3D fibre orientation reconstruction around a knot in Douglas fir

H. Penvern*, G. Pot*, J. Viguier*, R. Collet*, L. Demoulin *, B. Roux *, A. Olsson†, M. Hu†

* Arts et Métiers Sciences et Technologies, LaBoMaP, BFC, HESAM
F-71250 Cluny, FRANCE
helene.de_sauvage@ensam.eu

† Department of Building Technology, Linnaeus University
351 95 Växjö, SWEDEN
anders.olsson@lnu.se, min.hu@lnu.se

ABSTRACT

The mechanical properties of structural timber largely depend on the occurrence of knots and on fibre deviation in the vicinity of knots. In recent strength grading machines, lasers and cameras are used to detect surface characteristics such as size and position of knots and local fibre orientation. Studies have shown how data from optical surface scanning can be used to model local wood properties and enable good prediction of boards' mechanical behaviour. Since laser scanning only gives reliable information about the fibre orientation in the plane of board surfaces, simple assumptions are usually made both regarding the out-of-plane fibre angle and the fibre orientation in the interior of boards [1,2], with no calculation of the actual 3D fibre direction. Lukacevic *et al.* [3] used a model based on the "grain-flow" analogy that was developed by Foley [4] to determine 3D fibre orientation around knots (being considered of conical shape), and compared strains on board surfaces determined from experiments and finite element simulations. The results indicated a potential for improved accuracy of strength grading methods utilizing information of 3D fibre orientation. However, Briggert *et al.* [5] showed that Foley's model is dependent on information on the actual knots geometry to provide accurate results of growth layer geometry and fibre orientation.

The authors are unaware of studies utilizing Foley's model on other species than Norway Spruce. The present work aims to develop a laboratory method, inspired by the work of Hu *et al.* [6], to evaluate growth layers geometry and fibre orientation inside a Douglas fir timber sample. The method presented in [6] was based on successive destructive planning in two different directions, revealing longitudinal-tangential (LT) and longitudinal-radial (LR) planes to reconstruct 3D fibre orientation supposing knot symmetry. Conversely, in the present work, growth layers and 3D fibre orientation were reconstructed based on scanning of LT planes only, utilizing the fact that fibres must be oriented in the plane of the respective growth layers.

A 310x210x50 mm^3 wood block containing a complete, isolated splay knot was cut from a Douglas fir slab. The block was first planed in the LR plane close to the knot centre. 600 dpi colour scans were performed on revealed LR planes, with an additional 2x2 mm^2 resolution laser dot scanning on the last. The block was then planed off 2 mm at a time in the other direction, revealing a series of LT planes from the pith to the bark (Fig. 1a.). After each planing, colour and laser dot scannings were made (Fig. 1b. & 1c.) such that a dataset of in-plane fibre angles and colour shades of surfaces throughout the sample was collected.

Using morphological filters on colour scans, we managed to binarize each growth layer and use them to reconstruct each of the wood block 3D growth layer boundary surfaces (Fig. 1d.). Then, with computation of local normal directions to growth surfaces and in-plane fibre directions of scanned surfaces, 3D fibre orientation of the whole sample was reconstructed. As a preliminary validation, Figure 1.e. illustrates the good agreement of the computed fibre orientation to the real one on the last LR plane. The study provides valuable data for Douglas fir knots and fibre deviation even though the method's accuracy needs to be evaluated precisely.

Aknowledgement: This research was made possible thanks to financial support from the French national research agency through the EffiQuAss project (ANR-21- CE10-0002-01).

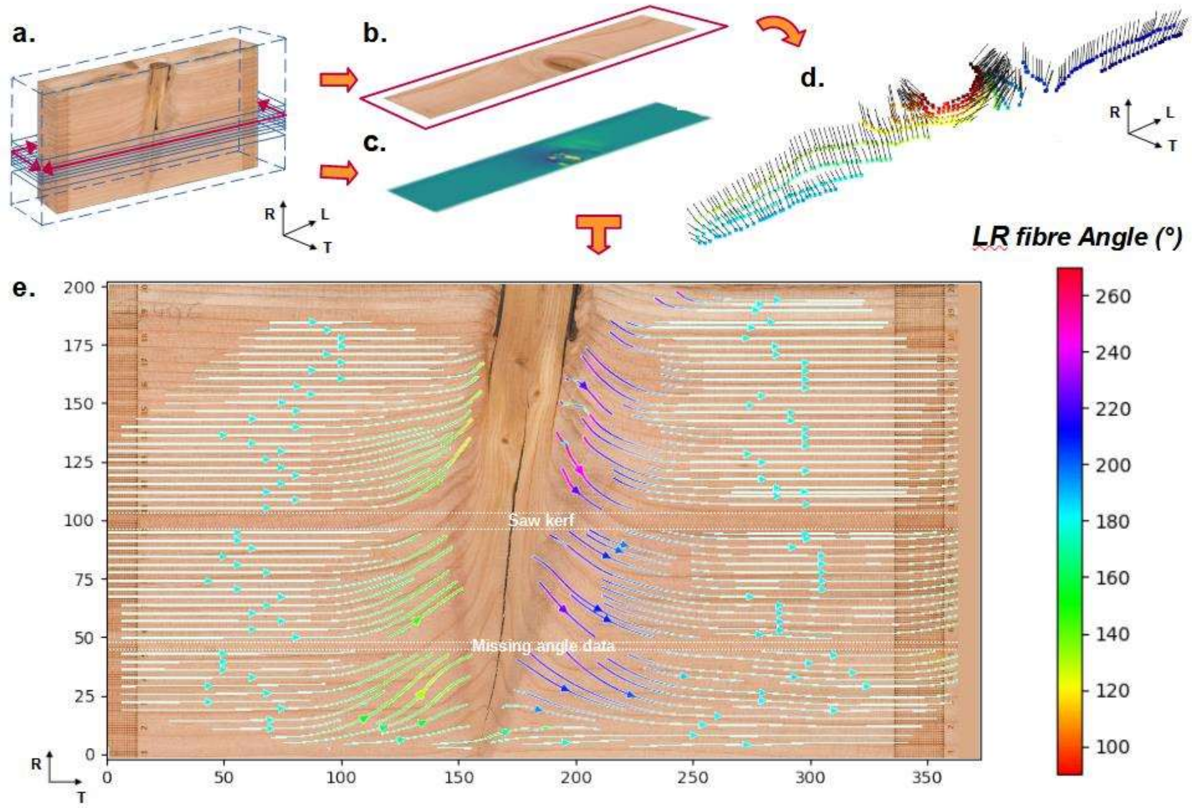

Figure 1. shows **a.** the original sample, which has been in cut into two halves on order to fasten the following successive **2-mm planing** with an industrial planing machine – **b. colour scanning** – **c. LT in-plane fibre angles** measurement with a laser point machine. After detecting growth-layer on the colour scans, **d.** a point cloud is made of the **boundary growth-ring surfaces, and normals** of these surfaces estimated. **e.** Streamplot showing the **resulting LR in-plane fibre orientation overlaid on the sample side colour scan**.

REFERENCES

[1] Rais, A. et al. Local 3D fibre orientation for tensile strength prediction of European beech timber. In : *Construction and Building Materials*, vol. 279 (3):122527, 2021.

[2] Olsson, A et al. Performance of strength grading methods based on fibre orientation and axial resonance frequency applied to Norway spruce, Douglas fir and European oak. In : *Annals of Forest Science*, vol.75 (4), pp.102, 2018.

[3] Lukacevic, M et al. A 3D model for knots and related fiber deviations in sawn timber for prediction of mechanical properties of boards. In: *Materials & Design*, vol.166, 2019.

[4] Foley, C.; Modeling the Effects of Knots in Structural Timber. In *Doctoral Thesis*. 10.13140/RG.2.2.30965.22243.

[5] Briggert, A. et al. Tracheid effect scanning and evaluation of in-plane and out-of-plane fiber direction in Norway spruce timber. In *Wood and Fiber Science*, vol. 50 *(4), 411–429, 2018.*

[6] Hu, M. et al. Growth layer and fibre orientation around knots in Norway spruce: a laboratory investigation. In : *Wood Science and Technology*, vol 52, pp. 7–27, 2018.