131 Mode Jumping in Post buckling Analysis of Curved Stiffened Panels

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Introduction

Plate structures are commonly used in aerospace and other engineering sectors because of their unique characteristics including high stiffness and strength to weight ratios, which enable efficient engineering designs with lower material requirements. Stiffened panels are one of the principal components used in a wide range of wing and fuselage structures. Stiffeners are commonly used to support the skin plate by carrying a proportion of the load. By dividing the plate into smaller panels, they also delay global buckling and provide a local post buckling reserve of strength.

Many experimental and theoretical studies have been made of the mode-jumping phenomenon in the local post buckling of flat plates and stiffened panels [1, 2]. The present study explores this phenomenon in isotropic curved plates stiffened by five L-shaped stiffeners. The asymmetry of such stiffeners can produce non-familiar buckling mode shapes. Panels with three different radii of curvature are considered. The paper outlines the experimental procedure and the measurements obtained through the test. A comparison with finite element analysis using ABAQUS software was made to validate the practical test results.

Material properties and dimensions

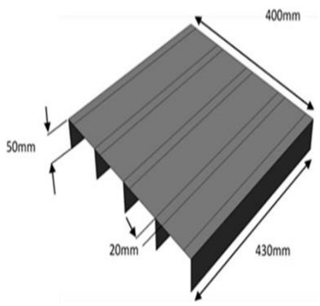
Curved panels were manufactured with the skin and stiffener dimensions shown in Fig. 1 but with three different radii of curvature: 400 mm, 800 mm and ∞ (i.e. a flat panel). The skins were made from aluminium alloy 6082 sheets while the stiffeners were made from 50x50 mm aluminium angle sections to form the 20x50 mm stiffener cross sections. The material properties listed in Table 1 include information from the manufacturer's material sheet and samples tested at Cardiff University according to the BS standard [3].

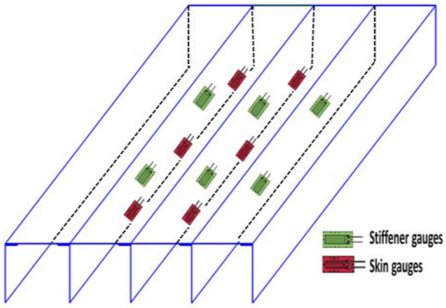
Test set-up and monitoring

Two samples of each curvature were manufactured and axially compressed under displacement control using a Zwick testing machine (maximum load = 500kN static). The test rig provided a fully fixed bottom edge while the top edge had free vertical movement only. A digital image correlation (DIC) LaVision system and KFG-5-120-C1-23 Kyowa strain gauge were used to monitor the tested specimens. Twelve strain gauges were used for each panel, six on the skin and six on the stiffeners (see Figs. 2 and 3).

Table 1 Mechanical properties and dimensions of the tested panels

Property	Value	Units
Young's modulus, E_{11} (material sheet)	70.0	GPa
Young's modulus, E_{11} (actual tested value), skin	72.2	GPa
Young's modulus, E_{11} (actual tested value), stiffener	72.6	GPa
Poisson's ratio, v_{12}	0.3	-
Mass density, ρ	2700	kgm^{-3}
Panel width, b	400	mm
Panel length, L	430	mm
Panel effective length, L_E	400	mm
Radius of curvature, R	400, 800, ∞	mm
Skin thickness, t_{sk}	1.0	mm
Stiffener thickness, t_{st}	1.5	mm
Stiffener web height, h_w	50	mm
Stiffener flange width, h_f	20	mm





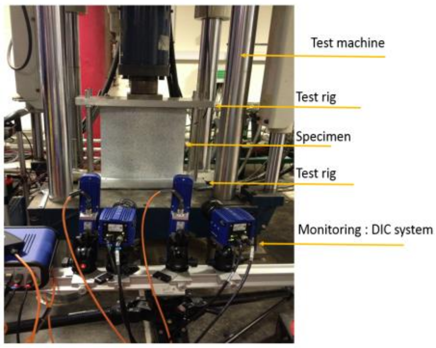
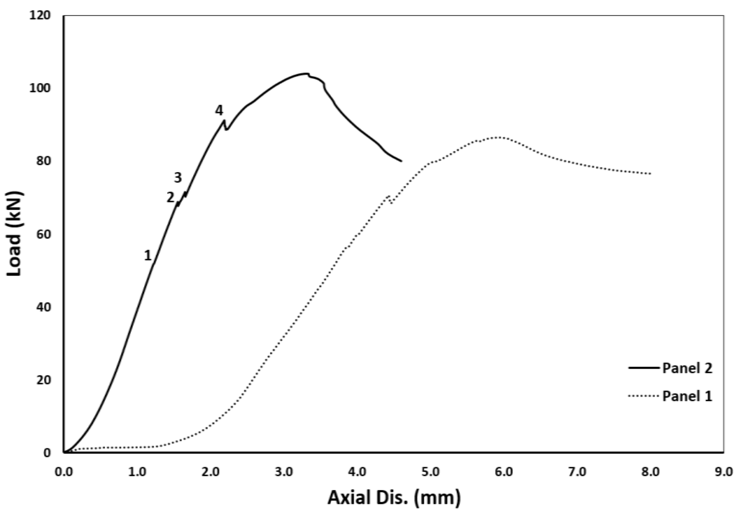


Fig. 1 Panel dimensions Fig. 2 Strain gauge positions map Fig. 3 Test setup

Results and discussion

Six panels were tested, two samples for each radius of curvature geometry. The panels were also modelled using ABAQUS dynamic explicit step analysis [4] to capture the mode jumping. The panel with 400 mm radius exhibited an initial local buckling mode with two buckles in the longitudinal direction, and then jumped to a local mode with three buckles. Moreover, a second jump was noticed after that so that the panel had four buckles in the longitudinal direction before failure. The most noticeable observations were that the four skin panels between the stiffeners behaved independently, which can be explained due to different initial imperfections and asymmetry effects. The first sample (Panel 1 in Fig. 4) had in-plane imperfections during the manufacturing, which meant that load was introduced to some of the stiffeners before the skin was loaded at all. This did not occur in the second sample (Panel 2 in Fig. 4). DIC images for Panel 2 are presented in Fig. 5 at the four locations shown in Fig. 4.



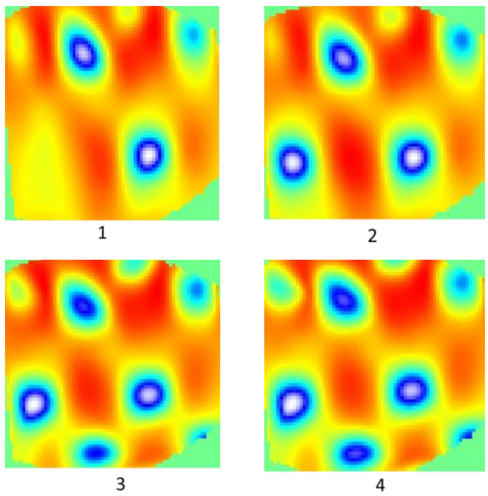


Fig. 4 Load vs axial displacements for panels with *R*=400mm Fig. 5 DIC out of plane configurations

Conclusion

The main conclusions were a confirmation that mode jumping can occur in local post buckling and that the panels were able to carry loads well in excess of their initial buckling loads. Also, the results showed that the initial imperfections had a significant effect on the mode-jumping phenomenon.

References

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