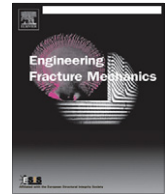




ELSEVIER

Contents lists available at SciVerse ScienceDirect

Engineering Fracture Mechanics

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

Characterization of timber fracture using the Digital Image Correlation technique and Finite Element Method

F. Dubois*, M. Méité, O. Pop, J. Absi

University of Limoges, Heterogeneous Materials Research Group, Department of Civil Engineering and Durability, Boulevard Jacques Dérche, 19300 Egletons, France

ARTICLE INFO

Article history:

Received 26 May 2011

Received in revised form 5 April 2012

Accepted 7 July 2012

Keywords:

Digital Image Correlation

Finite Element analysis

Coupling

Stress intensity factors

Crack relative displacement factors

Asymptotic fields

Orthotropic materials

Energy release rate

ABSTRACT

This paper focuses on a hybrid experimental and numerical approach to characterize both the energy and mechanical state in the vicinity of the crack tip within an orthotropic wood material. Optimization of the displacement field obtained by Digital Image Correlation techniques, enables determining the kinematic state of crack lips through the crack relative displacement factor. In parallel, a Finite Element discretization is performed to allow calculating stress intensity factors. A coupling between these two approaches is presented for the purpose of defining the energy release rate. The algorithm derived is then illustrated through an experimental test based on an opening mode configuration for a Douglas specimen.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

In assessing the durability of timber structures, a study of crack process provides critical information on the design optimization for beams or joints. At the material scale, scientific approaches are based on experimental tests in order to measure the tenacity, through critical energy release rate values. In conjunction with this step, Finite Element (FE) models have been developed for the purpose of calculating stress intensity factors, or energy release rate, by assuming knowledge of both the material properties and mechanical behavior definition in the vicinity of the crack tip. Local techniques (i.e. the Crack Opening Displacement method) and energy-based subroutines (independent path integrals) have been developed [1]. These approaches have then been generalized for viscoelastic behavior and mixed-mode configurations [2]. A coupling between experimental reality and model output however requires imposing hypotheses. Image analysis techniques currently allow exploring other scientific fields in the area of fracture mechanics. Considerable research has been based on marker tracking methods or Digital Image Correlation (DIC) techniques in either two or three dimensions. An initial approach relies on the notion of introducing experimental displacement fields into the independent path technique (J -integral or M -integral) [3,4], in which strain and stress tensors are computed by assuming knowledge of the elastic property [5–13]. The finite element calculation may be improved by enriching the shape functions (through applying the Extended Finite Element Method) or by taking into account singular fields in the vicinity of the crack tip [14]. These methods however proceed by integrating the experimental noise first induced by the crack lip opening and then accentuated by the strain field generated from experimental displacements. A second approach consists of optimizing experimental displacements by their theoretical asymptotic

* Corresponding author.

E-mail address: frederic.dubois@unilim.fr (F. Dubois).

Nomenclature

Latin symbols

a	matrix of polar functions integrating the rigid body motion
a^T	transpose of a matrix
Δa	crack extension
$A_{\alpha\chi}$	weighting coefficients of the power series
$\Delta A_{\alpha\chi}$	increment of power series coefficients $A_{\alpha\chi}$ corresponding to iterative step
b	matrix of derivative residues
b^T	transpose of b matrix
B	an arbitrary point
C_{α}	reduced elastic compliance ($\alpha = 1; 2$)
C_1	reduced elastic compliance in x_1 -direction (or longitudinal direction of wood material)
C_2	reduced elastic compliance in x_2 -direction (or radial direction of wood material)
\bar{C}_1	arbitrary reduced elastic compliance, corresponding to x_1 -direction
dV	elementary volume
E_L	elastic longitudinal modulus
E_R	elastic radial modulus
G	energy release rate
$G\theta$	energy release rate calculate with θ -method
G_{LR}	elastic shear modulus in wood longitudinal–radial system
J	J -integral
h	matrix of residues
h^T	transpose of h matrix
h_1^p	residue of displacement in x_1 -direction, corresponding to p th point
h_2^p	residue of displacement in x_2 -direction, corresponding to p th point
$f_{\chi}, g_{\chi}, l_{\chi}, z_{\chi}$	polar functions
$K_{\alpha}^{(\sigma)}$	stress intensity factor ($\alpha = 1; 2$)
$K_1^{(\sigma)}$	stress intensity factor corresponding to opening mode
$K_2^{(\sigma)}$	stress intensity factor corresponding to shear mode
$K_{\alpha}^{(\epsilon)}$	crack relative displacement factor ($\alpha = 1; 2$)
$K_1^{(\epsilon)}$	crack relative displacement factor corresponding to opening mode
$K_2^{(\epsilon)}$	crack relative displacement factor corresponding to shear mode
n	iteration step number
N	power series number
m	subsets number
r	distance in polar coordinate system
r_p	distance of p th point in polar coordinate system
p	index number, corresponding to the subset center number or the mesh node $p = 1, \dots, m$
R	rigid body rotation
ΔR	increment of rigid body rotation corresponding to iterative step
T_1	rigid body translation in x_1 -direction
T_2	rigid body translation in x_2 -direction
ΔT_1	increment of rigid body translation in x_1 -direction corresponding to iterative step
ΔT_2	increment of rigid body translation in x_2 -direction corresponding to iterative step
s_{α}	characteristic equation roots
S_{ij}	compliance tensor components
$[\bar{u}]$	relative displacement vector of the crack lips
$[u]_1$	relative displacement vector of the crack lips in x_1 -direction
$[u]_2$	relative displacement vector of the crack lips in x_2 -direction
u_1	displacement in x_1 -direction of a point located on the crack lips
u_2	displacement in x_2 -direction of a point located on the crack lips
u	vector of displacement fields
u^T	transpose of u vector
u_1^p	displacement of p th point in x_1 -direction
u_2^p	displacement of p th point in x_2 -direction
\bar{u}_i	virtual displacement vector
$\bar{u}_{i,k}$	gradient of virtual displacement vector
V	integration domain
$\underline{\Delta W}$	Gibbs energy
\bar{W}	virtual energy

Download English Version:

<https://daneshyari.com/en/article/770934>

Download Persian Version:

<https://daneshyari.com/article/770934>

[Daneshyari.com](https://daneshyari.com)