11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

APPLICATION OF A TWO-WAY LOOSE COUPLING PROCEDURE TO A STIFFENED COMPOSITE PANEL

Sina Hühne*, José Reinoso, Eelco Jansen and Raimund Rolfes

Leibniz Universität Hannover, Institute of Structural Analysis
Appelstr. 9A, 30167 Hannover, Germany, www.isd.uni-hannover.de
* Corresponding author: s.huehne@isd.uni-hannover.de

Key Words: *Loose Coupling, Multiscale Analysis, Composite Damage, Stiffened Panels.*

INTRODUCTION

For lightweight structures, especially in the field of aerospace engineering, the usage of fibre-reinforced composites is increasing. The further weight reduction of composite structures is an important objective to reduce the costs of aircraft designs. For a complete exploitation of the available load carrying capacity of composite structures, efficient and reliable simulations until final failure are required. So called multiscale or coupling analyses are developed to meet these demands. Thereby coarse (global) FE models for the fast simulation of the overall structural behaviour are connected with detailed (local) FE models for the accurate investigation of material failure and damage progression. An overview of existing multiscale techniques can be found e.g. in [1].

This abstract introduces a two-way loose coupling procedure that aims to overcome some of the computational limitations of the existing standard global-local methodologies and shows its application to a stiffened composite panel under compressive loading. First, the term two-way denotes that the information exchange between the different models is performed in both directions, i.e. from the global to the local model as well as from the local to the global model. Hence, an interaction of global and local effects can be taken into account. Second, loose coupling means that the analyses at global and local level are performed in different computations independently from each other. In the present approach the connection between the global and the local level is conducted by the transfer of displacements in one direction (from global to local) and by the transfer of degraded engineering constants in the other direction (from local to global) [2].

LOOSE COUPLING PROCEDURE

The main steps of the proposed two-way loose coupling process are described in the following. Initially the global analysis is performed and the critical global areas are determined on the basis of a composite damage criterion. To further investigate the critical global areas refined local models are built up, representing these areas of interest. For the separate local analysis the displacements from the global nodes are used as prescribed boundary conditions on the edges that delimit the local model. The material degradation during the loading process is computed by means of a user-material subroutine that includes a damage initiation criterion along with a material degradation model to calculate damaged material properties according to arising composite failure. Once the damage prediction step is accomplished, for the transition from the local back to the global model, the determination of equivalent material properties is required, since the local mesh is finer compared to the global mesh. Thus, linear characterisation tests are performed with local part models, which each represent the region of one global element and one laminate layer and include the degraded material properties from the local damage analysis. As a result each damaged global element receives degraded engineering constants from the associated local part. These updated material properties are incorporated into the global model via a global user material that reads them from an external file. Thereby the global computation is repeated from the last critical point, e.g. the onset of degradation, and loaded up to the same displacement as the former global analysis. The correct final global state can be reached after carrying out the coupling loop iteratively until the local material properties do not further change.

APPLICATION AND VERIFICATION

The presented procedure is tested on a stiffened composite panel with one single centered T-stringer subjected to uniaxial compressive loading. For the nonlinear static analysis of the panel under such loading the first eigenmode of the panel is applied as an initial geometric imperfection to trigger buckling of the specimen. The loading is increased beyond the onset of composite material degradation. Hence, the panel test case combines material as well as geometrical nonlinearities.

The global coupling model consists of shell elements with reduced integration including four nodes, whereas the local coupling model consists of solid elements with linear shape functions comprising eight nodes. Furthermore, the local model includes a material model comprising a damage initiation criterion as well as a progressive damage model. The verification of the method is achieved through a reference solid-like model that incorporates the mechanical features previously mentioned, i.e. the same element type, the same mesh refinement and the same degradation models as the local coupling model. Accuracy and efficiency of the procedure are evaluated by comparing the results using the coupling procedure with those obtained with the reference model.

ACKNOWLEDGEMENT

Parts of this research have received funding from the European Community’s Seventh Framework Programme (FP7/2007-2013) under grant agreement n°234147.

REFERENCES

[1] P. Kanouté, D.P. Boso, J.L. Chaboche, B.A. Schrefler, Multiscale Methods for Composites: A Review, *Archives of Computational Methods in Engineering*, vol. 16, pp. 31-75, 2009.

[2] S. Berg, E. Jansen, J. Reinoso, R. Rolfes, *Two-way loose coupling procedure for the analysis of local composite damage*, Composites 2013, IV ECCOMAS Thematic Conference on the Mechanical Response of Composites, S. Miguel, Azores, 2013.