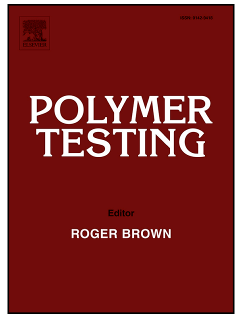
Accepted Manuscript



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PII: S0142-9418(17)30634-7

DOI: 10.1016/j.polymertesting.2017.08.001

Reference: POTE 5112

To appear in: *Polymer Testing*

Received Date: 13 May 2017

Revised Date: 25 July 2017

Accepted Date: 1 August 2017

Please cite this article as: C. Yilmaz, M. Yildiz, A study on correlating reduction in Poisson's ratio with transverse crack and delamination through acoustic emission signals, *Polymer Testing* (2017), doi: 10.1016/j.polymertesting.2017.08.001.

A Study on Correlating Reduction in Poisson's Ratio with Transverse Crack and Delamination Through Acoustic Emission Signals

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Abstract

During the uniaxial loading of fiber reinforced polymer (FRP) composites, Poisson's ratio (nxy), which is a constant elastic property for isotropic materials, decreases significantly. Micro-damage created within FRP composites as a result of an applied stress causes this decrease. As the level of micro-damage increases, a greater level of reduction in Poisson's ratio occurs. FRP composites, in general, `show three main micro-damage types under uniaxial tensile loading, namely, transverse crack, delamination and fiber rupture. To determine micro-damage types which dominantly affects the relevant reduction in Poisson's ratio, glass fiber reinforced cross-ply laminates with three different off-axis ply content are produced and then tested under a uniaxial tensile loading. The Acoustic Emission (AE) signals are concurrently recorded and grouped into three clusters in accordance with their frequency, which is either associated with transverse crack, delamination or fiber rupture. The frequency based clustering of AE signal facilitates detailed investigation of delamination onset and effect of different micro-damage types on Poisson's ratio. It is proven that stacking sequences with a higher number of transverse cracks and delaminations, quantified based on AE signals, show a greater reduction in Poisson's ratio.

Key words: Composite materials; Micro-damage formation; Poisson's ratio; Acoustic emission;

1. Introduction

FRP composites show a significant decrease in their elastic properties (axial elastic modulus $E_{xx} = \sigma_{xx} / \varepsilon_{xx}$ and Poisson's ratio, $\nu_{xy} = -\varepsilon_{yy}/\varepsilon_{xx}$, among others) when subjected to an axial strain until the fracture [1, 2]. Therefore, axial elastic modulus and Poisson's ratio which are measurable quantities using conventional sensor systems, lend themselves to monitoring the micro-damage state of composite materials. The reduction in these quantities is known to be associated with the accumulation of micro-damage created such as transverse crack, delamination and fiber rupture during the tensile loading of composite samples since these micro-damage types could significantly alter the elastic properties of the composite samples. In comparison to the elastic modulus, Poisson's ratio of composite materials reveals a greater level of reduction under uniaxial loading conditions [3]. This is related to the fact that during uniaxial loading, Poisson's ratio remains as a function of two-dimensional strain field which makes Poisson's ratio more sensitive to the accumulation of micro-damage within FRP composites in comparison with unidirectional elastic modulus which is only dependent on one dimensional strain field.

In this study, we endeavor to answer two questions by using the principle of Acoustic Emission (AE). First, which micro-damage type(s) are more dominant in the reduction of Poisson's ratio. Second, how a stacking sequence affects the delamination onset. The effects of thickness of laminate and thickness to width ratio on delamination onset, have been investigated in a series of papers for angle-ply laminates [4-6]. To the extent of our knowledge, there are not many studies on delamination onset in cross-ply laminates. AE has been used as a reliable method to determine micro-damage types in FRP composites [7-9]. The micro-damage formation inside the composite materials causes initiation and propagation of transient elastic waves, which have been used to characterize the type and level of micro-damage in composite materials by using the features of transient elastic wave. The analysis of AE signals reveals broad range of information about micro and macro damage behavior of FRP composites as well as the damage types. In literature, several studies have been conducted to classify the micro-damage types and micro-damage initiation and progress for FRP composites using the AE method. For example, for glass fiber reinforced materials, crack propagation [10], and micro-damage mechanism [11] process have been investigated through analyzing AE signals. The initiation and propagation of transverse crack for carbon fiber reinforced polymer have been investigated by