Delamination Resistance Enhancement for Metal Laminated Panel under the Effect of Constant Cyclic Load

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ABSTRACT

This paper presents the testing of a metal laminated panel with two main dimple core configurations under a four-point bending setup. The cavity features on the core layer led to unstable bonding strength. An alternative core design must be proposed to improve delamination resistance in panels as this plays a significant role in retaining their structural integrity. Specimens with AR500 steel outer skins and a magnesium alloy AZ31B main core were tested under constant cyclic loading conditions. The 50% and 70% of maximum cyclic flexural loading were given to the specimens at frequencies of 10 Hz. The tested specimens were cut into the cross-sections and the bonding regions were examined under a microscope. The results showed that the dimple core configuration with diameters of 6.0 mm and depths of 3.0 mm exhibited better delamination resistance, which improved for this configuration by between 31% to 38%, compared to the larger dimple configurations. The data survivability indicated a good correlation between the experimental and simulated data as the data lay within the 90% confidence intervals. In conclusion, a newly designed dimple configuration for laminated panels demonstrated improved delamination resistance.

Keywords: Dimple configuration, Laminated panel, Structural integrity, Delamination, Data survivability.

INTRODUCTION

Laminated panel failure mechanisms become critical under high loading conditions like cyclic loading. Under these conditions, the structural integrity at the bonding surface region between the panel layers is prone to failure mechanisms such as delamination, which leads to catastrophic failure and affects the fatigue life (Gerendt et al. 2023). Previous studies have noted four general core designs for laminated panels: foam, honeycomb, lattice, and solid plate (Wu et al. 2019). However, these core configurations generally have an open and/or closed cavities in their body structure, which affects the holding strength between the layers. Therefore, it is worth exploring alternative core geometries that would improve the holding strength between the panel layers.

The process of improving the alternative core geometries can be undertaken using a combination of simulation and experimental methods. Good correlations between experimental and simulated data are important for justifying that the results for different core configurations of laminated panels are improvements (Wu et al. 2019). Comparisons through regression analysis and data survivability analysis are worth pursuing as they might produce stable results that enable suitable dimple core configurations to be determined (Chin et al. 2022). Such comparisons are vital in proving how particular dimple core configurations provide better delamination resistance.

In this work, laminated panels were tested using a four-point bending setup under constant cyclic loading conditions. The tested specimens were cut into cross-sections to enable the delamination effects of different dimple core configurations to be observed using a microscope. The experimental and simulated results were compared to ascertain the correlations between, and stability of, the data.

METHODOLOGY

The experimental laminated panel process was performed using a four-point bending setup, which followed the ASTM C393 standard. Two main alternative dimple core configurations were tested to validate their suitability for improving the delamination resistance. These two main core configurations were determined through the simulated results. Fig. 1 shows the workflow of the study.

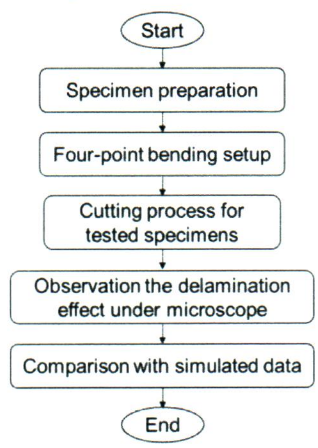

Fig. 1 The workflow of the study.

As Fig. 2 shows, the laminated panel had AR500 skins and the Mg alloy AZ31B as the main core. Resin epoxy was used as an adhesive element to bind the upper/lower skins to the main core surface. Fig. 3 shows the experimental setup for the four-point bending. The specimens were subjected to cyclic loading at 50% and 70% of maximum cyclic flexural loadings and with constant amplitude loading. The loading frequency was 10 Hz and the load ratio of 2 was chosen as this would provide suitable, stable constant conditions for the metal laminated panels (Gerendt et al. 2023). The total life cycles were recorded, and the tested specimens were cut into cross-sections using an abrasive cutter to observe the delamination effects. Regression coefficient and data survivability analyses were undertaken to check the consistency of and correlations between the experimental and simulated data.

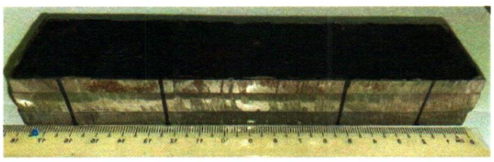

Fig. 2 The combination of panels, with AR500 skins (upper and lower) with Mg Alloy, AZ31B core.

Fig. 3 The four-point bending experimental setup.

RESULTS AND DISCUSSION

The experimental results focused on the upper and/or lower bonding regions of the panel layers. Fig. 4 indicates that the fatigue bending specimens with dimples that were 6.0 mm in diameter and 3.0 mm in depth performed differently in terms of delamination resistance by between 31% to 38%, which was better than the largest dimple configuration.

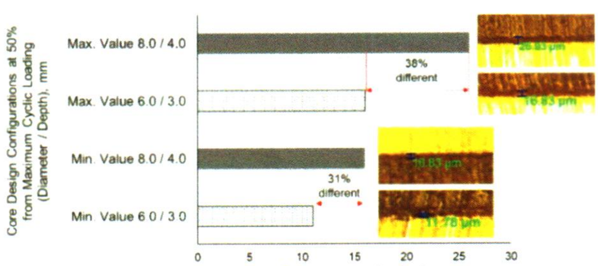

Fig. 4 The percentage difference at the maximum and minimum delamination value for different dimple core configuration based on the microscope evaluation at bonding region.

Fig. 5 shows the data survivability analysis of the life cycles from the experimental and simulated data, which revealed that all the values fell within the 90% confidence interval. Hence, the findings demonstrate that using dimple designs with smaller cores improved the delamination resistance and life cycles.

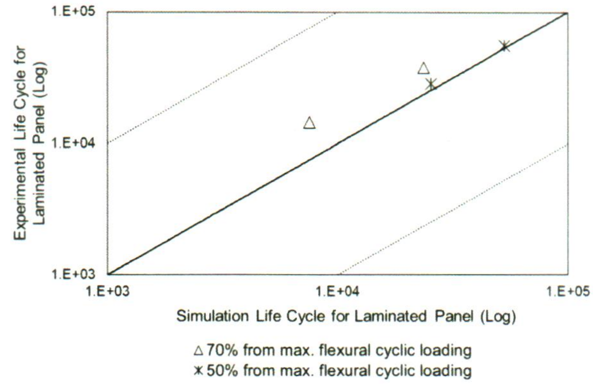

Fig. 5 Life cycle data survival analysis from experimental and simulated data with 90% confidence intervals.

CONCLUSION

Laminated panels with two alternative dimple core designs were tested using a four-point bending setup. The experimental analysis revealed that the alternative dimple core configuration with diameters of 6.0 mm and depths of 3.0 mm proved to be the optimal candidate for improving the delamination resistance, which showed improvements ranging from 31% to 38%, compared to the largest dimple core size. The data survivability analysis indicated a good correlation between the experimental and simulated data, based on a 90% confidence interval. In conclusion, this study revealed the potential for the dimple core configuration of a laminated panel to improve the delamination resistance, based on a core design determined through experimental and simulated analysis.

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