COST Action FP1302

WOOD MUSICK

Short Term Scientific Mission Application

Assessing wood spatial variability from heterogeneous plate bending tests

1. Abstract of the scope of the STSM

The parameters governing constitutive equations of materials are determined experimentally by means of suitable mechanical tests. In the field of solid mechanics, this issue is presented as an inverse problem where the material parameters are to be determined from the knowledge of geometry, boundary conditions and strains (or displacements). Conventionally, this identification is achieved by carrying out mechanical tests in which specimen geometry and loading system are designed to generate homogeneous or simple strain/stress states across the gauge region. The idea behind this assumption is useful for theoretical analyses because a closed-form solution can be deduced, relating the unknown material parameters to the load and strain measurements (statically determined tests). However, the practical implementation of these tests can be difficult, especially for anisotropic and heterogeneous materials such as wood. The recent development of full-field optical techniques has enabled a new glance on the mechanical tests for material characterisation. The basic idea driving this new approach is that a single specimen can be loaded in order that several parameters are involved in the mechanical response, yielding heterogeneous and complex strain fields (statically undetermined tests). By means of a suitable identification strategy all the active parameters can be determined afterwards. Among these method there is the Virtual Fields Methods for extracting relevant material constitutive parameters.

Wood is a biological composite material formed by trees. It can be analysed at several scales of observation from timber down to chemical constituents. The mechanisms of deformation in wood can be quite complex involving, for instance, anisotropic, viscoelastic and hygroscopic phenomena. Moreover, the intra and inter variability of wood is reflected on the material parameters governing relevant constitutive equations. Therefore, the investigation of the wood mechanical behaviour raises several difficulties from both modelling and experimental points of view. In most practical applications and with some simplification hypothesis, invoking low levels of stress, short periods of time and minor variations of moisture content and temperature, wood can be modelled as a linear elastic anisotropic material. Besides, at the macro scale (0.1-1 m) wood is usually

assumed as a continuous and homogeneous medium. The complete characterisation of the linear elastic orthotropic behaviour of clear wood requires the determination of nine independent stiffness components. Conventionally, this set of material parameters is determined experimentally by carrying out several tests, in which both loading and specimen geometry are usually oriented along the material directions. Moreover, these tests are based on the assumption of simple and homogeneous stress/strain states across the elementary representative volume of the material at the scale of observation. This approach represents a great effort from an experimental point of view because only a few (*i.e.*, one or two) stiffness components are obtained per test configuration. Besides, the complete stiffness matrix will be obtained from different specimens, enhancing variability.

Wood is formed by concentric annual rings across the stem. At the stem level, both width and number of growth rings varies as a function of the tree growing age, which is mostly controlled by external environment factors. Moreover, the stem is usually split into juvenile and mature woods, regarding the cambial age in which wood cells have been formed. Although not yet fully understood, this feature have been pointed out to justify the radial variations of wood properties in the transverse plane. This variability can play an important role in the elastic and damping behaviour of wood plates used on wood instrument such as guitar and pianoforte soundboards.

The purpose of this project is to use inverse identification methods for direct evaluation of the spatial distribution of wood properties within a tree. The approach is based on a heterogeneous bending test carried out on a longitudinal-radial plate taken from centre to periphery of the tree trunk. The plate bending test must be designed with regard to supports and loading points, yielding heterogeneous and complex curvatures fields for activating relevant constitutive parameters. The virtual fields method (VFM) will be used for processing full-field slope measurements provided by deflectometry. An investigation of the proposed approach has already been performed on a medium-density fibreboard (MDF) by simultaneously charactering all bending stiffness components, assuming a simple case of homogeneous and isotropic behaviour. This study was partially financed by Duratex S.A. (Brasil), interested in developing a low-cost MDF panel by incorporating residual sugarcane particles from bio-ethanol production.

2. Plan of the work to be carried out

The VFM for assessing the spatial variation of mechanical properties within a plate will be developed. This case study will be the most suitable for processing the experimental data, since a spatial variation of properties within the stem is expected to occur. However, to solve this problem some parameterisation has to be used in the VFM. This is a key issue in order to deal with gradient properties in the plate. A continuous parameterisation approach will be used because monotonic variations of stiffness components are expected in the plate. Polynomial base functions can be used to modelling this low-frequency spatial variation. In this case, the VFM will be adapted to identify the coefficients of the polynomial for assessing within-stem mechanical properties. Classical plate bending theory (Kirchhoff-Love theory) will be assumed in a first approximation, in which both transverse shear and transverse normal strain effects are neglected. In the developing process, a finite element model of the plate bending test will be used. The advantage is that known mechanical properties are input into the model, so reference values will be available for validation purposed. The plate bending mechanical test will be studies and analysed with regard to support and loading points. An optimisation study will be proposed for defining a suitable test to be used experimentally for material parameter identification.

3. Benefits to be obtained from the STSM

This STSM will enhance the collaborative work between CITAB/UTAD and University of Southampton, under to topic of wood mechanics and material parameters identification. Further master student co-supervision is expected from this collaboration. Research benefits will arise from the numerical analysis of a new test procedure for spatial variability of wooden plates using the Virtual Fields Methods, which is a highly original topic. This new approach is expected to have an impact on the quantitative evaluation of the mechanical behaviour of wooden plates used in the construction of wood musical instruments. Extension to dynamic properties to extract stiffness and damping is anticipated.

4. Agreement from the host institution

In the name of the host institution, University of Southampton, the undersigned Professor Fabrice Pierron invites José Xavier to undertake the proposed STSM within the COST FP1302 action.

The mission will take place between 21-28 June.

Fabrice Pierron

Professor Fabrice Pierron

Digitally signed by Professor Fabrice Pierron
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University of Southampton

In the name of the home institution, CITAB, the undersigned Eduardo Rosa supports the proposed STSM to be undertaken by José Xavier within the COST FP1302 action.

Eduardo Rosa

CITAB/UTAD