

Analysis of Innovative Composite Aircraft Structures

T. Havar

EADS Deutschland GmbH, EADS Innovation Works

Abstract: Innovative composite structures are increasingly being used in the aircraft industry. A critical point of these new composite parts is the attachment to the surrounding aircraft structure. In cooperation between different EADS Business Units, a new advanced composite load introduction rib is developed to minimize weight and manufacturing costs. The new design of the flap focuses on the load introduction rib and drive fitting including the integrated lugs for the attachment to the flap support structure. The calculation of composite load introduction requires the implementation of 3D elements for an accurate analysis of all stress components. This is achieved by the use of 3D continuum shell elements, which provide all stress components with an enhanced formulation for the transversal shear stresses (fig. 1). Since delamination is a common type of failure for composite load introduction, the transversal shear and peel stresses are of high interest. The load introduction rib (modelled with 3D elements) is attached to the surrounding structure (2D elements) with rivets. These rivets are implemented as elastic connectors in connection with rigid body elements..

Keywords: Aircraft, Composites, Connectors, Design Optimization.

1. Introduction

Innovative composite structures are increasingly being used in the aircraft industry. A critical point of these new composite parts is the attachment to the surrounding aircraft structure. Current composite high lift structures usually have metal load introduction structures, which have been designed as Fail Safe structures. This leads to high weights, high manufacturing costs and an increased assembly effort. Additional thermal loads may occur due to the different thermal expansion between metals and composites.

The aim of new innovative load introduction structures is to reduce structural complexity by an integrated design reducing weight and costs. The use of composite in load introduction structures permits a damage tolerance design instead of a fail safe structure, since a failure of one ply is compensated by the surrounding intact plies. This further eliminates additional thermal loads, since the high lift structure as the load introduction structure are made of the same material..

2. FEM Model

The new design focused on the load introduction rib and drive rib with integrated lugs for the attachment of the flap support structure. The aim of the new design was to decrease manufacturing costs by simplifying the component to have one thickness for geometrically complex pre-forms and allowing significant thickness variances only in areas, which are simple with respect to pre-forming. The new design consists of a composite load introduction rib being assembled by an Omega-profile and U- and L- profiles respectively, thus minimizing the manufacturing costs by an automatable preform lay-up and industrial concept (Figure 1).

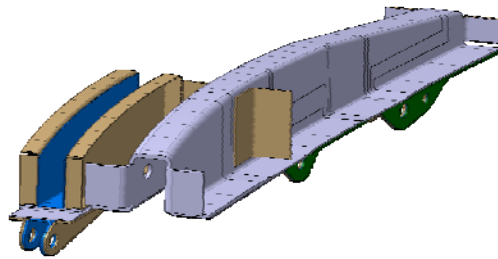


Figure 1. Composite Load Introduction Rib Design.

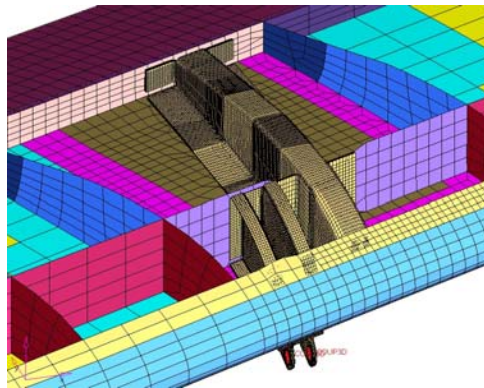


Figure 2. FEM model of load introduction rib and surrounding structure

The calculation of composite load introduction requires the implementation of 3D-elements for an accurate analysis of all stress components. This is achieved by the use of 3D continuum shell elements, which provide all stress components with an enhanced formulation for the transversal shear stresses (Figure 2). Since delamination is a common type of failure for composite load introduction, the transversal shear and peel stresses are of high interest.

3. Rivets

The load introduction rib (modelled with 3D-elements) is attached to the surrounding structure (2D-elements) with rivets. Each rivet is modelled, with an elastic connector between the parts. The connectors are on one side attached to the skin and on the other side MPC's are used to distribute the loads over the skin thickness (Figure 3). The connector stiffness is calculated according to the skin thickness and stiffness as well as the rivet material and size (HSB, 2000). The resulting connector forces are used to calculate reserve factor for skin bearing failure and rivet fracture.

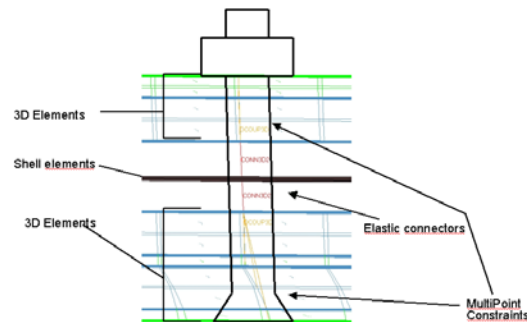


Figure 3. Modeling of Rivets

4. Lug Analysis

The flap cinematic system is attached to the load introduction rib through composite lugs. These lugs are calculated in the FE model. The loads are applied with a rigid body element in load direction for a good load distribution on the lug (Figure 4). For each load case a new rigid body element is created due to the varying loads.

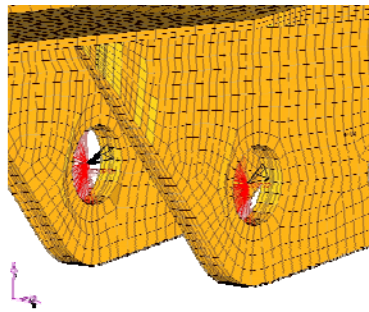
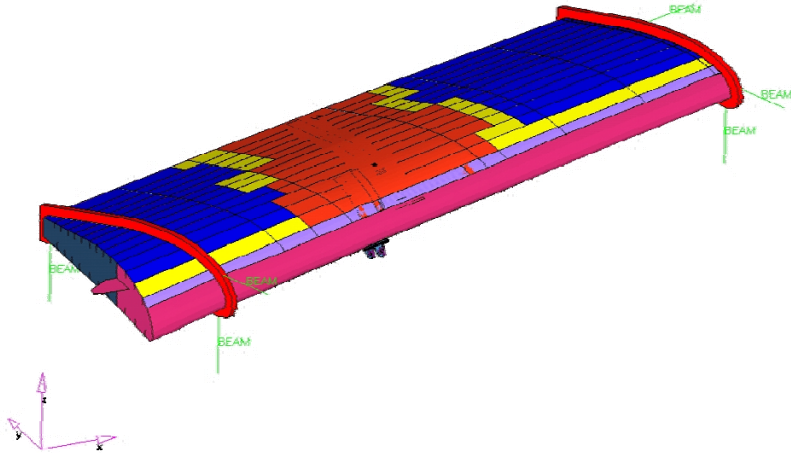


Figure 4. Composite lugs with load application through rigid body elements.

The load introduction rib is integrated into the composite flap. The flap is fixed at the edges with beam elements representing the test setup. At the ends, these beams are fixed in all 3 translational degrees of freedom. For some load cases the beam elements at the outboard end are translated symmetrically causing an additional torsion on the flap.



5. Results

Several load cases are calculated with the Abaqus implicit solver and post-processed with Abaqus CAE. It is shown that the in-plane as well as the transversal stress components are uncritical for the new composite design (Figure 5 and Figure 6).

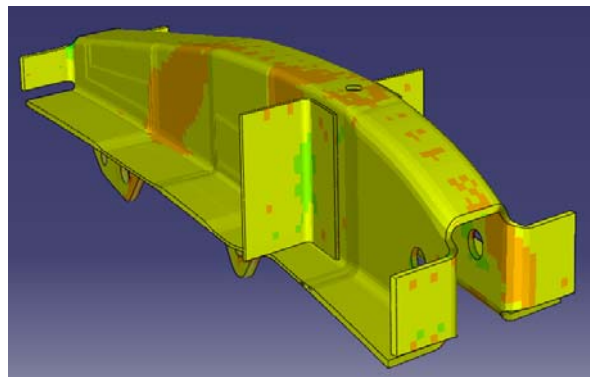


Figure 5. Stress in fiber direction.

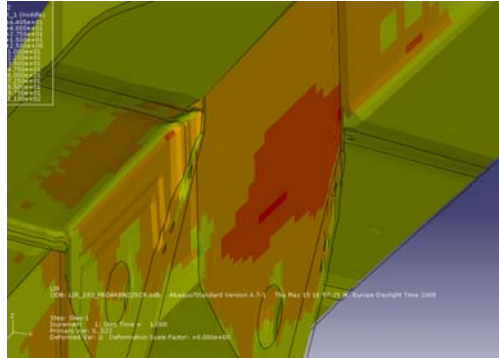


Figure 6. Local stress maxima above lug.

Additional extensive analysis of each rivet shows sufficient strength for the connection of the load introduction rib to the surrounding structure. The analytical calculation of the composite lugs (Kassapoglou, 2003) show an uncritical loading of the attachments.

6. References

1. Kassapoglou, Townsend, Failure Prediction of Composite Lugs under axial Loads. AIAA Journal Vol 41, No. 11, November 2003.
2. HSB, Handbuch für Strukturberechnung, Luftfahrttechnischen Handbuch, 2000.

Acknowledgement

This work was performed in a German national funded project InHiD in a cooperation between Airbus, EADS Military Air Systems, Eurocopter and EADS Innovation Works.