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NUNERICAL HOMOGENIZATION OF PERIODIC COMPOSITES BY PRESCRIBING THE AVERAGE STRESS

***Andrea Caporale, Raimondo Luciano**

Dipartimento di Meccanica, Strutture, Ambiente e Territorio, Università degli Studi di Cassino
Via G. Di Biasio 43, 03043, Cassino, Italy
a.caporale@unicas.it, luciano@unicas.it

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ABSTRACT

In this work a macromechanical model of a composite material is defined by purely micromechanical considerations: the global behaviour of the composite depends only on the mechanical properties defined in the microscale and assigned to the constituents of the composite and to the interface between the fibres and the matrix. The relationship between the microstructure and the global behaviour of the composite is determined by numerical analyses developed with the aid of the finite element method (FEM). The microstructural response is determined by adopting a homogenization technique valid for composites with periodic microstructure. The use of the FEM for the micromechanical analyses of random composites, which represent most of the real composites, is very expensive from a point of view of processing time and use of computer memory. In fact, the FEM discretization of a representative volume element (RVE) with many heterogeneities involves a problem with a large number of degrees of freedom (the RVE contains the heterogeneities characterizing the microstructure of the composite). Such problems have been analysed by Ghosh *et al.* [3], who have developed a plane finite element model based on a polygonal Voronoi cell. Inconveniences due to the use of random distributions of inclusions and defects can be avoided by assuming a periodic distribution of such heterogeneities. In fact, in this case it is possible to adopt, as RVE, a unit cell containing a small number of heterogeneities and equipped with suitable boundary conditions. Many authors have studied the homogenization problem of solids with periodic microstructure. For instance, hexagonal distributions of continuous fibres, perfectly bonded to a non-linear matrix, have been considered by Taliercio and Coruzzi [5] for the analysis of the transversal behaviour and by Carvelli and Taliercio [2] for the three-dimensional analysis. Debonding of constituents in a hexagonal distribution of continuous fibres has been analysed by Yeh [6] (transversal analysis). Several types of rectangular distributions of fibres have been considered by Lissenden and Herakovich [4] in presence of decohesion between fibre and matrix. In the present work, hexagonal and rectangular distributions of heterogeneities are considered. The following two homogenization approaches are adopted: in the approach number 1 an average strain (macrostrain) is imposed on the RVE and the corresponding average stress (macrostress) is computed [1]; in the approach number 2 an average stress is imposed on the RVE and the corresponding average strain is computed. A new method of micromechanical homogenization of

periodic composites is proposed according to the approach number 2, i.e. based on prescribing the load path in the spaces of the macrostresses. The proposed method is applied to the interesting case of unidirectional composites subjected to the debonding of the constituents; the influence of the geometrical and mechanical properties of the composite microstructure is estimated. The numerical simulations carried out in the work provide the envelopes of the average stresses in the RVE corresponding to the initiation of the fibre debonding, which is characterized by a considerable decay of the global stiffness and strength. The influence of the non-linearity of the matrix is evaluated by considering elastoplastic or viscoelastic matrix in order to simulate the typical behaviour of the composites made of ductile matrix (metals, thermoplastic resins) or of fragile matrix (epoxy resins, polyester). Specifically, the influence of the yield stress f_y of the plastic matrix and the influence of the velocity of application (load rate) of the macrostress $|\dot{\Sigma}|$ in viscoelastic matrix composites is analysed. For composites with elastoplastic matrix, the macrostress corresponding to the initiation of the debonding is smaller than that obtained in the case characterized by $f_y = +\infty$, i.e. without plastic yielding. For composites with viscoelastic matrix, load paths and relaxation laws exist such that the macrostress corresponding to the initiation of the debonding is smaller than that obtained in the case characterized by $|\dot{\Sigma}| = +\infty$, i.e. without considering the viscoelastic effects. In conclusion, this work shows that the envelops of the macrostress corresponding to the initiation of the debonding can result not safe if non-linear effects of the matrix are not take into account.

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