Investigation of core closeouts in fiber-reinforced sandwich laminates
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Abstract:
Wind is an environmentally friendly renewable energy source that becomes more attractive when composite materials technology is applied; particularly technology associated with fiber reinforced plastics. This technology allows the design of lighter wind turbine blades, which may increase the efficiency of wind turbines, making wind generated electric power less costly. The application of sandwich panel construction can stiffen the blades while keeping overall blade weights low. Due to manufacturing and design parameters, the sandwich panel configuration is only employed in certain areas of the blade, where additional buckling resistance is needed. Although initially thought to be of little importance, the effect that the transition between fiberglass/balsa sandwich panel and the fiberglass laminate may have on the performance of the blade is not trivial.

This research is an investigation of balsa core sandwich panels, thin laminates (which were the facesheets for the sandwich panel), and transitions from sandwich panels to thick and thin laminates. Sandwich panels were tested in tension, resulting in strengths slightly above the thin laminate without the balsa core in place.

A sandwich panel to thin laminate transition can reduce static tensile strength by up to a factor of six when using a 30 degree fillet transition, as discovered in this research through finite element models and experimental tests. Transitions were tested with fillet angles ranging from 5 to 30 degrees. The 5 degree specimens with a transition to a thin laminate reduced strength by only 7 percent, well above the performance of the 10 degree transition, which lowered strength by 48 percent. Finite element models were created for use as a design tool to evaluate the transition behavior, and were validated using experimental data.

A transition from a sandwich panel to a thick laminate was also investigated. Specimens tested included angles of balsa termination of 5, 10, and 90 degrees. The 5 degree termination performed the best, failing at a value that was only 23 percent less than that for a sandwich panel. The 90 degree specimens delaminated at a stress as much as 55 percent less than the sandwich panel alone.

Fatigue performance of the thin laminate, the sandwich panel, and the sandwich to thin laminate transition were investigated. The sandwich panel had fatigue strengths only 1.1 times lower than the baseline thin laminate at one million cycles. The transition had poor fatigue performance, 3.4 times lower than the thin laminate at a million cycles due to delamination in the transition region.

Design and manufacturing guidelines were made based on the results of experiments and models completed through this research. Recommendations for finite element modeling to be used as a design tool were also made.