Master Thesis Proposal

Coupled Multi-Scale Modelling of Short Fiber Reinforced Composites

Background

Short fiber reinforced composites (SFRCs) are being increasingly used due to their interesting mechanical properties and ease of processing. Figure 1 shows the finite element mesh of a part, and a view of fiber orientation distribution. In order to have efficient and optimized design, it is crucial to predict the mechanical behavior of SFRCs in a quantitative manner. Since a wide variety of micro-structural parameters affects their macro-mechanical behavior, it is necessary to use multi-scale models.

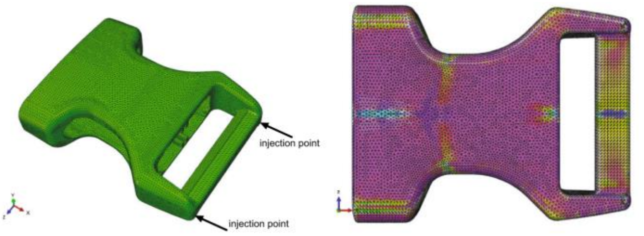

Figure 1: Injection molded quick release buckle socket: (a) finite elements mesh, (b) fiber orientation distribution (Köbler et al. (2018) Comput. Mech. 61:729–750)

Purpose

In order to model a specimen/part made from a short fiber reinforced composite, and considering the micro-structural parameters, it is needed to have a coupled multi-scale (macro-micro) model. This kind of models are typically computationally expensive. **Thus, the main purpose of this project is developing a computationally efficient coupled multi-scale model for SFRCs.**

Project description

In previous projects, a micro-mechanical model is developed for short fiber composite materials based on an orientation averaging scheme (Mirkhalaf et al. (2019) ICCM, and Mirkhalaf et al. (2020) Composites, Part B). In the next phase, a coupled multi-scale model is developed using the micro-mechanical model and a Finite Element code. This coupled model is schematically shown in Figure 2 (Castricum (2020), internship report, Chalmers University of Technology). Since the obtained multi-scale model was computationally expensive, the integration approach at the micro-level (trapezoidal integration) was replaced by the Bazant scheme (Bazant and Oh (1986), ZAMM 2. angcw. Math. 11. Mech). The modified model is computationally much more efficient, in particular for Voigt and Reuss interactions (upper and lower bounds). But we have also developed a self-consistent interaction which requires an Eshelby tensor. The calculation of the Eshelby tensor requires integration over a sphere domain which makes it computationally very heavy. The first goal in this project is to make the calculation of the Eshelby tensor more efficient by improving its integration scheme. Once the first goal is achieved, the second goal is to improve the trapezoidal integration scheme (at the micro-level) for desired orientations. The second goal is defined, because the Bazant scheme (already implemented) is useable for 3D random orientations. Hence, the idea is to replace the trapezoidal scheme with other schemes which could be used for different kind fiber orientation distributions.

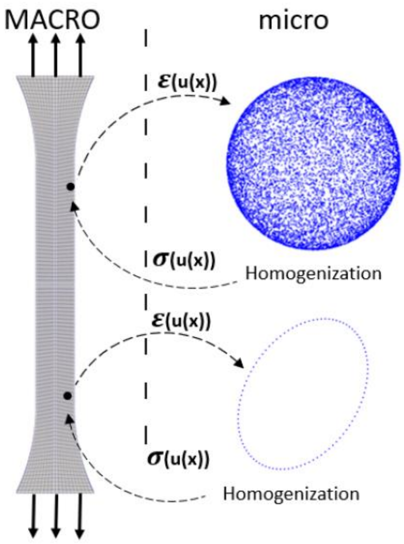

Figure 2: Schematic representation of the coupled multi-scale model for short fiber composites.

Student background

This project is suitable for one or two master students who are interested in computational mechanics and composite materials. Programming skills in Python are highly valued, and previous experiences with micro-mechanical and/or multi-scale modelling of materials is a plus.

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