Accepted Manuscript


# Fibrous composite matrix characterisation using nanoindentation: The effect of fibre constraint and the evolution from bulk to in-situ matrix properties

M. Hardiman, T.J. Vaughan, C.T. McCarthy


PII: S1359-835X(14)00296-6
DOI: http://dx.doi.org/10.1016/j.compositesa.2014.09.022
Reference: JCOMA 3731

To appear in: *Composites: Part A*

Received Date: 26 February 2014
Revised Date: 5 September 2014
Accepted Date: 29 September 2014


Please cite this article as: Hardiman, M., Vaughan, T.J., McCarthy, C.T., Fibrous composite matrix characterisation using nanoindentation: The effect of fibre constraint and the evolution from bulk to in-situ matrix properties, *Composites: Part A* (2014), doi: http://dx.doi.org/10.1016/j.compositesa.2014.09.022

# Fibrous composite matrix characterisation using nanoindentation: The effect of fibre constraint and the evolution from bulk to in-situ matrix properties

M. Hardiman[a], T. J. Vaughan[b], C. T. McCarthy[a,*]

[a] *The Irish Centre for Composites Research (IComp), Materials and Surface Science Institute (MSSI), Department of Mechanical, Aeronautical and Biomedical Engineering, University of Limerick, Limerick, Ireland*
[b] *Biomechanics Research Centre (BMEC), Biomedical Engineering, National University of Ireland, Galway, Ireland*

**Abstract**

The variation of the in-situ matrix properties of a carbon-fibre composite has been investigated using nanoindentation. The aerospace carbon-fibre composite material (HTA/6376) and the bulk matrix (6376) have been co-cured to produce specimens ideal for matrix characterisation. The in-situ matrix has been characterised using fifty indentations in matrix pockets of many different sizes. The fibre constraint effect on in-situ matrix indentations has been characterised experimentally using the continuous stiffness measurement (CSM) technique, showing good correlation with finite element results from a previous study. The co-cured specimens allow the evolution of property change in the matrix material to be observed. The in-situ matrix modulus increases with decreasing matrix pocket size, and is up to 19% greater than the bulk matrix. This property change occurs outside the normal range of the interphase region for CFRP materials, and is statistically significant relative to the experimental scatter associated with the nanoindentation technique.

*Keywords:* A. Polymer-matrix composites (PMCs); A. Prepreg; C. Micro-mechanics; D. Non-destructive testing.

## 1. Introduction

In order to predict microscopic damage accumulation and its effect on the macroscopic structure, multiscale modelling approaches have emerged that enable detailed predictions of local deformation mechanisms in fibrous composite materials. Such studies have shown that the load-bearing capacity and failure behaviour of fibrous composite materials are governed by the local microstructure and in-situ constituent material properties [1–4]. While such models have provided insight into the role of the material microstructure on physical properties at higher length scales, the vast majority have assumed that the behaviour of individual constituents are equivalent to those in bulk form. However, the high-temperature curing process associated with composite manufacture leads to intensive thermal, mechanical and chemical processes taking place during the consolidation of the constituent phases. In

*Corresponding author. Tel.:+353 (0)61234334; Fax: +353 (0)61201944
*Email address:* conor.mccarthy@ul.ie (C. T. McCarthy)