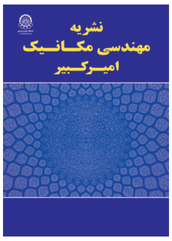

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Acoustic Emission Based Methodology to Evaluate the Fracture Toughness in Carbon/Epoxy Composites

R. Mohammadi[1*] , M. Saeedifar[1], M. Ahmadi Najafabadi[1], H. Hosseini Toudeshky[2]

[1] Department of Mechanical Engineering, Amirkabir University of Technology, Tehran, Iran
[2] Department of Aerospace Engineering, Amirkabir University of Technology, Tehran, Iran

ABSTRACT: Fiber-reinforced polymer (FRP) composites are an important category of advanced engineering materials. These materials are widely used in the industry due to their unique characteristics such as high specific strength and stiffness. In FRP composite materials, there are several failure mechanisms such as matrix cracking, fiber breakage, fiber/matrix debonding and delamination. Delamination is the most striking one. In this paper, mechanical and acoustic emission (AE) behaviors of delamination are investigated under the actual operation loading modes (i.e. mode I, mode II and the combination of these pure modes). The composite laminates have been fabricated with 14 layers of woven carbon/epoxy prepregs. DCB, ENF and MMB specimens were prepared according to ASTM D5528 and D6671 standards and subjected to the different loading modes. First, inter-laminar fracture toughness of the specimens is calculated using the represented methods in ASTM D5528 and ASTM D6671 standards. Then, fracture toughness of the specimens is determined using the AE-based methods. The results indicate that, the AE-based methods have good applicability to determine the fracture toughness of the composite materials.

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1- Introduction

Carbon fiber reinforced plastics (CFRP) have many advantages such as high specific strength, specific stiffness, etc [1]. In contrary, these materials suffer from different failure mechanisms [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].
Some of literature have been published on investigation of mode I delamination using acoustic emission (AE) monitoring [5]. Refahi et al. [6], studied delamination in glass/polyester composites under mode I loading condition using AE. They determined the initiation of delamination and ranges of the AE parameters of the damage mechanisms that occur during delamination propagation.
In this work, the aim is to enhance some applicable and sensitive AE-based methods for prediction of the delamination initiation and determination of interlaminar fracture toughness in the actual loading conditions (mode I, mode II, and mixed mode I&II). To this aim, first, inter-laminar fracture toughness of the specimens is calculated using the represented methods in ASTM D5528 [6] and ASTM D6671 [7] standards. Then, fracture toughness of the specimens is determined using the AE-based methods. The results indicate that, the AE-based methods have good applicability to determine the fracture toughness of the composite materials.

2- Methodology

The samples were fabricated from 14 layers of woven carbon/epoxy prepregs. In this work, the double cantilever beam (DCB), Mixed-mode bending (MMB) and end notched flexure (ENF) specimens were loaded according to the procedures represented in ASTM D5528 and ASTM D6671. A properly calibrated tensile test machine (HIWA) in the range from 0.5 to 500 mm/min was used in a displacement control mode. All the specimens were loaded with constant 1 mm/min crosshead rate. AE signals 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.

Corresponding author, E-mail: rezam69@aut.ac.ir

3- Results

Figure 1 illustrates load–displacement curves of the specimens. For evaluation of GC, first, critical load (PC) must be determined. For determination of PC, the following procedures are presented in ASTM D5528 and ASTM D6671 standards: (a) Nonlinearity in the load-displacement diagram (NL), (b) Visual Inspection (VIS), and (c) 5% increasing of compliance (5%/max). Figure 2 shows the values of PC which are obtained from the above methods for ENF specimen.

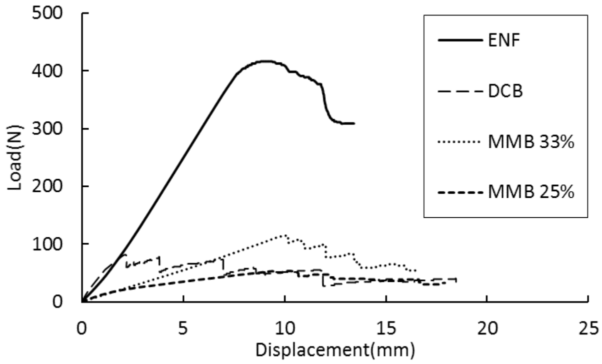

Figure 1. Load – displacement curves of the spcimens

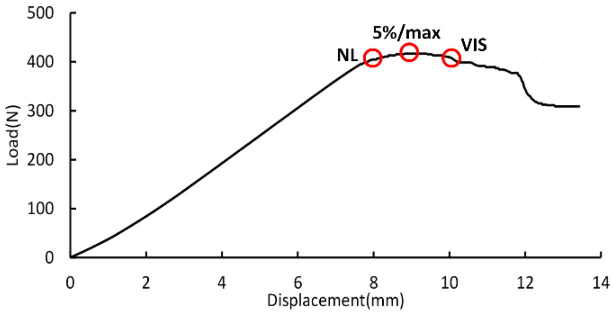

Figure 2. Determination of PC according to the ASTM standard methods

In order to determine the critical load using AE method, four different AE features were utilized: AE energy, cumulative AE energy, AE count, and cumulative AE count. In these procedures, first significant increasing in the AE feature corresponding to the critical load. Figure 3 shows determination of critical load using AE count method.

4- Conclusions

In this paper, in order to calculate interlaminar fracture toughness of carbon/epoxy composite specimens, the critical load was determined using mechanical and AE methods. Table 1 shows the values of interlaminar fracture toughness obtained from the proposed methods. The results indicate that the AE-based methods have good applicability to determine the interlaminar fracture toughness of the composite materials.

Table 1. The values of interlaminar fracture toughness obtained from the proposed methods

Method \ Sample	DCB	MMB 25%	MMB 33%	ENF
NL	0.114	0.030	0.341	0.413
5%/max	0.238	0.289	0.348	0.454
VIS	0.140	0.263	0.312	0.426
AE Energy	0.190	0.183	0.330	0.410
AE Cum Energy	0.200	0.190	0.342	0.425
AE Count	0.230	0.282	0.343	0.450
AE Cum Count	0.230	0.288	0.345	0.450

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