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Engineering Fracture Mechanics 75 (2008) 3852–3865
Engineering Fracture Mechanics
www.elsevier.com/locate/engfracmech

A new data reduction scheme for mode I wood fracture characterization using the double cantilever beam test

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Received 21 September 2007; received in revised form 6 February 2008; accepted 25 February 2008
Available online 4 March 2008

Abstract

This paper describes experimental and numerical studies on double cantilever beam test applied to fracture characterization of wood in mode I. A new data reduction scheme based on the beam theory and specimen compliance is proposed in order to overcome the difficulties inherent to crack monitoring during propagation. A cohesive damage model adapted to wood is used to simulate the test. The cohesive properties are evaluated using an inverse method based on a developed Genetic Algorithm through an optimisation strategy. The results demonstrate the effectiveness of the proposed methodology as a suitable data reduction scheme for the double cantilever beam test.

Keywords: Mode I; Double cantilever beam test; Fracture toughness; Wood; Cohesive model

1. Introduction

Wood is the most abundant and widely used material in the world. Nowadays, interest in renewable resources is increasing worldwide because of concern about depleting resources and energy shortages. Wood is a renewable construction material and it is energy efficient in production, processing and use. These advantages increase the interest in developing reliable and practical quantitative means for predicting the fracture behaviour of wood structures. Wood has three orthogonal directions of material symmetry: L (the longitudinal direction of tracheid cells), R (the radial direction of parenchyma cells) and T (the tangential direction to the annual rings). Hence, eight sets of crack propagation systems can be defined, each one identified by a pair of letters, the first indicating the normal to the crack plane and the second indicating the direction of crack propagation. The most frequent crack propagation systems are the RL and TL. In this work the RL system was studied. It is recognized that Fracture Mechanics provides better mechanical rupture description when compared to classical strength of material approaches. Consequently, it is fundamental to provide accurate

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0013-7944/$ - see front matter
doi:10.1016/j.engfracmech.2008.02.006

Nomenclature

a	crack length
a_e	equivalent crack length
a_0	initial crack length
B	specimen width
$\mathbf{b}$	vector of design variables
$\underline{\mathbf{b}}$	lower bound of design variables
$\overline{\mathbf{b}}$	upper bound of design variables
$\mathbf{D}$	matrix of stiffness parameters
c	beam half-thickness
C	specimen compliance
C_0	initial specimen compliance
d_n	normal stiffness at the interface
d_s	shear stiffness at the interface
D_z	domain of the state variables
$\mathbf{E}$	matrix of damage parameter
E_f	corrected flexural modulus
E_T	modulus of elasticity of wood along the tangential direction
E_L	modulus of elasticity of wood along the longitudinal direction
f_b	strength at the onset of bridging
F_{max}	arbitrary constant
f_t	local strength in the loading direction
g_j ($\mathbf{b}$)	vector of the restrictions associated to the IP
G_{fb}	fracture energy due to fibre-bridging
$G_{f\mu}$	fracture energy due to micro-cracking
G_{Ic}	fracture toughness in mode I
G_{LR}	shear modulus of wood (system LR)
h	specimen mid-height
$\mathbf{I}$	identity matrix
j	specimen label
k	total number of design variables
L	wood longitudinal direction
L	specimen length
m_i	number of bits of design variable i
n	subscript used to refer to mode I loading
M_f	bending moment
N	number of points of the P–δ curve
N_g	number of constraints of the IP
p	precision required to determine $y(\mathbf{b})$
P	load acting on the specimen
$P(t)$	population in generation t
p_c	probability of Crossover
p_m	probability of Mutation
$Pop(t)$	number of solutions in generation t
r_s	gene of the offspring generated by the *Crossover* operator
R	wood Radial direction
t	generation label
T	wood Tangential direction
$\mathbf{v}_i$	chromosome label