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INFLUENCE OF STITCH DENSITY AND STITCH THREAD THICKNESS ON COMPRESSION AFTER IMPACT STRENGTH OF STITCHED COMPOSITES

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Summary *This study aims to investigate the influence of stitch density and stitch thread thickness on compression after impact (CAI) strength of stitched composites. Unstitched laminated composites and specimens stitched with varying stitch density and stitch thread thickness are subjected to impact damage and then compressive loading. It is shown that stitched composites have higher CAI strength than unstitched counterpart due to smaller impact-induced delamination area, where local buckling occurs during compressive failure. However, it is revealed that the effectiveness of stitching in suppressing delamination growth and inhibiting sublaminate buckling under compressive loading is intimately related to stitch density. It is also found out that stitch thread thickness has little influence on CAI strength at low impact energy level, but has considerable effect at high impact energy level.*

1 INTRODUCTION

Compression After Impact (CAI) performance of light weight composites remains an important criteria for aerospace structures application [1]. Besides being extremely susceptible to delamination damage by impact loading, such delamination hidden beneath the composite structure greatly reduces the post impact strength of the material, especially in compression loading. Over the decades, researchers have been seeking solutions to improve impact resistance and ultimately CAI strength of composite materials. One such effective ways of interlaminar reinforcement is by stitching. Stitching has been proven effective in suppressing impact damage, resulting in smaller impact-induced delamination area [2]. However, CAI strength of stitched composites is less studied; especially the way stitch density and stitch thread thickness affect CAI performance. This study aims to fill this gap.

2 EXPERIMENTAL DETAILS

The specimens were made using T800SC-24K carbon fibre fabric (32-ply). The linear density of Vectran stitch fibre is 200denier or 400denier, with a stitch density of 3mm x 3mm (densely stitched) or 6mm x 6mm (moderately stitched). The type of stitch is the Modified Lock Stitch. Resin transfer moulding technique using resin XNR/H6813, was adopted to consolidate the composite. Low-velocity impact test was performed using Instron Dynatup 9250HV. Compression test was carried out using Instron 5589 test machine (600kN load cell). Ultrasonic C-scan and X-ray radiography were employed to examine damages and failure mechanisms both due to impact and compression after impact.

3 RESULTS AND DISCUSSION

The CAI strength of stitched composites is observed to be higher than unstitched composites. Densely stitched composites have significantly much higher CAI strength (by 60%) than unstitched laminate. This is partly due to smaller impact induced delamination area, and more notably due to stronger bridging forces between delaminated layers by the closely spaced stitches. X-radiographs revealed that delamination growth is confined by the stitches, resulting in numerous stitch fractures at compressive failure. There is lesser influence of stitch bridging and ultimately stitch fracture in moderately stitched composites compared to densely stitched composites, due to the fact that local buckling “slips” between stitch thread. It is demonstrated that moderately stitched composites have CAI strength highly dependent on delamination area, behaving in the same fashion as unstitched composites. Thicker stitch thread improves CAI strength noticeably at higher impact energy levels, only when the delamination area is relatively large and when bridging zone is sufficiently significant.

4 CONCLUSIONS

Compression after impact tests were performed on laminated composites stitched with Vectran fibre, at various stitch density and stitch thread thickness. It is demonstrated that stitching significantly improves delamination resistance to impact damage, inevitably resulting in higher CAI strength due to smaller impact induced delamination area. It is revealed that stitch density, which is related to stitch spacing, is critical in suppressing delamination growth during compression loading. Stitching thread thickness has little influence at lower impact energy level, but has significant effect at higher impact energy.

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