Influence of the fiber length distribution on the modeling procedure of short fiber-reinforced composites by cross-correlated non-Gaussian random fields

Ilona Małgorzata Widera* and Natalie Rauter[1]

[1]Helmut-Schmidt University Hamburg – Germany

Abstract

Short fiber-reinforced composites are highly suitable for lightweight structures due to their high specific strength and stiffness. One major advantage is that components made from short fiber-reinforced composites can be manufactured rapidly and cost-effectively in large quantities by mold injection. However, modeling such components accurately presents challenges due to the resulting heterogeneous nature of the material on the microstructural level, where fibers are not only distributed randomly but also show stochastic characteristics. These characteristics comprise the fiber length, diameter, and orientation and hence play a critical role in determining the overall mechanical properties of the composite.
Following this, research focuses on developing methods to model components made from short fiber-reinforced composites to capture their random nature accurately. Among these efforts, approaches utilizing random fields have emerged as a promising strategy to address this complexity.

This work aims to develop a method to represent the spatial distribution of local mechanical properties at the component level using cross-correlated non-Gaussian random fields. Thereby, the focus is to investigate the influence of the fiber length distribution on the micro- and macrostructural behavior. To achieve this, microstructures with two various fiber length distributions are generated. The remaining geometrical information regarding diameter and orientation are in both cases the same.From these microstructures, statistical volume elements are extracted and analyzed using the moving window method. The resulting probability distributions and correlation structures of the stiffness tensor elements are identified and compared.

For the subsequent analysis at the component level, this data is employed to generate non-Gaussian, cross-correlated random fields using the expansion optimal linear estimation in combination with the Nataf transformation. These non-Gaussian random fields are then utilized in FEM-based numerical simulations of tensile tests on the component level. For both fiber length distributions, the statistical properties of the obtained Young's modulus are analyzed considering different correlation lengths. This allows to establish a relationship between the mean value and standard deviation both as a function of the correlation lengths. Finally, the statistical behavior of the longitudinal Young's modulus obtained from numerical simulations using non-Gaussian random fields is compared to experimental results. This analysis reveals the influence of the fiber length distribution on Young's modulus at the component level.

*Speaker