ELASTIC STIFFNESS AND YIELD STRENGTH OF PERIODIC CLOSED-CELL HONEYCOMBS

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Cellular materials are made up of interconnected network of cells with solid edges. The regular geometric arrangements of solid skeleton are called honeycombs (Gibson L., Ashby M.F., 1997). Such a kind of structure can be found in many natural materials (wood, cork). A wide range of honeycombs is fabricated with conventional metal bending technology and manufactured from polymers and ceramics. Because of their structure natural and synthetic cellular solids show unique physical properties, which provide their functionality. Serching for new multifunctional materials corresponds to recent trend of searching for advanced materials tailored for special requirement.

The aim of this presentation is to formulate an effective model of elastic behaviour of cellular materials. For this purpose the idea of multiscale modeling (Philips R. 2001) is applied. It is based on intrinsic relation between structure and macroscopic properties. This concept leads to formulation of equivalent continuum. Such an approach is typical for micromechanics (Nemat-Naser S., Hori M., 1999).

Closed-cell materials with diverse structures representing different types of symmetries are considered. It is assumed that essential macroscopic features of mechanical behaviour can be inferred from the deformation response of a representative volume element. The method of structural mechanics for plate model of a skeleton is applied. An analytical formulation of force-displacement relations for the skeleton elements are found by considering the affinity of node displacement in tensile, bending and shear deformation. Micro-macro transition enables to produce stiffness tensor for anisotropic solid in dependence on material properties of a solid phase and topological arrangement of a cell structure. Graphical representation of choosen material constants is also given.

The modeling of microstructure with the help of the linear elasticity theory enables to predict the macroscopic yield condition. The general formulation for energy based yield criterion for anisotropic solids was proposed by Rychlewski J., 1995. It is presented in the form of a sum of elastic energies corresponding to uniquely defined energy-orthogonal parts of stress with certain weights representing the limiting values of these energies. The present formulation leads to specification of energy-based limit condition for closed-cell microstructures by analytical calculation of the critical energy densities, with an account of elementary interactions. This idea was sucessfully applied to metallic foam by Janus-Michalska M., Pęcherski R.B.,2003. and cellular materials with cubic cells by Kordzikowski P., Janus-Michalska M., R.B.Pęcherski R.B., 2004 and to open-cell materials of different symmetries by Janus-Michalska M., Kordzikowski P., Pęcherski R.B.,2004. The study based on the assumption of linear elasticity leads to analytical formulae.The modeling possibility of the influence of morphology and topology parameters on the choosen materials constant and distribution of energy limits is studied. Experimental verification of the energy based criterion is discussed and compared with available experimental data.

The proposed theoretical framework of micromechanical modeling can be extended to nonlinear behaviour, plasticity and failure analysis. For such problems numerical approach is required.

References

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