Buckling and Post-Buckling Behavior of Stringer Stiffened Laminated Composite Curved Panels subjected to Shear

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Summary

The buckling and post-buckling behavior of stringer stiffened laminated composite curved panels subjected to shear is experimentally and numerically analyzed. During the tests, the buckling deformation is identified using Moiré fringes. The numerical results, obtained using finite element codes, are compared with the experimental data.

Introduction

It is well known that stiffened panels can have considerable post-buckling reserve strength. However, their use in aeronautical engineering is still limited above all because of studies on composite panels are scarce [1]. To reduce the actual too conservative design approach, designers need detailed finite element analyses, validated by extended experimental data.

Experimental Tests

Two curved longitudinally stiffened panels were fabricated by Israel Aircraft Industries and were tested at the laboratory of Politecnico di Milano by means of a position controlled equipment [2]. The panels are of the same type already tested under pure axial compression at Technion [3]. The dimensions of the panels are: 720 *mm* width, 800 *mm* height and 938 *mm* radius. Each panel is stiffened by 5 blade stringers.

The two panels were tested together in a closed box, so, by applying a torque, the two panels were subjected to shear. Various tests were performed before reaching the collapse of the box under torsion, including combined axial compression load and torsion moments. For each case, the first buckling load was reached in the skin, while the collapse was performed under torsion only.

During the tests, the values of axial displacement, rotation, axial compression load and torque of the closed box were measured using LVDT's and a load cell. The experimental interaction curve obtained with the first skin buckling loads is reported in Figure 1.

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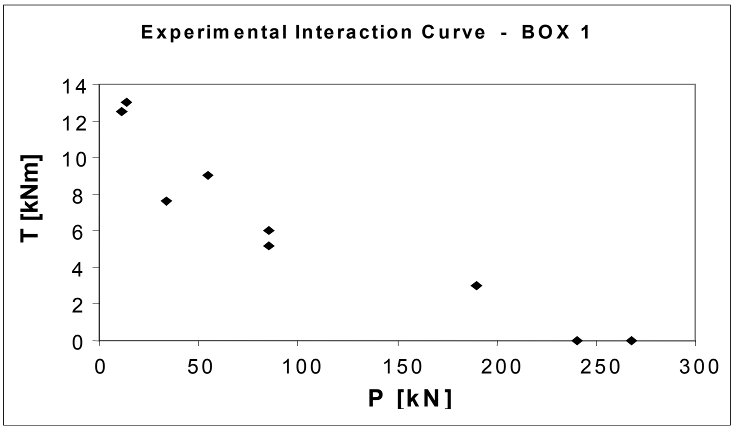

Figure 1 – Experimental interaction curve

Eighty strain gauges were bonded back to back on each panel, both on the skin and on the stringers. The strain gauges map and the LVDT's position is shown in Figure 2, while Figure 3 reports a photo of the panel with the bonded strain gauges.

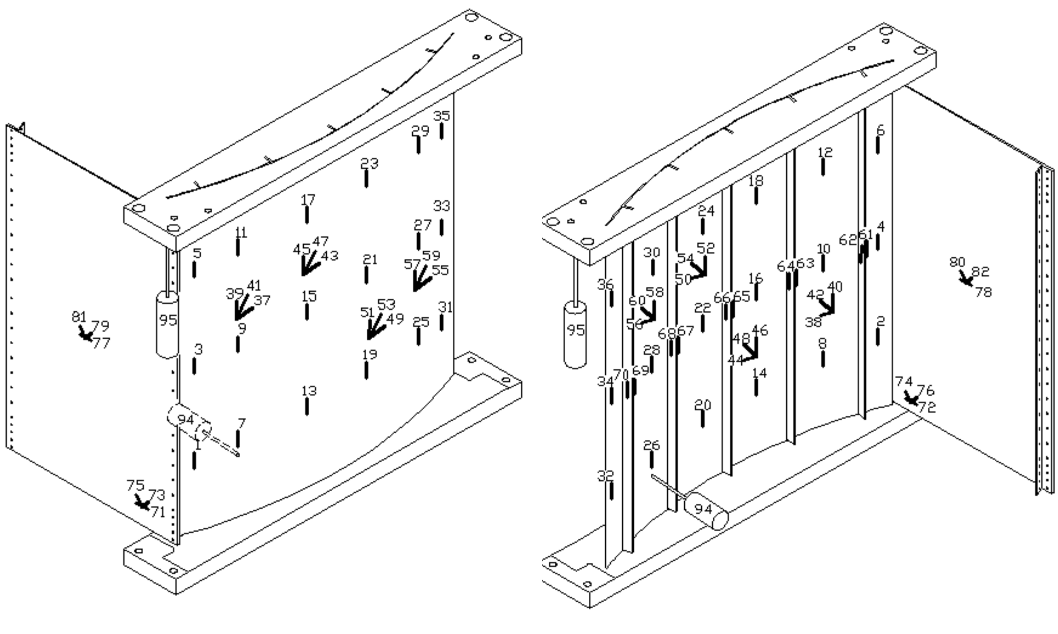

Figure 2 – Strain gauges and LVDT's position: external and internal view

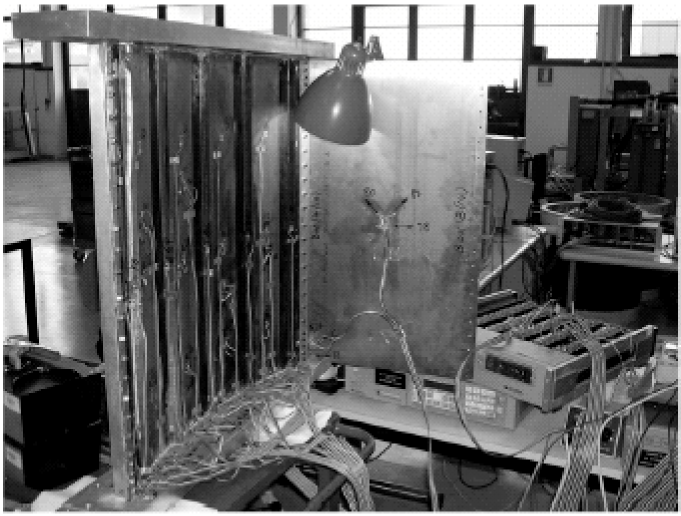

Figure 3 – Photo of the panel with the stringers and bonded strain gauges

Typical measurements of strain gauges are given in Figure 4.

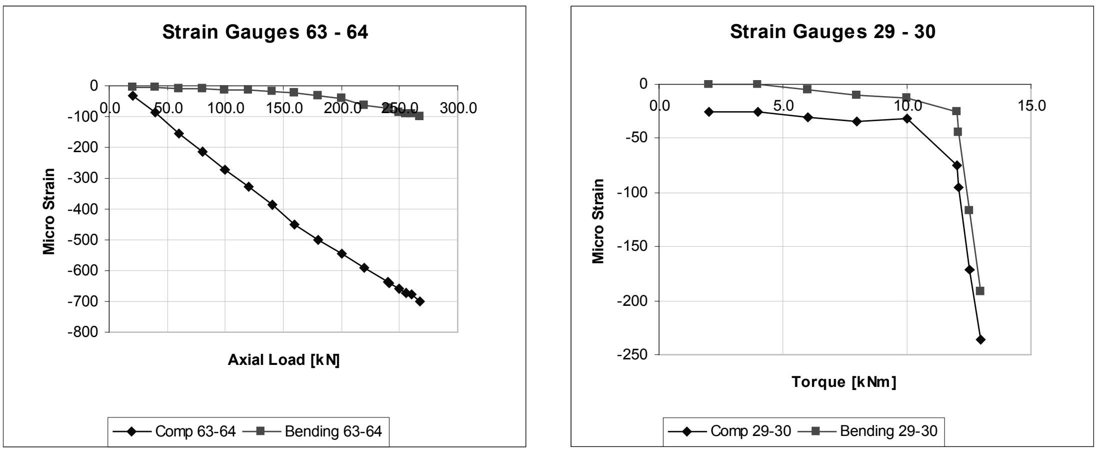

Figure 4 – Strain gauges measurements for axial compression and torsion

The Moiré fringes were used to identify the buckling deformation on each panel, as shown in Figure 5.

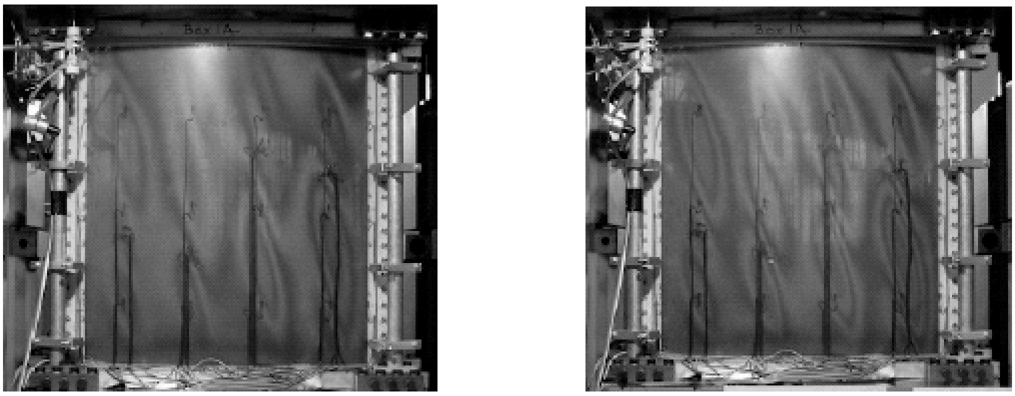

Figure 5 – Photos of the post-buckling deformation

Figure 6 presents the collapse mode of the box as seen on the panel A of the box.

Figure 6 – The collapse picture of the box

Typical results are presented in Figure 7, where the torque versus the rotation angle is shown.

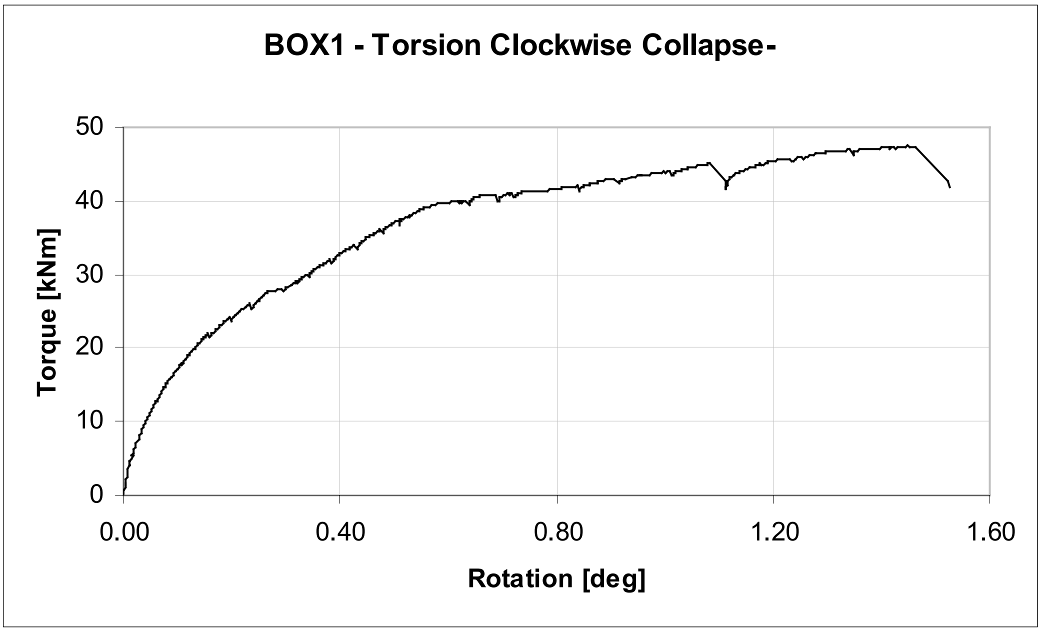

Figure 7 – Torque vs. rotation curve

Numerical Analyses

The experimental results were compared with the predicted data obtained from the finite element analyses performed using ABAQUS code. Figure 8 shows the moment as a function of the circumferential displacement, obtained using ABAQUS code.

The mode shapes at various critical points are also reported. The numerical first skin buckling torque is evaluated at 13.2 *kNm*. It is in good agreement with the experimental one, measured at 14 *kNm*. The collapse is numerically obtained at 50 *kNm*, which is comparable with the value measured experimentally at 45 *kNm*.

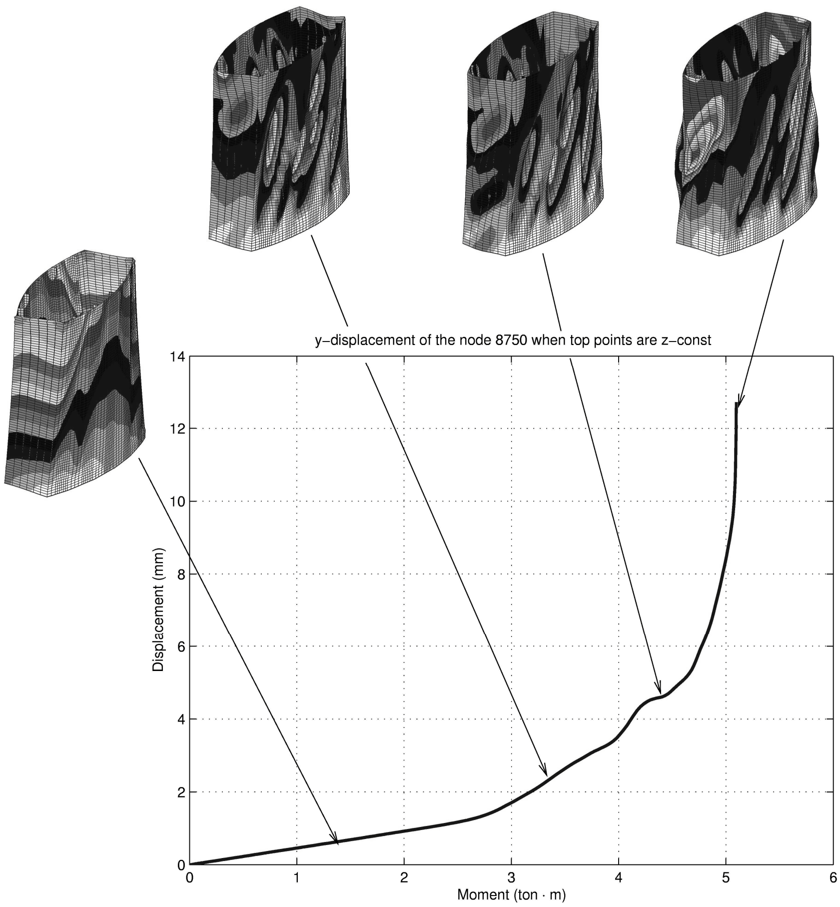

Figure 8 – ABAQUS code results: moment vs. circumferential displacement and mode shapes at various critical points

Reference

1 Singer, J., Arbocz, J., and Weller, T. (2002): *Buckling Experiments – Experimental Methods in Buckling of Thin-Walled Structures*, Vol. 2, John Wiley & Sons Inc.

2 Bisagni, C., and Cordisco, P. (2003): "An Experimental Investigation into the Buckling and Post-Buckling of CFRP Shells under Combined Axial and Torsion Loading", *Composite Structures*, Vol. 60, pp. 391-402.

3 Abramovich, H., Grunwald, A., Pevsner, P., Weller T., David, A., Ghilai, G., Green, A., and Pekker, N. (2003): "Experiments on Axial Compression Postbuckling Behavior of Stiffened Cylindrical Composite Panels", *Proceeding of 44th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Material Conference*, AIAA 2003-1793.