Copyright © 2009 ICCES ICCES, vol.12, no.2, pp.43-44

Novel trends in failure analysis of composite structures

Raimund Rolfes, Matthias Vogler, Benedikt Kriegesmann[1]

Summary

Fiber composite structures are usually thin-walled and hence, prone to buckling. Thus, beside material failure also stability problems have to be considered.

Thin-walled cylindrical composite shells buckle in the elastic region and thus, there is no need to consider material non-linearities or material failure. Never the less, a robust design guide for composite shells does not exist until today. The most frequently guideline is NASA SP-8007, which gives an empirical based knock-down factor. Because this guideline is not intended for composite shells and it turned out to be very conservative in numerous cases several approaches have been developed to define a lower bound for composite shells. One branch of research is the determination of probabilistic motivated lower bounds, as it is proposed e.g. by Arbocz. Measured shell surfaces are described by double Fourier series whereas the Fourier coefficients characterize the scattering of the imperfection patterns. Additionally, non-traditional imperfections are regarded as random parameters. Then, the stochastic distribution of the buckling load with respect to the imperfections is obtained from a probabilistic analysis. The lower bound is defined as the buckling load that is associated to a chosen level of reliability. Another approach is the deterministic identification of a lower bound as it is proposed by Hühne. A perturbation load is applied, which causes a single buckle and decreases the buckling load. For a certain perturbation load, the buckling load does not decrease by increasing the perturbation load. The buckling load at this ultimate state is defined as lower bound.

In case of buckling of stiffened structures like stringer stiffened panels, large deformations occur and material non-linearities have to be considered. Consequently, global failure of structures appears as a combination of stability and material failure. For textile composites, appropriate material and failure models are not available at present, regarding the complex three-dimensional structure. A further challenge is the determination of strength parameters. Especially through-thickness parameters are hardly to obtain. Therefore, in addition to real material testings, virtual material testings are performed by use of an information-passing multiscale approach. The multiscale approach consists of three scales and is based on computation of representative volume elements (RVE's) on micro-, meso- and macroscale. On microscale, epoxy resin and single fibers are modeled, regarding statistical distribution of fibers. This yields stiffness and strength parameters of unidirectional fiber bundle material. The homogenized material parameters of the microscale

[1]Institute for Structural Analysis, Leibniz University Hannover, Germany

are used as input data for the mesoscale. In the mesomechanical RVE, fiber architecture, in particular fiber undulations and the influence of through-thickness reinforcements, are studied. The obtained stiffnesses and strengthes are used as input for the macroscale. On macroscale, structural components are calculated. At each scale, special material and failure models are developed. For epoxy resin, an isotropic elastic-plastic material model with an isotropic damage formulation is presented, regarding triaxiality in the yield- and failure surface formulation. For fiber bundles, a transversely isotropic material model is developed, considering the nonlinear behavior under shear. Homogenization of one textile layer yields to orthotropic material properties at macroscale. Therefore, an orthotropic material model with a layer based failure criterion is presented.