A Comprehensive Analysis of the Correlation Between Cross-Sectional Characteristics and Mechanical Behavior in Composite Materials

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Abstract:

This study investigates the intricate correlation between microstructural properties of composite materials and their mechanical behavior, a topic currently not thoroughly understood in scientific literature. Although advances are being made in understanding the relationship between the microstructure properties of composites and their mechanical behavior, there is still an important gap in the overall understanding. Research has focused primarily on specific aspects such as the influence of layer thickness, geometry, pore size and their distribution on key mechanical properties such as tensile strength and Young's modulus [1]. In addition, the use of digital image correlation at elevated temperatures has provided insight into the behavior of polymer composites under thermal conditions [2]. However, these studies often focus on isolated variables and may not fully capture the complex interplay of the information that can be accessed through cross-sectional imaging. Also analysis of the mechanical properties of carbon fibre composites has been conducted [3], but it also highlights the need for more integrated and holistic research approaches.

Therefore, this study focuses on investigating how internal structural elements such as fibre orientation, cell diameter and distribution significantly affect the mechanical properties of composites. Specifically, the study aims to determine the relationship between thickness, geometry, pore size, fiber volume fractions and fiber distribution with key mechanical properties such as tensile strength and Young's modulus. This will be achieved by measuring the mechanical properties of polymer composites through tensile testing and obtaining micro-mechanical information through cross-sectional evaluation, which will provide insight into the relationship between cross-sectional properties and mechanical behaviour.

Methodologically, the research involves several steps (fig 1): acquisition of mechanical test data of composites, acquisition of cross-sectional data, and classification of composite areas (including fiber type, voids, matrix-rich areas, geometries and distributions) via semantic segmentation from digital image correlation. This is followed by data extraction and exploratory data analysis to understand the structure and distribution of the data. A pre-processed data set is then produced and experimental characterization of composite samples is carried out through tensile testing. The final step in this process is the creation of a machine learning model using the tensile test data and cross-sectional data.

This model, once built and tested, has the ability to predict the output value for newly generated input information, such as alternative material combinations and fiber volume fractions. This predictive capability enables cost-effective exploration of new material configurations and a deeper understanding of the failure behavior of fiber-reinforced plastics.

Keywords: *composite, digital image correlation,hybrid composite, machine learning.*

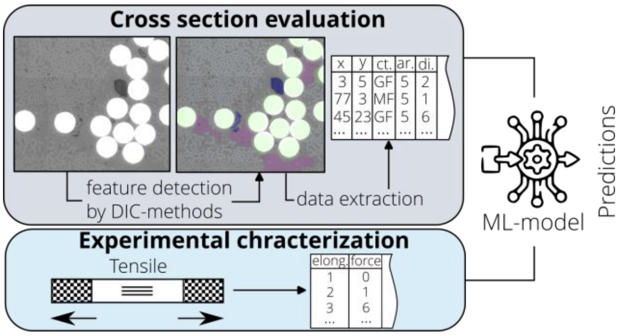

Figure 1: schematically method to model

Acknowledgement: *Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 441549528.*

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