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Integrating Optical Measurement and Modeling for Quantitative Analysis of the Micromechanical Load Transfer in Wood-Adhesive Bond Interphase

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The principal role of adhesive bonds is to facilitate transfer of loads between adherents. The way stress is transferred through the bond interphase is important for many critical mechanical properties of wood-based composites, and may to some extent be modified by changing surface preparation procedures and bonding parameters. One specific feature of adhesive bonds in wood and wood-based composites is that the adhesive tends to penetrate the substrates to various degrees forming dispersed interphase extending beyond the actual bond-line. This interphase region comprises of cell wall substance, voids, and voids filled with the cured adhesive system [1].

Currently these correlations are commonly studied by means of standard test methods which rely on the inspection of specimen failure planes. These methods provide limited information on the role of adhesive penetration, the role of wood morphology, and other parameters affecting the efficiency of load transfer and micromechanics of loaded bonds, and are of very limited use in modeling. Better understanding of the mechanical contribution of the interphase region to the overall mechanical performance of a composite requires a methodology that is sensitive to the inherent inhomogeneity and complexity of the wood-adhesive system.
In this project [2] we combine state-of-the-art imaging tools with morphology-based numerical modeling methods for an integrated, multi-modal and multi-scale characterization of stress transfer across adhesive bonds. The numerical model designed to simulate the micro-mechanical behavior of wood-adhesive interphase is informed by empirical studies on 3D cell-level morphological structure and adhesive penetration in small samples, and by full-field displacement and strain maps measured on the same samples during the course of non-destructive shear tests. The methodology involves elements of the inverse problem approach (Figure 1).

This integration has led to a quantitative assessment and numerical simulation of the elastic behavior of bonded wood systems. The effects of adhesive penetration into cell lumens and the complex nature of the micro-morphology of wood are investigated using micro-bond testing for verification. The robustness of this approach relies on accurate quantitative measurement and analysis of full-field deformation and strains distributions across the loaded wood-adhesive interphase at a micro-mechanical level.
In this paper we present the conceptual framework of the project and data flow between the experimental study and the model, with the focus on the optical measurement of strain distributions across the bond interphase.

The micro-bond tensile tests were conducted on small lap shear specimens of varying wood species and adhesive formulation. The deformations and strains are measured using a stereomicroscopic optical measurement system which was focused on an area of interest (3 mm x 2.5 mm) which included the adhesive bond interphase. The measurement technique is based on digital image correlation (DIC) principles. The DIC software provides us with surface coordinates, components of displacement vector, surface strain components. This data is compatible with the numerical modeling output generated by the larger project.

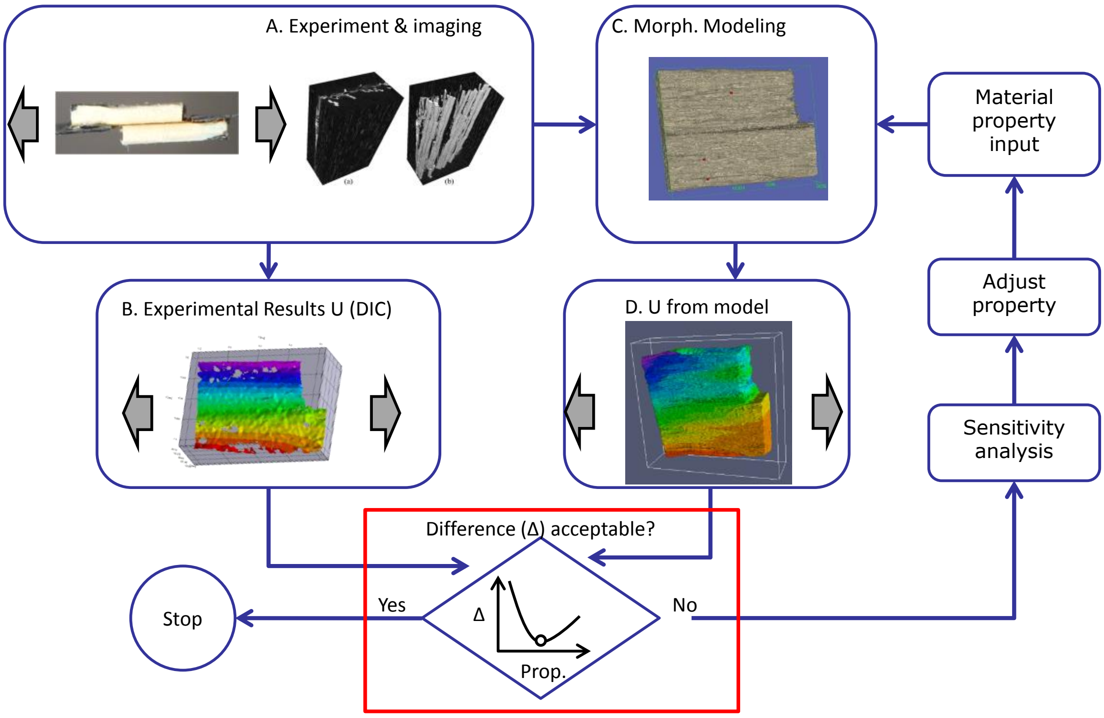

Figure 1 Diagram summarizing the data flow in the inverse problem approach as implemented in this project.

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