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Technical Report

Acoustic Emission based on sentry function to monitor the initiation of delamination in composite materials

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ABSTRACT

Delamination is the most common failure mode in composite materials, since it will result in the reduction of stiffness and can grow throughout other layers. Delamination is consisted of two main stages including initiation and propagation. Understanding the behavior of the material in these zones is very important, hence it has been thoroughly studied by different methods such as numerical methods, Acoustic Emission (AE), and modeling. Between these two regions initiation is a more vital stage in the delamination of the material. Once initiation occurs, which normally requires greater amount of force, cracks can easily propagate through the structure with little force and cause the failure of the structure. A better knowledge of initiation can lead to better design and production of stronger materials. Additionally, more knowledge about crack initiation and its internal microevents would help improve other parameters and result in higher strength against crack initiation. AE is a suitable method for in situ monitoring of damage in composite materials. In this study, AE was applied to test different glass/epoxy specimens which were loaded under mode I delamination. A function that combines AE and mechanical information is employed to investigate the initiation of delamination. Scanning electron microscope (SEM) was used to verify the results of this function. It is shown that this method is an appropriate technique to monitor the behavior of the initiation of delamination.

1. Introduction

Composite materials are being utilized for applications to aircraft and automotive structures to meet strict weight and manufacturing cost restrictions. Composite structures have an extensive array of applications because of their high stiffness and strength with respect to their weight. In addition, composite materials have high corrosion resistance and thermal resistivity and are considered as nonconductive materials.

Long fiber reinforced composite laminates are an intricate composition at the meso-scale. The fibers implanted in the matrix form the lamina and the overlapping of these laminas makes the composite laminate. Complex mechanical performance and diversity in failure mechanisms that determine damage progression is the result of such a complicated design while in service. In these materials, failure can be detected in many forms such as (i) breaking of fibers (ii) microcracking of matrix (iii) separation of fibers from matrix (called debonding) (iv) separation of lamina from each other in laminated composites (called delamination). Amongst these failure modes, due to the inbuilt layered structure of laminated composites, delamination constitutes a fundamental weakness of the material. When subjected to complex three dimensional loads, delamination may cause severe reduction of in-plane modulus and strength which can lead to catastrophic failure of the entire structure. It has been found that delamination may be introduced due to external loading, whether in static tension or bending, in cyclic loading causing fatigue, in impact loading or during manufacturing. An eccentricity in the structural load paths is also a contributing factor to the initiation of delamination. Potential delamination sites are locations with discontinuities in the load path. These may include: (I) straight or curved free edges; (II) ply terminations or ply drop; (III) bonded or co-cured joints; (IV) bolted joints; (V) specimens under cracked lap shear. These discontinuities give rise to interlaminar stresses even under in-plane loading. The mismatch of the Poisson's ratios and cross coupling coefficients of the adjacent lamina is primarily responsible for giving rise to the interlaminar stresses.

Laminates are extremely susceptible to crack initiation and growth preferentially along the laminar interfaces (i.e. interface between two adjacent laminas) since there are no fibers in the transverse direction to carry the load in the out-of-plane direction and to stop the crack propagation along the interlaminar surface. Delamination is the most prevalent life-limiting crack growth mode in laminated composites, consequently it is vital to study and understand this type of failure.

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