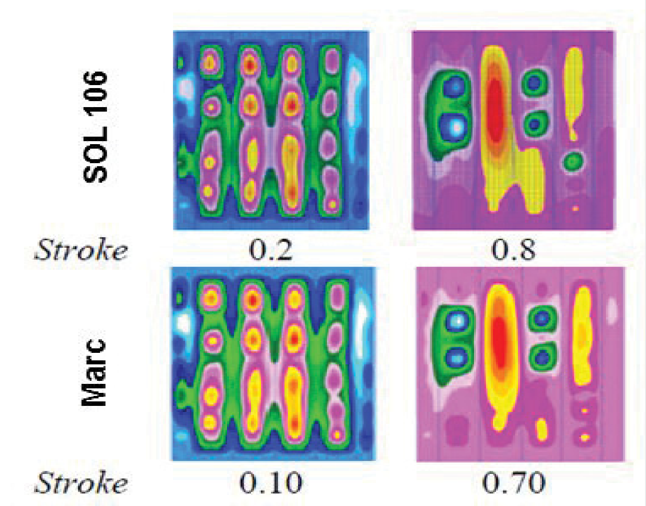
Case Study: **CRC-ACS**

Accurately Solving Postbuckling Composite Stiffened Panels in Marc and MSC Nastran SOL106

Overview

This paper outlines the CRC-ACS (Cooperative Research Centre for Advanced Composite Structures) contribution to a software code benchmarking exercise as part of the European Commission Project COCOMAT investigating composite postbuckling stiffened panels. Analysis was carried out using MSC Nastran (Nastran) solution sequences SOL 106 and SOL 600, Abaqus/Standard (Abaqus) and LS-Dyna, and compared to experimental data generated previously at the Technion, Israel and DLR, Germany. The finite element (FE) analyses generally gave very good comparison up to initial postbuckling, with excellent predictions of stiffness, and mostly accurate representations of the initial postbuckling mode shape, leading to fair comparison in deep postbuckling. Accurate modeling of boundary conditions and panel imperfections were crucial to achieve accurate results, with boundary conditions in particular presenting the most critical problem.



The deformation pattern and displacement of various points around the panel showed close agreement, with only small variations in the deep postbuckling region.

Challenge

Utilizing composite compression tests performed by the Israel Institute of Technology (Tension) and the Israel Aircraft Industries, a “state of the art” study was performed for composite buckling verification via Finite Element Analysis. Comparisons were completed for MSC Nastran SOL106, Marc (via Nastran SOL600), Abaqus and LSDyna.

Solution

The particular panel selected was a fuselage-representative, 5-blade stiffened, curved panel. A summary of the panel specifications is given in Table 1, where the 0° direction is parallel to the stiffeners. The stiffener and skin are joined using a flange, where the stiffener plies are continued over the web, half on each side, and the flange outer plies are sequentially terminated 4 layers at a time, at increments of 10 mm. The test panel was encased in potting on both ends to ensure a homogenous distribution of the applied displacement. Large plates were used on the panel sides, aligned with the tangent to the panel edge, to restrict radial displacements without adding constraint in the tangential direction. Panel skin imperfections were measured using an LVDT probe. The testing procedure involved loading the panel in compression up to a point where global buckling was seen in a moiré fringe pattern, then unloading. This was repeated twice, before the moiré fringe was removed and the panel loaded to collapse.

Results Validation / Correlation to Test Data

The structural stiffness and buckling load were predicted well, though all models slightly under-predicted the buckling point by a maximum of 11%. The strain data gave less acceptable correlations, while the pre-buckling and initial postbuckling predicted moderately well, leading to poor correlations in deep postbuckling. Panel failure was not captured by either solution sequence, though Marc has the capacity to monitor various failure criteria.

Comparatively, the two Nastran solution sequences gave very similar behavior for most results, with only strain values data showing significant discrepancies. The axial shortening of both solution sequences did show slight discrepancies, especially in the deep postbuckling region. The SOL 600 (Marc) solution gave higher stiffness, seen in a slightly higher global buckling load, and a slightly different stiffness in the deep postbuckling region. The deformation pattern and displacement of various points around the panel showed close agreement, with only small variations in the deep postbuckling region.

Key Highlights:

Product: MSC Nastran (SOL 106), Marc

Industry: Aerospace

Benefits:

- Accurately predict performance of panels before buckling and even with post buckled performance
- Close agreement to experimental data
- By utilizing accurate simulation, millions of dollars can be saved on a single new aircraft program

About MSC Software’s Composites Solutions

Due to today’s use of composite parts and their highly complex material behaviors, companies are required to do thousands of small tests, leading to a few major tests at every level of the validation or testing pyramid. These tests are not only extremely expensive, but also time consuming and complex to set up and carry out.

MSC Software offers a complete Composites Simulation Solution at all levels of the validation pyramid, whether it be the material level, the joint elemental level, or the subcomponent level. By enabling virtual testing and reducing the amount of physical testing that is needed, companies can drastically reduce the cost of their aerospace composite design while maintaining the same level of accuracy.

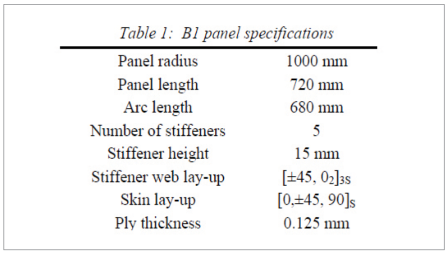
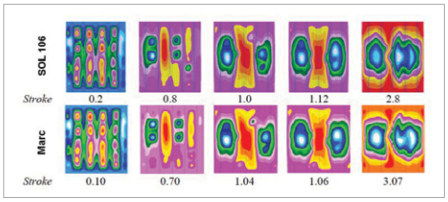
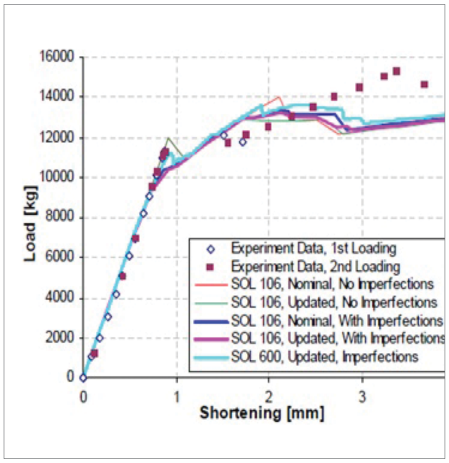


Table 1: B1 panel specifications

Panel radius	1000 mm
Panel length	720 mm
Arc length	680 mm
Number of stiffeners	5
Stiffener height	15 mm
Stiffener web lay-up	$[\pm45, 0_2]_{3S}$
Skin lay-up	$[0,\pm45, 90]_S$
Ply thickness	0.125 mm





Looking at the close correlation between experimental data and simulation runs, you can see that using MSC Software’s Marc & MSC Nastran very accurately predicts the performance of this panel before buckling and even with post buckling performance.

For more information, please visit: **www.mscsoftware.com/aerosolutions** or contact **AeroSolutions@mscsoftware.com**

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