36th Conference and 30th Symposium of ICAF, Poland, Krakow 2-7 June 2019

Novel Methods for Measuring the Mode I and Mixed Modes I/II Interlaminar Fracture Toughnesses of Composite

W. XU [1*], Z.Z. Guo [1], Y. Yu[1], X.J. Zhang[1], X. Wang[2]

[1] School of Aeronautics and Astronautics, Shanghai Jiao Tong University, Shanghai 200240, China
[2]Structure and Strength Division, Shanghai Aircraft Airworthiness Certification Center of CAAC Shanghai, China
*Assistant Professor, corresponding Author: xuwu@sjtu.edu.cn

Abstract:

Delamination is one of the most serious failure modes in laminated composite materials and structures. Interlaminar fracture toughness is used to characterize the delamination resistance of composite materials. The ASTM test standard D5528 is frequently used to measure the modes I interlaminar fracture toughness for unidirectional fiber reinforced composites. When this standard is applied to measure the interlaminar fracture toughness, the applied load and its associated displacement and crack length are required. However, it is tedious to measure the growing crack length and to record the corresponding load and displacement simultaneously, especially for unstable crack growth and test in temperature chamber, where the crack growth length is difficult to be measured. For the mixed modes I/II interlanimar fracture, The ASTM D6671 is widely used to measure the mixed modes I/II interlaminar fracture toughness. One of the shortcoming of the current ASTM D6671 is the requirement of measuring the material Young's moduli from separate tensile tests and samples, which is time-consuming and source of uncertainty. From the material testing and characterization point of view, it is highly desirable to have a testing procedure which is easy to prepare, conduct and yields consistent result.

The present authors devised two novel methods to measure the mode I and mixed modes I/II fracture toughnesses for composite materials. For the mode I interlaminar fracture, only the load and displacement recorded from the test machine are required for the determination of the fracture toughness. It is not necessary to measure the growing crack length and other parameters as sacrifice. This method was demonstrated to be simple and accurate for unidirectional carbon fiber/epoxy composite. Its theoretical foundation will be briefly given in this paper. It is then used for two special cases, where the crack growth length is difficult to get access. One is a DCB test in a cold temperature environment. The other is a DCB test for a 2D plain weave woven textile composite. There are several finite crack growths and associated load drops in the load displacement curve in the DCB test for woven textile composites, which increase the difficulty in measuring the crack growth length, displacement and load simultaneously. Using this method, the finite crack length

and fracture toughness can be obtained from the load-displacement relation. In addition, a simple method is proposed to overcome the shortcoming of the current ASTM D6671 by using the mixed modes bending (MMB) specimen. It avoids the measurement of the Young's moduli from separate tensile tests. The average relative difference between the mixed modes fracture toughness measured from the present method and that from the ASTM D6671 with additional tensile tests to measure the Young's moduli is within 5%, thus the present paper provides a consistent and simple method for measuring the mixed modes I/II interlaminar fracture toughness. Figure 1 shows the mixed modes fracture toughness obtained from the present method. The present methods are simple and accurate, therefore significantly simplifying the procedure for measuring the mixed modes interlaminar fracture toughness.

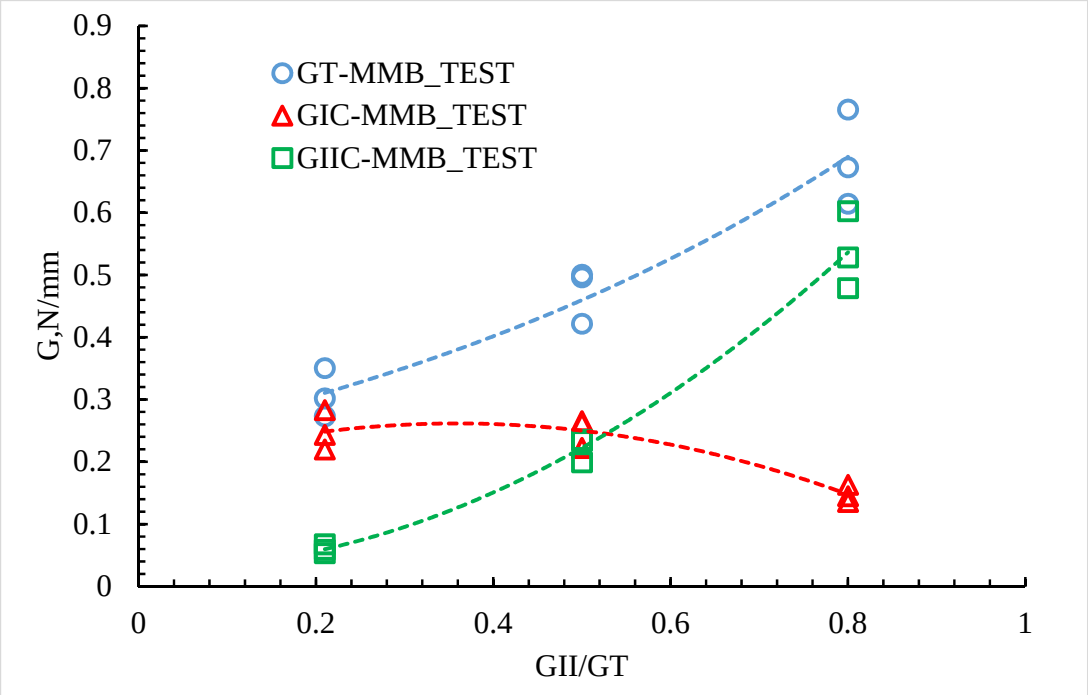

Fig.1 The mode I (G_{IC}) , mode II (G_{IIC}) fracture toughnesses measured by using the present method

Keywords:

Delamination; interlaminar fracture toughness; mode I; mixed modes; energy release rate

Main References:

(1) **W Xu**, ZZ Guo, Y Yu, J Xiong, Y Gao. Experimental and analytical characterizations of finite interlaminar crack growth of 2D woven textile composites. *Composite Structures* 2018; 206: 713–721.
(2) **W Xu**, ZZ Guo. A simple method for determining the mode I interlaminar fracture toughness of composites without measuring the growing crack length. *Engineering Fracture Mechanics* 2018; 191: 476-485.