Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/jmbbm

Research paper

Fracture characterization of bone under mode II loading using the end loaded split test

F.A.M. Pereira[a], J.J.L. Morais[a], N. Dourado[a], M.F.S.F. de Moura[b,*], M.I.R. Dias[c]

[a] CITAB/UTAD, Departamento de Engenharias, Quinta de Prados, 5001-801 Vila Real, Portugal
[b] Faculdade de Engenharia da Universidade do Porto, Departamento de Engenharia Mecânica, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[c] UTAD, Departamento de Ciências Veterinárias, Quinta de Prados, 5001-801 Vila Real, Portugal

ARTICLE INFO

Article history:
Received 25 February 2011
Received in revised form
17 May 2011
Accepted 28 May 2011
Published online 6 June 2011

Keywords:
Bone
Fracture characterization
Mode II
End loaded split test

ABSTRACT

Fracture energy release rate under mode II loading of bovine cortical bone is determined using a miniaturized testing device of the end loaded split test. The energy release rate is evaluated by means of a data reduction scheme based on specimen compliance, beam theory and crack equivalent concept. Experimental tests were carried out to evaluate the *Resistance* curve which provides a successful method to characterize fracture behavior of quasi-brittle materials like bone. A numerical analysis including a cohesive damage model was used to validate the procedure. It was demonstrated that the end loaded split test and proposed data reduction scheme provide a valuable solution for mode II fracture characterization of bone.

1. Introduction

The study of bone fracture is an important research topic since it can contribute to understanding the fundamentals of bone failure induced by disease, age, drugs and exercise. In fact, fracture mechanics measurements can be viewed as a valuable method to characterize the toughness of bone, providing a quantitative determination of its fracture resistance. In this context, the definition of appropriate testing methods to evaluate fracture properties of bone is fundamental. However, classical fracture tests used for other materials require special adaptations owing to bone characteristics. Effectively, bone can be viewed as a natural composite material mainly constituted by an inorganic (mineral) phase (hydroxyapatite), collagen fibers and water, organized in a highly anisotropic and heterogeneous microstructure. The mineral phase is essentially responsible for stiffness and strength while the organic phase (collagen) and water play an essential role on toughness (Hernandez et al., 2001; Wang et al., 2002; Morais et al., 2010). As a consequence of its microstructure and of interaction between its constituents, fracture of bone reveals some toughening mechanisms in the vicinity of the crack tip, like micro-cracking, crack deflection and fiber bridging (Zioupos, 1998; Nalla et al., 2003). These mechanisms are responsible for the development of a non-negligible fracture process zone (FPZ), which means that linear elastic fracture mechanics (LEFM) theory does not apply. In this case, the best method

* *Corresponding author.* Tel.: +351 225 081 727; fax: +351 225 081 584.
E-mail address: mfmoura@fe.up.pt (M.F.S.F. de Moura).

1751-6161/$ - see front matter
doi:10.1016/j.jmbbm.2011.05.033