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A NEW DAMAGE TOLERANT DESIGN APPROACH FOR SANDWICH PANELS LOADED IN FATIGUE

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ABSTRACT

A new experimental procedure for crack propagation in composite sandwich structures under fatigue loading conditions is proposed and used to evaluate the performance of a damage tolerant design approach [1]. The investigation concerns crack propagation in all 3 dimensions and thus, composite sandwich panels are utilized as specimens. Few investigations have been conducted on crack propagation inside a sandwich panel [2] as the use of beam specimens is often more convenient and results are easier to assess. Sandwich structures, though, are commonly used in large panels and less often as beam elements making failure inside them a multidimensional problem. Testing sandwich panels instead of beams to evaluate the performance of the damage tolerant approach in fatigue appears to be a more resourceful experimental investigation.

The panel specimens consist of glass fiber laminates while the core structure includes the main core foam material, the peel stopper and the insert, (Fig. 1). The panels are mounted in a specially designed rig that restricts displacement in the lateral direction and imposes simple support boundary conditions on all four edges of the plate, (Fig. 1).

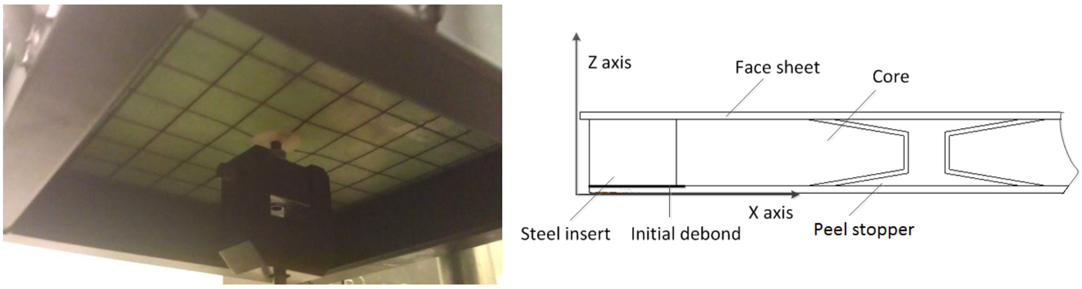

Figure 1: Experimental set-up for testing sandwich panels and cut view of the core structure.

The structure is loaded in fatigue and an initial debond is propagating outwards, towards the support of the panels. A Circular peel stopper is built into the panels core structure. The peel stopper confines a circular area in which the initial debond should propagate freely but not exceed its limits, “spreading” into the rest of the panel. A thin circular Teflon layer is included at the center of the panel in the lower interface in order to induce an initial debond in the structure.

The fatigue loading conditions are induced close to the maximum load limit of the panel, 80% of the maximum load. The limit refers to the maximum load needed to propagate the initial debond and is determined quasistaticaly. The experimental investigation aims at evaluating the overall effect of the peel stopper on the fatigue life of the specimens. To achieve this goal, panels that do not contain peel stoppers are also tested for comparison reasons. Results from first experiments showed that the peel stopper is able to extend the fatigue life of the specimens.

The experimental procedure is designed such that axisymmetric behavior can be approximated around the area of the peel stopper. A cylindrical steel insert in the middle of the plate is utilized to apply the load, a circular initial debond is introduced on the structure and a circular peel stopper is used to confine the propagating crack. By doing so, the initial debond propagates in a circular shaped crack front and “strikes” the peel stopper at the same time. Axisymmetric behavior is evaluated through a series of numerical analyses by comparing displacement and stresses responses of an axisymmetric model with a full rectangular plate model (Fig. 2). The analysis indicates that a certain radius exists around the center of the panel on which the deviation of the two responses does not exceed a small percent. The peel stopper is well inside this radius.

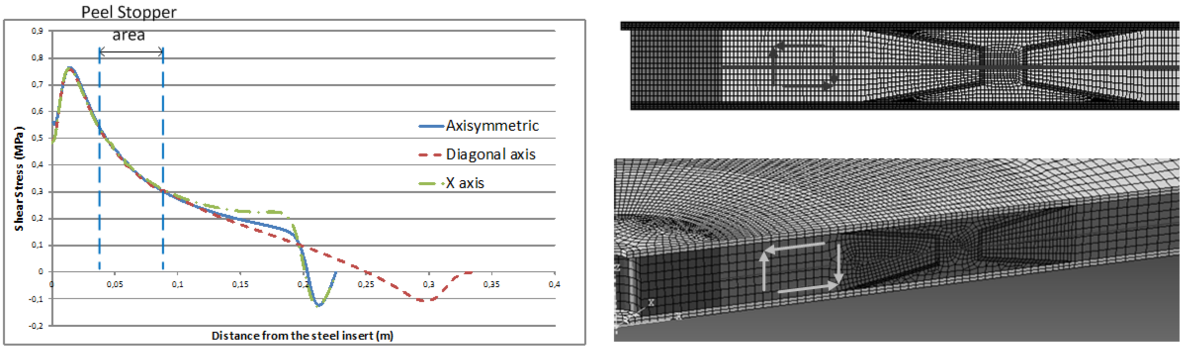

Figure 2: Transverse shear stress resultant comparison in the core material. The comparison is made for the axisymmetric model (right and up) and the 3D plate model (right and down) in the diagonal and one of the main axes (X-axis).

For the purpose of assessing the results of the experiment, the compliance of the specimen was obtained. The compliance is derived and expressed as a function of the crack propagation radius, R while the specimen retains its axisymmetric behavior. Using the compliance of the test specimen, the energy release rate can be obtained for the propagating crack [3-4]. Monitoring energy release rate can be essential for assessing the results of crack propagation in fatigue and can provide insight for the performance of damage tolerant design. Finally, the compliance of the structure also relates the vertical displacement of the steel insert, measured by the test machine, with the crack propagation length (radius, R) inside the panel. An approximation can thus be made for the position of the crack while fatigue testing is running.

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