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Development of a Mesomechanical Modell for the Assessment of Void Inclusions

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Introduction

Manufacturing defects such as waviness defects or void inclusions can cause a significant loss in stiffness and strength of composite materials. Several analytical approaches to determine the detrimental effect on elastic parameters exist [1]. As of today, quality acessment via non-destructive testing is generally based on void content only. Size, shape and location of voids are neglected and thus, only fairly general knock-down factors or safety margins exist. A precise description of the parameters mentioned above and the use of advanced finite element modelling techniques will help to determine less conservative knock-down values for a given set of void defects.

Phenomenological Description of voids

Three main phenomena have a detrimental effect on composite material behavior. Most importantly, fiber ondulations in the surrounding of void inclusions cause a reduction in fiber stiffness and strength under compressive loading (fiber kinking). Secondly, voids cause stress inhomogenities that reduce strength values. Finally, voids in between layers reduce delaminatin resistance. Voids in composite materials vary significantly in shape, size and location and can be confined to a single layer, in between layers as well as across more than one layer.

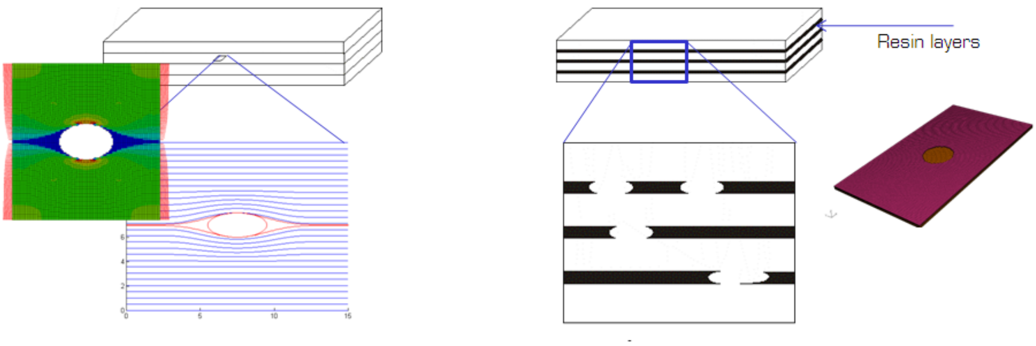

Figure 1: Unidirectional layer with void inclusion under compressive loading.

Multiscale Approach

Discretisation of each individual void inclusion is not feasible for problems on the macroscale. Thus, homogenization methods must be applied. Figure 1 shows two different possibilities of void occurance - within layers (left) and in-between layers (right). The former leads to fiber ondulations which are modeled by assuming a sinusodial fiber deviation arround the void and prescribing a unique orientation for each finite element. This approach is validated using analytical and experimental results from Hsiao and Daniel [2], who investigated pure waviness defects described by amplitude-to-wavelength-ratio. Voids

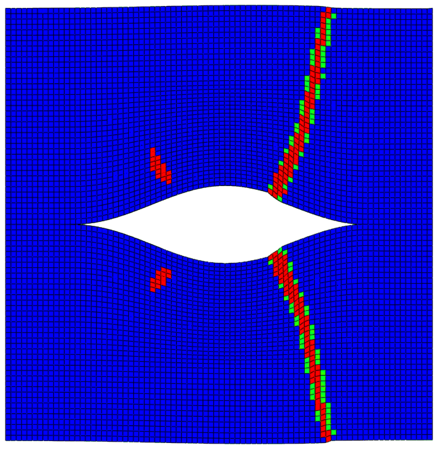

Figure 2: Progressive failure under compression load, colors indicate the damage state

in-between the layers mainly influence delamination resistance. Mixed types are also possible.

A continuum damage approach based on the invariant based quadratic criterion (IQC), presented by Ernst [3] is utilized to model progressive failure. Results are compared with a continuum damage approach based on the failure criterion of Puck. A voxel discretization approach is compared to a conformal mesh and respective advantages and disadvantages are discussed. An example configuration of a void inclusion is depicted in Figure 2. Here, a conformal mesh is used and failure is modelled with IQC.

Several load-cases (shear, tension, compression) have been applied. A parametric study, investigating on the influence of size and shape of the void inclusions has been conducted. Results indicate that the maximum fiber deviation angle determines the reduction in strength.

Distribution of void defects within a laminate is accounted for by including a variety of voids into a larger model. Homogenization techniques are applied to obtain stress-strain relations for the macroscale. Experimental data on coupon level will be used to validate the approach in a later stage of the project.

References

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