A FINITE ELEMENT METHOD FOR EVALUATING DISBONDS AND THEIR IMPACT ON SINGLE LAP JOINTS

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Abstract

Adhesive technologies are widely employed in the aerospace and automobile industries due to its advantages over the conventional fasteners. However, the adhesive technologies come with its own shortcomings in bonding two materials together. One of the key challenges in using composites is the occurrence of disbonds. A disbond refers to the failure of an adhesive to fully cure or attach to the adherend surface, leading to a lack of stress transfer at the interface. Achieving a strong bond in such situations can be challenging because it's difficult to spread the adhesive evenly over the surface. In this study, a numerical framework is considered to evaluate the quantitative and qualitative effect of disbonds on the single lap joints. Finite element technique showed that there was a reduction in the strength of the lap joints as different discontinuities were applied at the joint area.

1. Introduction

The use of composites in the aerospace industry has been growing over the past decades, due to their high strength-to-weight ratio and excellent fatigue resistance. However, one of the key challenges in using composite is the occurrence of disbonds which can drastically reduce the durability and the strength of the composite structure. A disbond refers to the failure of an adhesive to fully cure or attach to the adherend surface, leading to a lack of stress transfer at the interface. This can lead to delamination, cracking, and other forms of damage that are not visible over time. To actually understand the mechanism of disbond, this paper describes the simulation of flaws in composite lap joints using finite element techniques.

2. Results

A finite element study was initially carried out on 3-ply unidirectional layups. A zero-strength discontinuity was introduced between the top and middle layups to understand the effect of the flaw on the composite. Visible strain distribution contour was compared for the different flaw insertion. The transverse strain distribution for a composite with no flaw interface is smooth compared to the composite with center and edge flaw.

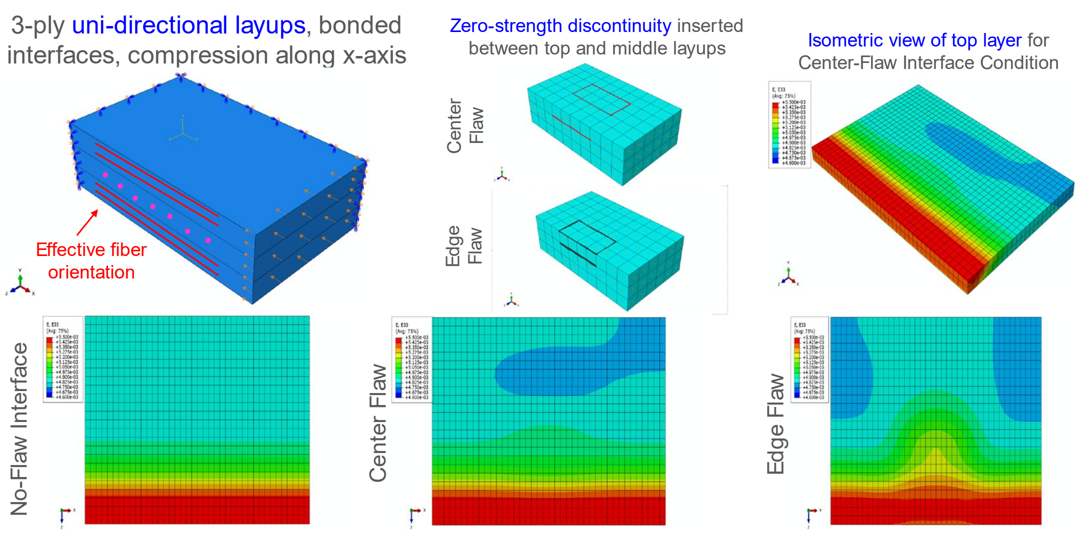


Fig: Flaw induced composite features

The edge flaw has the maximum disturbance, and this showed why the disbond between the edges can be devastating. Initial flaw study showed that any slight discontinuity within the layups can be observed from the surface using finite element analysis.
The study of flaw led to the preliminary study of mesh sensitivity within the 3D lap joint. A 3D geometry of the lap joint was generated using Abaqus CAE and different mesh refinement were considered to determine the stress concentration within the lap joint.

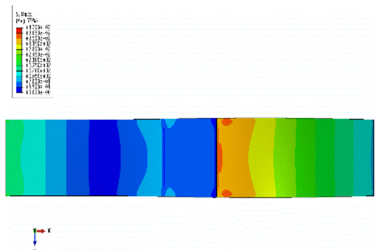


Fig: 62,118 elements

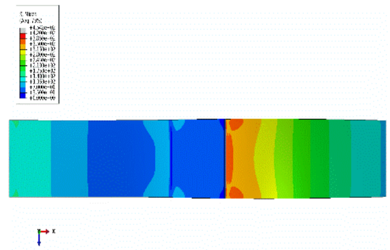


Fig: 110,000 elements

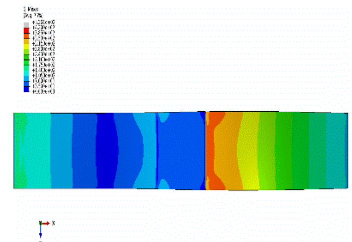
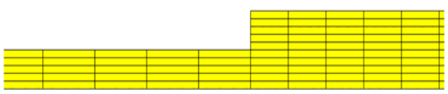
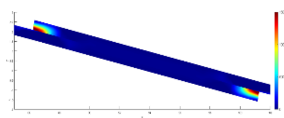


Fig: 1,280,000 elements

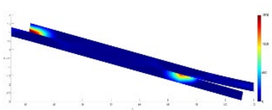
The stress concentrations within the edges of the overlap regions were analyzed. The changes within the Von Mises stress as the stresses were refined were less than 10%. With the preliminary studies done, a 2D MATLAB code was generated to automate the geometry of the lap joint, and was decoupled at the joint area to see the effect of the discontinuity on the overall strength of the lap joint.



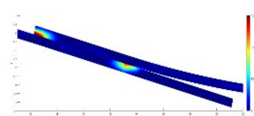
Mesh plot of overlap with zero thickness cohesive elements



Shear stress at the fully bonded adhesive



Shear stress at the middle and edge weak bond



Shear stress at the half length weak bond

The force displacement plot of these analyses showed that the flaw inserted has an impact on the overall stress transfer of the lap joint. The fully bonded joint produced a force of 4053 N, the joint with the edge and middle coupler produced 3922 N, while the bond with half the length decoupled produced 3792 N

3. Conclusions

The evaluation of disbonds is important for ensuring the integrity and durability of composite structures in the aerospace industry. The step-by-step methodology used in this study provides a sequential approach to understanding the inclusion of flaws and their effect on composite materials. This is a work in progress, and further research is needed to understand the effect of damage parameters on the affected composite panels, and the need to improve methods for detecting and preventing disbonds in composite structures.

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