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FAILURE AND DAMAGE ANALYSIS OF UNDULATED FIBER COMPOSITES DEPENDING ON THE FIBER VOLUME CONTENT

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Composite materials such as continuous fiber-reinforced polymers (CoFRP) are ideal lightweight materials and have high weight-specific stiffness and strength. Full potential of such materials is achieved, if the load is transferred directly into the straight fibers. However, depending on the geometrical complexity of composite parts, the forming (draping) process and the interaction of plies during forming cause local fiber waviness and variations in fiber volume content. Therefore, the fibers cannot always be aligned in loading direction. With increasing fiber amplitude to wave length ratio, the stiffness in fiber direction drops significantly. Besides the local fiber orientation and waviness, the fiber volume content is another major factor, which strongly influences the stiffness. Former studies have shown a performance reduction due to fiber waviness. Especially the failure of CoFRPs with imposed waviness have been investigated [1 - 3]. Furthermore, the effect of the fiber volume content in conjunction with fiber waviness showed a significant correlation on the composite stiffness [4]. The understanding of the fiber misalignment on the failure initiation in fiber compression led to new failure criteria [5, 6].
Despite the prior publications, the combination of fiber waviness and fiber volume content needs further investigation to get more understanding of the failure and damage propagation and, thus, to enable reliable macroscopic modelling. This is particularly useful since recent developments in forming simulation allow predicting the distribution of local fiber volume content and fiber waviness. Using this knowledge, a more realistic prediction of the structural loading capacity can be achieved.
Since the structure of a carbon fiber roving consist of randomly distributed single fiber filaments, it cannot be captured sufficiently by a strongly periodical unit cell. Therefore, a more suitable unit cell, like a statistical representative volume element (SRVE) can be used. An SRVE has multiple (10-200) fiber filaments with varying fiber positions and fiber diameters and is typically much larger than a periodical unit cell. It provides the opportunity to evaluate the stiffness at different amplitude to wave length ratios and fiber volume contents, but also to analyze the damage propagation more realistically, due to different distances and thus different stresses and strain rates between the fibers.
In the present work, the failure and damage propagation for undulated SRVEs at different amplitude to wave length ratios and fiber volume content is presented. Each constituent is modeled by a user defined material subroutine. The anisotropic elastic material parameters of the carbon fibers are determined by reverse engineering from an experimental test program at unidirectional CoFRP samples. The isotropic hypo-viscoplastic and damage-mechanics material parameters of the epoxy resin matrix are determined by experimental tests at pure resin samples at different strain rates.

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