



HAL
open science

Optimal and reliable design of timber beams for a maximum breaking load considering thermal and hydrological effects

Y Aoues, Rostand Moutou Pitti, H. Riahi, S E Hamdi, E Bastida

► To cite this version:

Y Aoues, Rostand Moutou Pitti, H. Riahi, S E Hamdi, E Bastida. Optimal and reliable design of timber beams for a maximum breaking load considering thermal and hydrological effects. COST Action FP1407 2 nd Conference – Innovative production technologies and increased wood products recycling and reuse , Sep 2016, Brno, Czech Republic. hal-01616946

HAL Id: hal-01616946

<https://hal.science/hal-01616946>

Submitted on 15 Oct 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

OPTIMAL AND RELIABLE DESIGN OF TIMBER BEAMS FOR A MAXIMUM BREAKING LOAD CONSIDERING THERMAL AND HYDROLOGICAL EFFECTS

Y. AOUES¹, H. RIAHI², S.E. HAMDI³, R. MOUTOU PITTI³, E. BASTIDA⁴

¹ Normandie Univ, INSA Rouen, LOFIMS, 76000 Rouen, France

² LARIS, UPRES EA7315, Université d'Angers-ISTIA, 62 avenue Notre Dame du Lac, Angers, France

³ Clermont Université, Université Blaise Pascal, Institut Pascal, EA 3867, F-63000 Clermont Ferrand, France

⁴ Laboratoire GeM Institut de recherche en Génie Civil et Mécanique, Université de Nantes, France

e-mail of the corresponding author: younes.aoues@insa-rouen.fr

Keywords: Reliability based optimization, Finite Element Analysis, Orthotropic materials, Probability of failure, crack growth.

The use of bio materials in sustainable construction aims to reduce the environmental impact of buildings. However, the wood material suffers from several drawbacks, such as the uncertainties of the timber mechanical properties, the knots of the material and the appearance of cracks. However, the timber elements exhibit micro-cracks, which can propagate due to fatigue, overload or creep loading. Thus, crack initiation is one of the most important factors involved in the collapse of timber component in building structures. To predict the crack initiation, many numerical methods have already been developed to characterize the mechanical fields in the crack tip vicinity [1]. In this work, energy method based on invariant integrals is used to estimate the fracture parameters such as energy release rate and stress intensity factors [2]. The analytical formulation of the T-integral to viscoelastic materials [3] is extended to A-integral in order to take into account the effect of thermal loading and the effect of moisture variation [4]. In fact, the study of the crack growth initiation and crack propagation in wood timber may consider the effect of temperature and the moisture content on the mechanical field distribution in the crack tip vicinity.

Structural optimization is widely used for effective cost reduction of civil engineering structure. Several works have used the Deterministic Design Optimisation (DDO) approach to design timber trusses [5]. The Deterministic Design Optimization procedure is based on minimizing an objective function as the structural volume or cost subjected to geometric, stress and deflection constraints. These design conditions are considered in accordance with Eurocode 5 in order to satisfy the requirements of both the ultimate and the serviceability limit states. However, in the context of fracture mechanic limit state, the DDO-based on the partial safety factors is not conservative since these safety factors are not calibrated on the basis of the fracture mechanic limit state.

The rational approach consists in considering uncertainties arising from the material properties, crack geometry and loading parameters in the design optimization procedure. The Reliability-Based Design Optimization is developed to balance cost and reliability, where it offers a means to quantify uncertainty propagation and determine a priori the most reliable design that meets performance criteria. However, the RBDO implies the evaluation of probabilistic constraints, which can be performed by nested loops of optimization and reliability procedures, leading to expensive computation effort for RBDO of real engineering structures [6].

In the present work, a new methodology of reliability-based design optimization of timber beams considering the crack propagation is proposed. The proposed method uses the Kriging metamodel to approximate of the mechanical response (i.e. the stress intensity factors and the energy release rates). The kriging metamodel approximation is adopted in order to surrogate the performance functions. The RBDO approach combines updating kriging approximation by using the technique of constraint boundary sampling to enhance the prediction of the Kriging model. Consequently, the obtained approximation is close to the target limit state function, especially in the vicinity of the most likely failure point. The application to search the optimal design of timber beams with the maximum strength to the fracture failure shows the interest and the effectiveness of the proposed method.

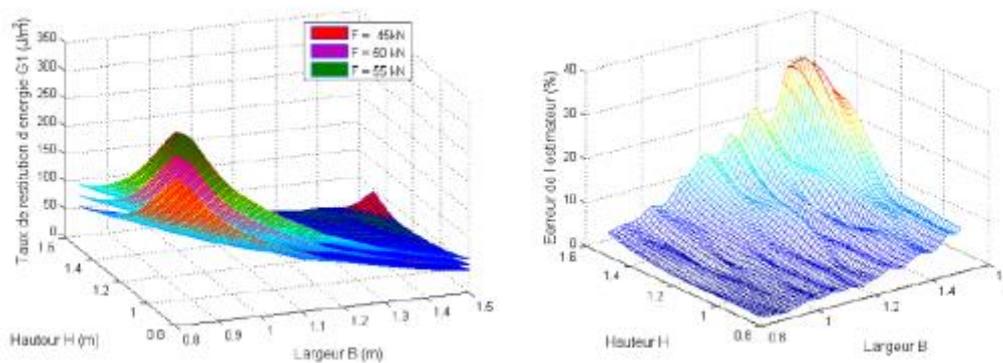


Figure 1: Kriging approximation of the energy release rate and the mean square error

REFERENCES

- [1] F. Dubois, H. Randriambololona, C. Petit, Creep in wood under variable climate condition: numerical modelling and experimental validation, *Mech. Time-Depend Mater.* 9 (2005) 173–202
- [2] L. Banks-Sills, O. Dolev, The conservative M-integral for thermal-elastic problems, *Int. J. Fract.* 125 (2004) 149–170.
- [3] R. Moutou Pitti, F. Dubois, C. Petit, Generalization of T and A integrals to timedependent materials: analytical formulations, *Int. J. Fract.* 161 (2010) 187–198.
- [4] Hassen Riahi, Rostand Moutou Pitti, Frédéric Dubois, Alaa Chateaneuf, Mixed-mode fracture analysis combining mechanical, thermal and hydrological effects in an isotropic and orthotropic material by means of invariant integrals. *Theoretical and Applied Fracture Mechanics*, in press, 2016.
- [5] Šilih, S., Premrov, M., Kravanja, S., 2005. Optimum design of plane timber trusses considering joint flexibility. *Eng. Struct.* Vol 27, pp.145–154.

- [6] Aoues, Y., Chateauneuf, A. (2009). "Benchmark study of numerical methods for reliability-based design optimization." *Struct Multidisc Optim*, 41(2), 277–294