CONTINUUM MECHANICS ON THE MICRO SCALE IN DESIGN OF COMPOSITE MATERIAL SYSTEMS

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Abstract

In design of structural components there is today a large potential for targeted material design. For composite material systems in particular but also for more traditional materials, the structural properties can to a large extent be controlled by choice of constituent composition and processing conditions. The number of possible combinations is in principle infinite. In case of composite material systems the volume fractions of the constituents can continuously be varied and the constituent properties themselves are influenced by the processing route. It is evident that in order to fully utilize the opportunity of material design, the relationships between material composition and structural properties must be known. To empirically derive these relationships is however practically infeasable, the knowledge must be based on physical models for the controlling micro mechanisms. Regarding structural properties the most important micro mechanisms occur on scales which best are modelled by continuum mechanical methods. Mechanics on the micro scale for analysis of material properties is a research area which in recent years has received an ever increasing attention. In this lecture a particular problem will be presented in order to illustrate the opportunities of continuum mechanics on the micro scale for analysis of material properties. The development of so called transverse matrix cracks in composite laminates will be analyzed.

The first microstructural damage which develops in composite laminates is generally matrix cracking parallell to fibres in different plies of the laminate. This damage is however in most cases not critical from a structural failure point of view. The laminate can in most cases take substantially higher loads before final failure occurs. Matrix cracking can however induce more severe damages such as delaminations, fibre fractures and fibre/matrix debondings. They also influence the thermoelastic properties which may cause stress redistributions in the material. It is hence of importance being able to model initiation and growth of matrix cracks.

A simple to use theory based on continuum mechanics on the micro scale for the prediction of mechanical properties of composite laminates containing

matrix cracks will be presented. The theory is applicable to two- and three-dimensional laminates of arbitrary layup configurations. The prediction of thermoelastic properties is solely based on ply-property data and matrix crack densities. No experimental or other unknown theoretical parameters are required. Also crack closure effects have been taken into account in the model. The crack closure introduces nonlinearities in the constitutive behaviour of a micro cracked laminate. The theory has been applied to laminates of various layup configurations and loading conditions. Predictions of mechanical properties at varying micro crack densities for cross ply laminates have been compared to experimental results. For angle ply and quasi-isotropic laminates the model has been compared to finite element simulations of periodically cracked laminates. Extremely good agreements between model predictions and experimental as well as numerical results was found. In order to simulate micro crack initiation and growth a criterion based on critical energy release rates was investigated. It appears that for thin plies the energy release rate criterion reasonably well captures the micro cracking process. As an example predictions of the stress-strain behaviour as well as the damage evolution of a quasi-isotropic glass fibre reinforced epoxy laminate was presented.

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