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Computational Implementation and Experimental Validation of a Micro-mechanics Informed Progressive Damage Strain Invariant Failure Theory

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Abstract

The current paper deals with the failure modelling in continuously reinforced composite structures taking into account the material's inherent microstructure. The implementation of a constitutive model for transversely isotropic damage in fibre reinforced composites is presented. Damage initiation in the orthotropic linear elastically modelled composite is governed by the Strain Invariant Failure Theory (SIFT), utilising the first strain invariant and the second deviatoric strain invariant for damage initiation. To phenomenologically account for the material's microstructure, the homogenised macro strain is related to the micro strain by means of strain amplification factors determined from prior simulations of Repeating Unit Cells (RUCs) with different fibre arrangements utilising Periodic Boundary Conditions (PBCs). For validation of the numerically implemented model, experimental tests of composite laminates with varying layups are performed. The conducted experiments are simulated utilising the implemented models and the obtained results are validated with the experimental data.

Keywords: A. Laminates, C. Micro-mechanics, C. Damage Mechanics, C. Finite Element Analysis

1. Introduction

The Strain Invariant Failure Theory (SIFT) is a failure criterion originally proposed in [1] for analysing damage initiation within the polymer of a composite material and then in [2] applied in a more general framework for determining failure in continuously reinforced composites. Being based, as the name suggests, on the invariants of the strain tensor, failure initiation in this physically based theory occurs once the first strain invariant, describing dilatational deformation within the composite, or the second deviatoric strain invariant, governing the distortional deformation, exceed a critical value [1]. The composite micro-mechanics are taken into account phenomenologically by means of strain amplification factors obtained from modelling idealised composite Repeating Unit

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