EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF DEBONDING AT THE INTERFACE OF TWO L-SHAPED PMMA BEAMS

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Summary This study contains experimental and computational analyses of delamination initiation and propagation triggered by the interlaminar stresses on the curved region of L-shaped composite beams. In order to understand the fundamental mechanics of the delamination in L-beams, a simple model material consisting of two Polycarbonate L-shaped beams bonded to each other are used. In experiments the full-field technique of photoelasticity used whereas in computational study L-shaped beams are investigated using finite element analysis in conjunction with cohesive zone method. The effect of end loading and thickness on the crack initiation and propagation is investigated.

INTRODUCTION

Composite materials have been in demand especially in commercial aircraft industry because of their high specific stiffness and strength properties. In addition geometrically complex aircraft parts have been manufactured and used with advances in manufacturing technologies. One of these parts is the L-shaped composite flange. However, the nature of the complex geometry causes high interlaminar tensile (opening) stresses in addition to the shear stresses on the curved region of the L-shaped beam under the loading. Consequently cause delamination on the curved region of the L-shaped composite beam.

In the literature, delamination of L-shaped composite beam was studied first by Martin [1] in the early 1990s. They studied experimentally and computationally the delamination problem of L-shaped uni-directional and cross-ply laminate under loading perpendicular to the arm (transverse tension loading (1), see Fig. 1). They showed that the delamination at the curved region is the main failure mechanism of the component. After almost 20 years, the problem was revisited by Wimmer et. al. [2]. They investigate both the initiation and propagation phases of delamination by static analyses for loading perpendicular to the arm. Both of these studies were carried out under one type of loading. In contrast to these investigations, Gözlüklü and Coker [3] carried out delamination simulations with loading parallel to the upper arm. They showed that highly dynamic crack growth occurs under shear dominated loading on the top arm and that a secondary crack initiates as the thickness of the laminate is increased.

This study aims to understand the basic physics and mechanics of delamination of L-shaped composite beams by studying delamination of L-shaped PMMA bonded plates. The effect of loading type and the effect of thickness is experimentally and computationally studied.

METHOD

Experimental Study

Full-field technique of photoelasticity is used in experiment in order to visualize isochromatic fringe pattern around the curved region of the L-shaped beam. The material is Macrolon Polycarbonate plate. Geometry of the specimens and the boundary and loading conditions used in experiments are shown in the Fig. 1a. Experiments are conducted under three types of loading; namely (1) transverse tension, (2) transverse compression, and (3) normal loads, applied at the end of the upper arm of the beam. In order to mimic the pre-crack Teflon tape is used in the curved region before bonding with an adhesive.

Computational Study

The finite element model (Fig1a) is a uniform mesh where the length of each cohesive element is 25 μm and a precrack is located at the mid-line. The model uses bi-linear 2-D plane strain elements with no contact definition and has 115,196 degrees of freedom. Loading is applied parallel to one of the arms quasi-statically, which is a loading type that is attainable in real applications and not covered in the literature in the past. This loading yields different traction fields and mode-mixities on the two sides of the crack.

The computational procedures are similar to those used to study delamination of L-shaped unidirectional laminated composites [3]. L-shaped beams are investigated using finite element analysis in conjunction with cohesive zone method. The cohesive law at the interface in the centre is a bi-linear traction displacement law. Finite element model of the L-shaped beam is shown in Fig. 1b with the finer mesh near the pre-crack.

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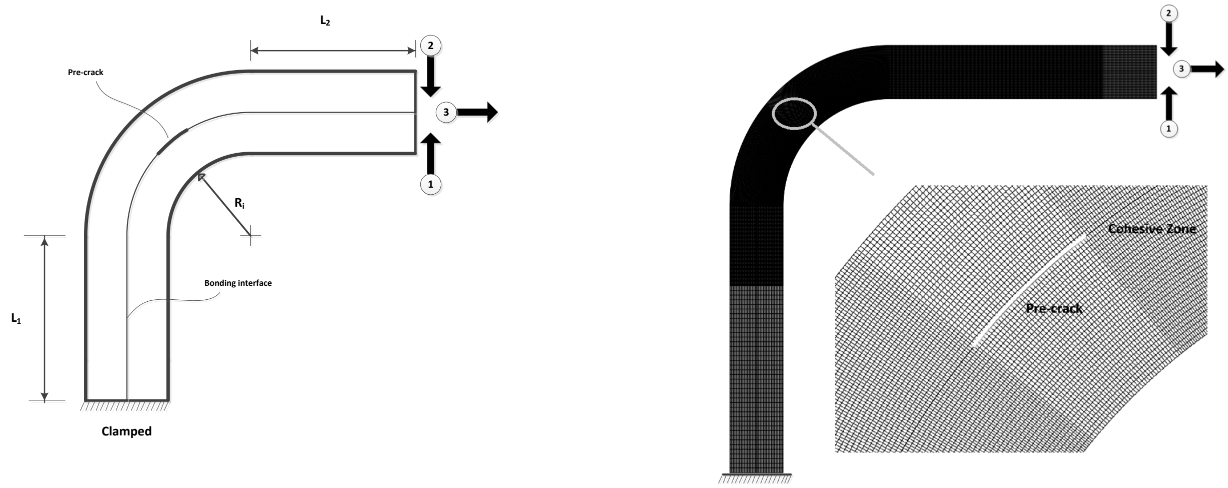
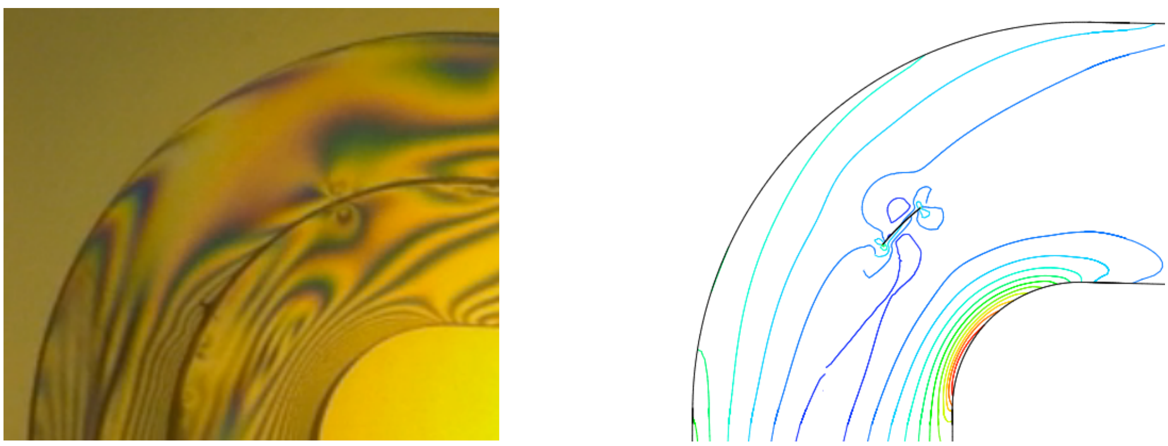


(a) (b)

Figure 1. (a) Geometry and loading conditions in this study, (b) finite element model of the L-shaped specimen.

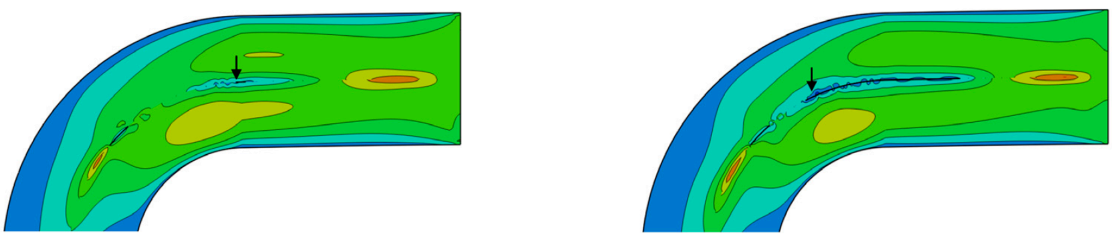
RESULTS

The photoelastic fringes obtained from compressive loading perpendicular to the arm is shown in figure 2a. The initial crack tip is propagating towards the right arm. The simulations using cohesive elements show the stress concentration near the precrack. The isochromatic fringe patterns are similar in both cases. The formation of a secondary crack for thicker composite specimens is shown in Figure 3. The effect of loading and thickness on the failure mode for PMMA L-beams is further discussed in the paper.



(a) (b)

Fig. 2 Isochromatic fringe patterns around the pre-crack at the bend (a) experimental, (b) computational.



(a) (b)

Fig. 3 Radial stress contours at (a) the nucleation of a secondary crack and (b) propagation of the secondary crack towards the center pre-crack.

References

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