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Investigation of Initiation and Evolution of Delamination in Glass/ Epoxy Laminated Composites Using Acoustic Emission Method

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ABSTRACT

In order to access the reliable structures, detection of the damages initiation and evolution in materials is necessary. Delamination is the most common failure mode in laminated composites. The present study is concerned with an investigation of initiation and propagation behavior of delamination using Acoustic Emission (AE) method. In this work, various lay-ups of glass/epoxy composite laminates have been fabricated and subjected to mode I quasi-static loading condition. The behavior of delamination is investigated in two sections. In the first section, the main focus is on the initiation of damage. In this section, initiation of various damage mechanisms are determined using AE method. In the second section, evolution of delamination is investigated using AE. In order to determine the instantaneous crack tip position during the propagation of delamination, at first, AE wave velocity in the specimens is specified. Then, using the proposed method, unwanted signals are eliminated. The obtained results indicate that AE method has a good performance to detect initiation stage of interlaminar damage and to determine the delamination propagation in the laminated composite structures.

KEYWORDS:

Delamination, Acoustic Emission, Mode I Loading Condition.

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1- Introduction

Fiber reinforced plastics composites (FRPC) have many advantages such as high specific strength, specific stiffness, etc. In contrary, these materials suffer from different damage mechanisms [1-2]. Delamination is one of the most common modes of failure in laminated composites [3]. Delamination may occur mainly in mode I, mode II, or the combination of these pure modes, resulting in a dramatic loss of the residual strength and the stiffness of the structures [4]. Benzeggagh and kenane [5], investigated delamination in glass/epoxy specimens under mode I, mode II and mixed mode I&II loading condition. Refahi and Ahmadi [6], utilized the AE method to determine interlaminar fracture toughness of polyester/glass composites under mode I loading condition.

In this work, various lay-ups of glass/epoxy composite laminates have been fabricated and subjected to mode I quasi-static loading condition. The behavior of delamination is investigated in two sections. In the first section, the focus is on the initiation of damage. In this section, initiation of various damage mechanisms are determined using AE method. In the second section, evolution of delamination is investigated using AE. In order to determine the instantaneous crack tip position during the propagation of delamination, at first, AE wave velocity in the specimens is specified. Then, using the proposed method, unwanted signals are eliminated. The obtained results indicate that AE method has a good performance to detect initiation stage of interlaminar damage and to determine the delamination propagation in the laminated composite structures.

2- Methodology

The specimens were fabricated from 14 layers of glass/epoxy. The hand lay-up procedure was used to produce the specimens. In this work, specimens were loaded under mode I loading condition according to the procedures represented in ASTM D5528 [7]. A properly calibrated tensile test machine (HIWA) in the range from 0.5 to 500 mm/min was used in a displacement control mode. AE events were recorded using AE software AE-Win and a data acquisition system Physical Acoustics Corporation (PAC) PCI-2 with a maximum sampling rate of 40 MHz.

3- Results

In order to determine sequencing of different damage mechanisms, first, the characteristic of each distinct damage modes must be determined. Therefore, pure damage tests (matrix cracking and fiber breakage) were carried out to discriminate the mentioned damages. The dominant frequency ranges of damages are 125-250 kHz, 250-350 kHz and 350-450 kHz for matrix cracking, fiber/matrix debonding and fiber breakage, respectively. Figure 1 shows AE frequency spectrum of the specimens. As can be seen, matrix cracking, fiber/matrix cracking and fiber breakage damages were occurred in the specimens. By investigating the AE frequency spectrum of the AE signals at the various time of the tests, it is deduced that the first damage mechanism, which is active is matrix cracking. Consequently fiber/matrix debonding and fiber breakage occurred. Figure 2 shows SEM images of damage surfaces of the specimens.

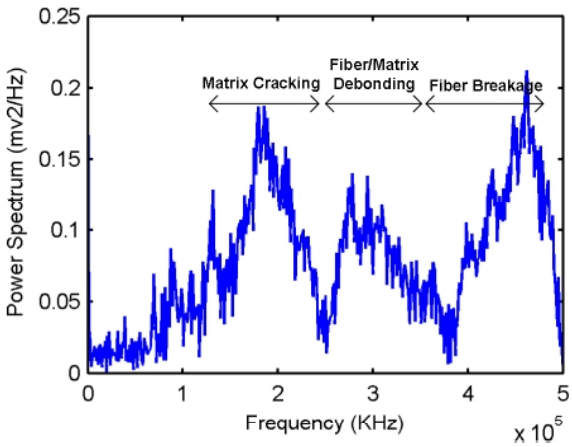

Figure 1. AE frequency spectrum of the specimens

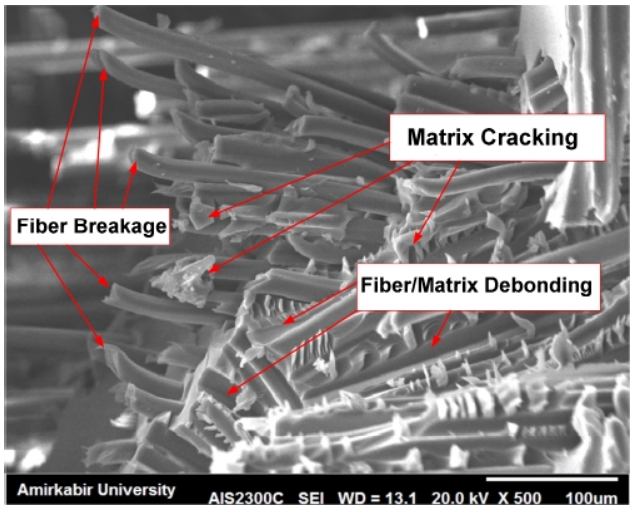

Figure 2. SEM images of damage surfaces of the specimens

In order to determine the instantaneous crack tip position during the propagation of delamination, at first, AE wave velocity in the specimens is specified. Then using the proposed method, unwanted signals are eliminated. Figure 3 shows the predicted crack tip position in the woven specimen using AE method versus the visual inspection data. As can be seen, there is good agreement between AE prediction and visual inspection for determination of crack tip position.

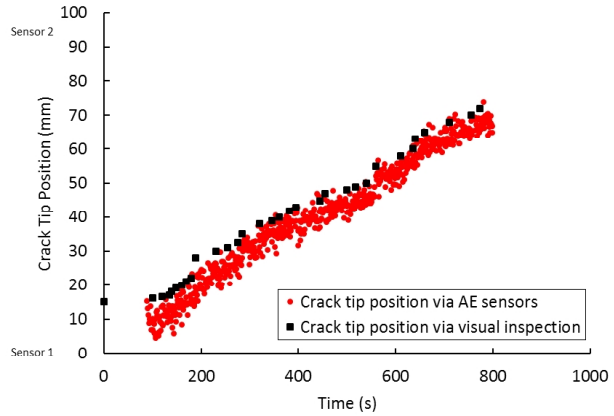

Figure 3. The predicted crack tip position using AE method versus visual inspection data

4- Conclusions

In this paper, delamination initiation and propagation in epoxy/glass composites, under mode I loading condition were investigated using AE method. The behavior of damages is investigated in two sections. In the first section, the focus is on the initiation of damages. In this section, sequencing of different damages was determined. It is seen that the first damage mechanism, which is active, is matrix cracking. Consequently fiber/matrix debonding and fiber breakage occurred. In second section, propagation of delamination in the specimens was investigated. In this section, in order to determine the instantaneous crack tip position during the propagation of delamination, at first, AE wave velocity in the specimens was specified. Then using the proposed method, unwanted signals are eliminated. The obtained results indicate that AE method has a good performance to detect initiation stage of interlaminar damage and to determine the delamination propagation in the laminated composite structures.

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