid structure interaction during the Resin Transfer Molding (RTM) manufacturing process for continuous fiber reinforced composites

Julian Seuffert*, Luise Kärger*, Gerasimos Chourdakis†, Benjamin Uekermann†, Frank Henning*

*Karlsruhe Institute of Technology, Institute of Vehicle System Technology (FAST) – Lightweight Technology, Rintheimer Querallee 2, 76131 Karlsruhe, Germany
Email: julian.seuffert@kit.edu – Web page: www.fast.kit.edu/lbt

†Technische Universität München, Informatik 5, Boltzmannstr. 3, 85748 Garching, Germany

ABSTRACT

Structural sandwich components made of continuous fiber reinforced composites are increasingly demanded by the automotive industry. A fast, robust and highly automated process is needed to produce those parts economically. In the Resin Transfer Molding (RTM) manufacturing process, a liquid polymer resin infiltrates a dry fibrous preform, which behaves like anisotropic porous media. Additionally, polymer foam cores can be embedded between the fibrous layers before resin infiltration to manufacture sandwich parts. To avoid infiltration or crushing of the core material during the following injection, the fluid pressure inside the mold must not exceed a specific limit [1].

Mold filling simulations can help to understand the complex interaction of fluid pressure, preform deformation and foam core deformation, but a fluid structure interaction (FSI) between all components is mandatory for this purpose. The resin flow characteristics are based on the permeability of the preform, which depends on the fiber volume fraction and thus on the preform compaction, which changes during the infiltration. Furthermore, the viscosity of the polymer resin is dependent on temperature and cure degree of the ongoing polymerization. Those two parameters strongly influence the pressure inside the mold and therefore also the deformation of the foam core.

By using the computational fluid dynamics (CFD) tool OpenFOAM®, conventional RTM mold filling simulations can be conducted as a compressible two-phase flow through porous media. The finite volume (FV) based method was implemented and successfully validated in previous works of the authors [2, 3]. To simulate the mold filling with a deforming foam core, an FSI coupling between OpenFOAM and CalculiX is implemented using the preCICE coupling library [4].

An application example of mold filling simulations with a foam core shows the implementation of the FSI coupling. By a variation of process and material parameters like e.g. injection velocity, temperature or fiber volume fraction, the influence on the foam core deformation can be evaluated.

In the future, this FSI coupling allows simulating the mold filling process with any deforming core material. This enables a sophisticated optimization of the manufacturing process regarding process time as well as part quality and therefore can increase the use of continuous fiber reinforced composites in the automotive industry.

REFERENCES

[1] Gerstenkorn, J., Kothmann, M., Deinzer, G., Kärger, L., and Henning, F., "Characterization of the multi-axial material behavior of polymer foams during the RTM process," *Proceedings of ECCM17- European Conference on Composite Materials*, 2016.

[2] Magagnato, D., Frey, M., Bernath, A., Steibler, P., and Henning, F., "Experimentelle und numerische Untersuchung der Infiltration bei der RTM-Fertigung," *Verbundwerkstoffe und Werkstoffverbunde,* edited by A. Wanner and K. Weidenmann, 2016, pp. 511–517.

[3] Seuffert, J., Kärger, L., and Henning, F., "Simulating Mold Filling in Compression Resin Transfer Molding (CRTM) Using a Three-Dimensional Finite-Volume Formulation," *Journal of Composites Science*; Vol. 2, No. 2, 2018, p. 23. doi: 10.3390/jcs2020023.

[4] Bungartz, H.-J., Lindner, F., Gatzhammer, B., Mehl, M., Scheufele, K., Shukaev, A., and Uekermann, B., "preCICE – A fully parallel library for multi-physics surface coupling," *Computers & Fluids*; Vol. 141, 2016, pp. 250–258. doi: 10.1016/j.compfluid.2016.04.003.