Investigation of interlayer and intralayer delaminations

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Abstract

Experimental results are presented from an investigation into angle cracks emanating from delamination tips in crossply composite plates. The development and growth of the delamination-intralayer crack system is examined under axial compressive cyclic (fatigue) loading. A study of the results indicate different behavior for the intralayer crack formation depending on the composite material configuration and the position of the delamination through the thickness of the specimen.

Introduction

Goals

We have been studying how cracks develop in the advanced composite materials used in helicopter blades and in other machines. Such cracks may pose a threat to safety, increase the need for inspections, and shorten the working lifetimes of the machines. Our laboratory observations help check theoretical models of the ways that composite material deteriorate and break under service. Our studies lead to better design methodologies, better damage detection and serviceability of helicopter components and thus increase the safety of helicopters.

Definitions

A material is characterized as a composite material if it has two or more constituents. There are a lot of different kinds of composite materials. In this study we are interested in polymer fiber reinforced composites. These type of composites have a matrix (main body) made of epoxy and we reinforce this epoxy with long fibers of graphite (here) in order to increase the strength of the final product.

One way to manufacture polymer fiber reinforced composites is to obtain sheets (they are called plies) of fiber reinforced epoxy and stack them together in the desired orientation. This way you can manufacture $[0]_{24}$ specimens which are composed of 24 unidirectional 0^o plies, or $[0/90]_{24}$ specimens which are composed of 12 unidirectional 0^o and 12 unidirectional 90^o plies. Once you stack the plies together you put them in an autoclave where high pressure and temperature are applied and you cure them.

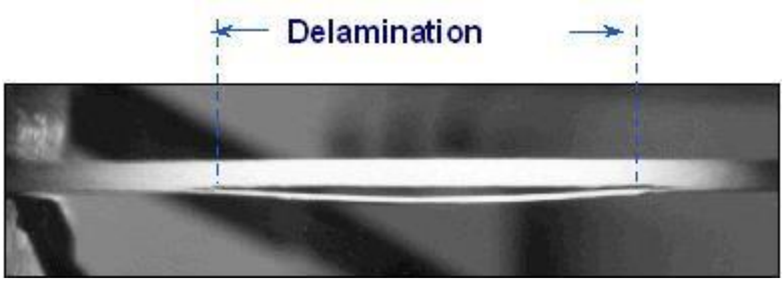
A delamination or interfacial crack is a crack that initiates and grows between the different plies of a composite material.

A primary delamination (PD), for the purposes of this work, is one created by embedding a Teflon insert. A primary delamination is illustrated in Figure 1, below.

An intralayer crack (IC) is a crack that is initiated at the tips of an embedded delamination and that grows through the neighboring 90^o ply.

A secondary delamination (SD) is a delamination that follows the development of an intralayer crack.

Figure 1. A primary delamination (PD) in a composite material



An interlayer delamination is a crack that grows in the interface of two plies without breaking the plies. That means that it always has the same direction (Figure 2).

An intralayer delamination is a crack that while it grows in the interface occasionally "jumps" to a neighboring interface. Then it breaks one, or more, of the plies and it also changes orientation (Figures 2 and 3).

Figure 2. Intralayer and Interlayer delaminations

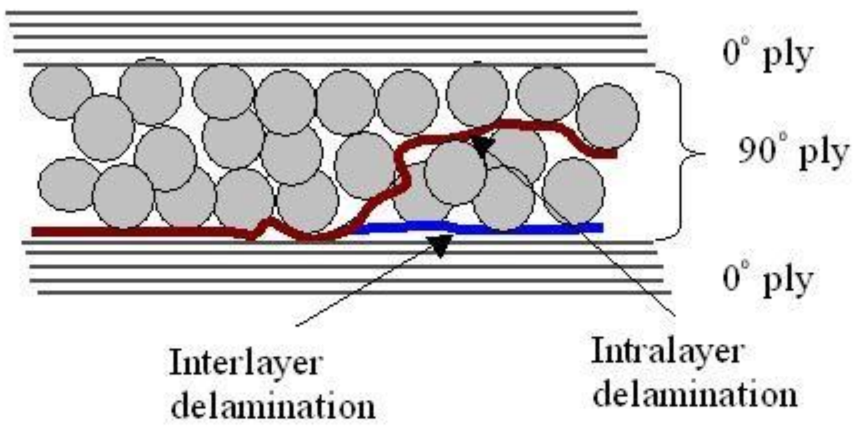


Figure 3. Intralayer delamination in a graphite/epoxy specimen

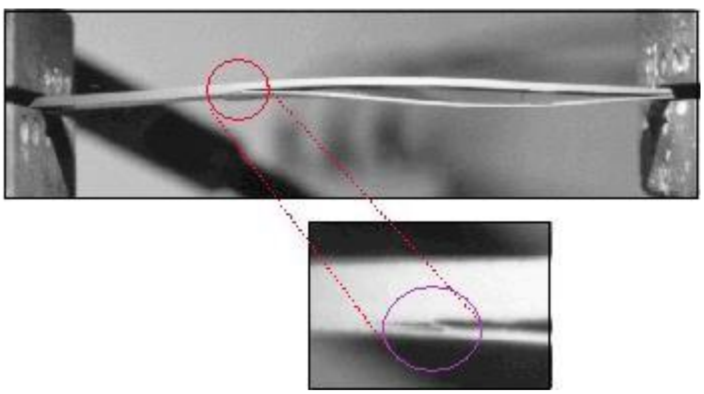


Figure 4. Results of axial compressive test for glass/epoxy sample S2/SP250, 4/29, specimen #2

Experimental methods

Experimental setup

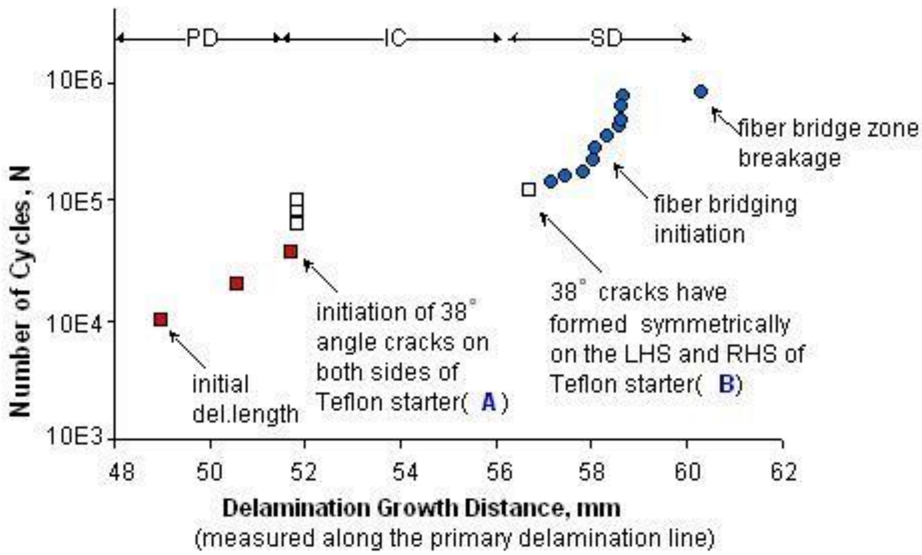
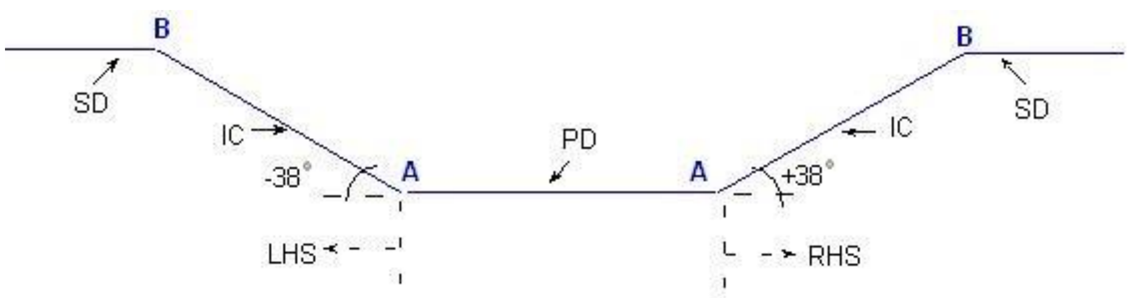
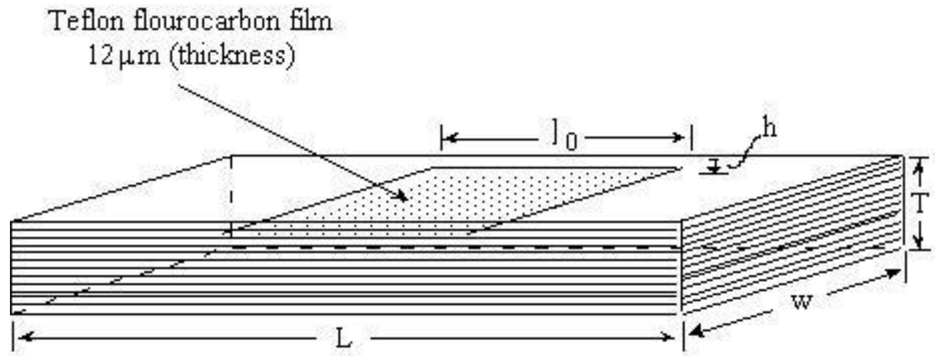


Figure 5. Evolution of intralayer delamination for Glass/Epoxy specimen 4/15 #3



The numbers 4/29 and 4/15 in the figures above are referring to the specific stacking sequence of these specimens. In order to help the delaminations to grow in the composite material, a predetermined delamination is fabricated into the specimen (Figure 6). As such, in 4/29 the first number indicates where we put the delamination (between the fourth and the fifth ply) while the second number indicates the total number of plies of the whole specimen (29 plies).

Figure 6. Fabrication of a laminated composite with predetermined delamination



Conclusions

Experimental results

Our experimental results indicate that the damage in helicopter blades can be detected very accurately using non-destructive techniques, i.e., ultrasound. Various modes of damage can exist, i.e. interlayer or intralayer delaminations.

The mechanical behavior and the life expectancy of a composite component depend in part on interlayer and intralayer delaminations.

Intralayer delaminations are more likely to grow catastrophically and lead to destruction of the component.

If delaminations are of the intralayer kind, it is more probable that they will get arrest and the component will be able to perform its function.

Future Goals

To advance the predictive methodology for composite materials in order to accurately assess the remaining life of composite components used in aviation and automotive industries.

To improvise ways of controlling the damage process. For example our studies show that if a delamination is of the intralayer kind eventually it will stop growing, i.e. it will be arrested. To this extent, we may find ways to deviate cracks from their original path, therefore turning them from interlayer to intralayer delaminations, in order to inhibit their growth.

Acknowledgment

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