Asociación Argentina de Mecánica Computacional

Mecánica Computacional Vol XXXVI, págs. 3-3 (resumen)
José G. Etse, Bibiana M. Luccioni, Martín A. Pucheta, Mario A. Storti (Eds.)
San Miguel de Tucumán, 6-9 Noviembre 2018

MESH REDUCTION METHODS FOR MULTISCALE MODELLING OF ADVANCED MATERIALS

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Keywords: Boundary Element Method, Meshfree Element Free Galerkin, woven composite, polycrystalline materials.

Abstract. In this talk recent advances in mesh reduction methods, namely the Boundary Element Method and Meshfree Element Free Galerkin will be presented for modelling material degradation and failure through consideration of two material scales. It is generally recognized that macroscopic material properties depend on the features of the microstructure. The understanding of the links between microscopic and macroscopic material properties, main topic of Micromechanics, is of relevant technological interest, as it may enable deep understanding of the mechanisms governing materials degradation, damage characteristics and failure. In this talk damage initiation and failure in two very different types of material, that is polycrystalline and woven composite are discussed. Polycrystalline materials are used in many engineering applications. Their microstructure is determined by distribution, size, morphology, anisotropy and orientation of the crystals. The microscopic degradation is explicitly modelled by associating Representative Volume Elements (RVEs) to relevant points of the macro continuum, for representing the polycrystalline microstructure in the neighbourhood of the selected points. A grain-boundary formulation is used to simulate intergranular/transgranular degradation and failure in the microstructure, whose morphology is generated using the Voronoi tessellations. Intergranular/transgranular degradation and failure are modeled through cohesive and frictional contact laws. To couple the two scales, macro-strains are transferred to the RVEs as periodic boundary conditions, while overall macro-stresses are obtained as volume averages of the micro-stress field. Micromechanical approach for predicting the material properties and mechanical responses of woven composites is gaining popularity. In this approach, both normal and off-axis unit cell (UC) models are developed to describe the internal architectures of plain, twill and 3D woven composites with high fidelity. Material models are also selected or proposed to model the constitutive behaviours of the individual constituents. Specifically, a viscoplasticity model is selected to identify the nonlinear, rate-dependent response of the polymer matrix, and an improved Weibull function based formulation is proposed to characterize the anisotropic, post-failure behaviour of the fibre yarn material. Computational methods presented include the FEM and newly developed meshfree method. The analysis of a unit cell for 2D plain woven with two different geometries is discussed. The FEA of twill, satin and 3D woven composites are detailed. A newly more realistic mathematical representation of 2D and 3D woven composites is also reported. Finally, damage at the unit cell scale of plain woven composites using meshfree methods is examined in and multi-scale progressive failure analysis of plain woven composites using semi-analytical homogenisation with the FEM.