Master Thesis Proposal

Deep learning enriched micro-mechanical modelling of elasto-plastic behavior 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. There are a wide variety of microstructural parameters which affect the macro-mechanical response of short fiber reinforced composites. Figure 1 shows a numerical Representative Volume Element (RVE) of an SFRC and its spatial discretization.

Purpose

In order to model an SFRC considering micro-structural parameters, we need to use accurate micro-mechanical models, such as direct numerical simulation of numerical RVEs. This kind of models are typically computationally expensive. Machine Learning (ML) techniques can be used to develop computationally efficient models. **Thus, the main purpose of this project is to use Artificial Neural Networks (ANN) and RVE simulations to develop an efficient and accurate model for elasto-plastic behavior of SFRCs.**

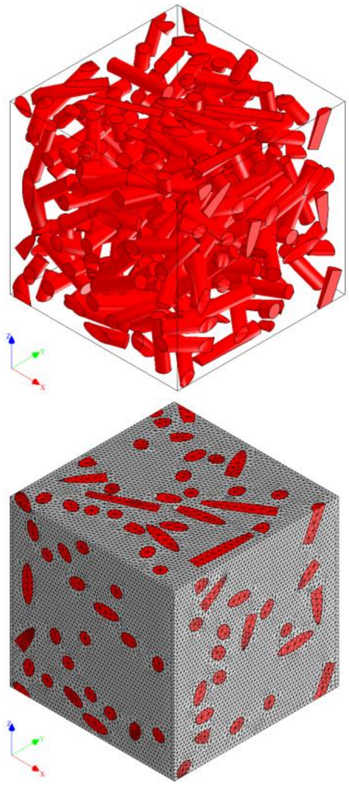

Figure 1: An RVE of a short fiber composites and its spatial discretization [1]

Project description

In previous projects, we have developed an ANN model for elastic properties of SFRCs [2]. We carried out two step micro-mechanical simulations on SFRCs with a wide variety of micro-structural properties. In the first step, Finite Element Analysis was used to obtain homogenized properties of unidirectional (UD) RVEs (using a commercial package: Digimat-FE). In the second step, analytical homogenization was used together with homogenized properties of UD RVEs to obtain composite homogenized properties. The conducted simulations and obtained results were used to train a Feed Forward ANN model [2]. This study was then extended in another project [3] to non-linear path dependent elasto-plastic behavior of SFRCs. To create the required data base for training an ANN model, mean-field simulations were conducted using a commercial software (Digimat-MF). As opposed to the first project, where a Feed forward ANN was sufficient to develop the model, in this project we needed to use a Recurrent Neural Network (RNN) due to the time-series nature of the data for the model. The obtained stress-strain curves (from the mean-field) simulations were then used to train an RNN network. Gated Recurrent Unit (GRU) architecture was used to develop the ANN model.

In this current proposed project, we intend to extend the non-linear study by developing a data base using full-field simulations data i.e. by conducting finite element analysis of numerical RVEs. We will also try to address physical aspects of the ANN model such as the energy dissipation.

Student background

This project is suitable for one or two master students who are interested in numerical simulations and artificial neural networks. Programming skills are highly valued, and previous experiences with solid mechanics and material modelling is a plus.

References:

[1] Mirkhalaf et al. (2020). Composites Part B, Volume 202, 108388.

[2] Mentges et al. (2021). Composites Part B, (accepted for publications).

[3] Friemann (2021). Master thesis, Chalmers University of Technology.

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