Multiscale analysis of fracture in short glass fiber reinforced polymers through phase field

A. M. Fajardo Lacave[1,2*], F. Welschinger[1], L. De Lorenzis[2]

[1] Robert Bosch GmbH - CR/AMP5, Robert-Bosch-Campus 1 71272 Renningen, Stuttgart, Germany
angelamaria.fajardolacave@de.bosch.com
[2] ETH Zurich, Department of Mechanical and Process Engineering, Computational Mechanics Group, Tannenstr. 3, 8092 - Zurich, Switzerland

Understanding and modeling the fracture mechanical behavior of short glass fiber reinforced polymers (SFRPs) is challenging: the strong heterogeneity induced by the manufacturing process causes a tight coupling of the material microstructure to the effective response on the component scale. Aiming to account for this microstructural complexity, fracture is approached using a multiscale approach. Typically manufactured via injection moulding, SFRP components exhibit locally varying microstructural configurations [6] e.g., fiber orientations, fiber volume contents, and fiber length distributions, which render fracture modelling a challenging task. To resolve the microstructure induced anisotropy and its relationship with the macroscopic material behavior, the well established isotropic phase field models of brittle fracture [5, 4] is extended towards the anisotropic case making use of the fiber orientation interpolation concept [3].To create the database, the anisotropic elastic coefficients are obtained from previously executed micromechanical simulations on realistic microstructures [6] using the efficient microscopic solver FeelMath. At the simulation level, the local microstructure must be known in order to access the database: microstructural information stemming from either X-ray micro computed tomography [2] or from injection moulding process simulation is mapped into the Abaqus mesh prior the execution of the macroscopic simulaiton. The performance of the simulation method is demonstrated by means of several numerical analyses and the predicion quality together with the limitations of the proposed method are demonstrated.

Therefore, an innovative approach is proposed using an offline training of a database plus a fiber interpolation concept to take into account the heterogeneity of the material. The approach is fully integrated into the seamless simulation chain for SFRPs ranging from the manufacturing process to the structure mechanical fracture analysis. The limitations of the approach stemming from the underlying assumptions are quantified and further development needs are identified.

References

[1] Hessman, P. A.; Riedel, T.; Welschinger, F.; Hornberger, K.; Bhlke, T., 2019, *Microstructural analysis of short glass fiber reinforced thermoplastics based on x-ray micro-computed tomography.* Composites Science and Technology, 183: 107752

[2] Kbler, J.; Schneider, M.; Ospald, F.; Andr, H.; Mller, R., 2019, *Fiber orientation interpolation for the multiscale analysis of short fiber reinforced composite parts.* Computational Mechanics, 61: 729 - 750.

[3] Miehe, C.; Hofacker, M.; Welschinger, F., 2010, *A phase field model for rate-independent crack propagation: robust algorithmic implementation based on operator splits.* Computer Methods in Applied Mechanics and Engineering, 199: 2765 2778.

[4] Pham, K.; Amor, H.; Marigo, J.-J.; Maurini, C., 2011, *Gradient damage models and their use to approximate brittle fracture.* International Journal of Damage Mechanics 20 (4): 618-652.

[5] Schneider, M., 2017, *The sequential addition and migration method to generate representative volume elements for the homogenization of short fiber reinforced plastics.* Computational Mechanics, 59: 247 - 263.

[6] Seles, K.; Lesicar, T.; Tonkovic, Z.; Soric, J., 2019, *A residual control staggered solution scheme for the phase-field modeling of brittle fracture.* Engineering Fracture Mechanics, 205: 370 386.