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Micromechanics of the Internal Bond in Wood Plastic Composites: Integrating Measurement and Modeling

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Wood plastic composites (WPCs) are heterogeneous materials comprised of irregular wood flour particles dispersed in thermoplastic polymer matrices. The matrix is typically high-density polyethylene (HDPE), polypropylene (PP), or poly (vinyl chloride) (PVC). Mechanical properties of the composite are determined by the micromechanics of the internal bonds between the particle and the matrix. The ability to model and predict this interaction is crucial for designing improved, more efficient composites. Existing theories and models for short fiber composites allow prediction of composite properties based on the morphology of the composite, mechanical properties of the components, and on the properties of the internal bond. These theories idealize the internal bond and particle morphology. It is unclear if such idealization can be extended to wood plastic composites where wood particles are porous, permeable, and irregular. The primary challenge has been lack of reliable quantitative measurement techniques that would allow analysis of the load transfer in composites at a scale relevant to wood flour particle size.

The presented study is part of a larger project, whose overall goal was to characterize an effective load transfer between wood flour particles and polymer matrix in WPCs through direct measurement of the deformation and strain distribution in and around embedded particles and morphology-based numerical simulations. The general approach was to couple advanced imaging techniques, optical measurement tools based on digital image correlation (DIC) principles, and material point modeling (MPM) techniques with inverse problem methodology for a multi-scale investigation of correlations between internal micro-morphology, micro-mechanics, and bulk properties of bio-particle reinforced polymer composites [1].

The micromechanical tensile tests were performed on sparse composite specimens containing a single wood flour particle (≈ 1 mm in length) embedded in HDPE. The development of surface deformation and strain patterns in the matrix near the particle was recorded using a stereomicroscopic optical measurement system. Full-field deformation and strain maps were calculated for local areas of interest (7.18 mm x 6.00 mm) focused on the particles.

One of the issues observed in a preliminary test series was great variability in the extent and magnitude of the apparent zones of influence (ZOI) identified as areas of strain concentration or disturbance generated by the particles on the surfaces of the test specimens. In order to explain this variability the spatial position of the embedded particles in the polymer films was determined from x-ray computed tomography (XCT) scans performed before the micromechanical tests. The scan data was also used as direct morphological input for numerical simulations of the mechanical tests.

The procedure allowed more realistic comparisons between the outcomes of the simulations and the strain maps measured on the specimen. Numerical comparison of the simulated and measured strain maps are then used in an iterative procedure based on the inverse problem methodology to adjust mechanical characteristics of the particles by minimizing local errors (Figure 2). This procedure allows better definition of the micromechanical properties of the internal bond.

In this presentation the integration of MPM generated simulation results, optically measured displacements and strains, and morphologic data will be discussed.

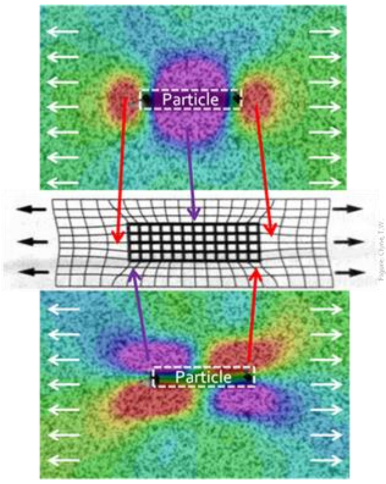

Figure 1. Optical measurements of principal and shear strain patterns of embedded particles being tested in tension compared with theoretical predictions.

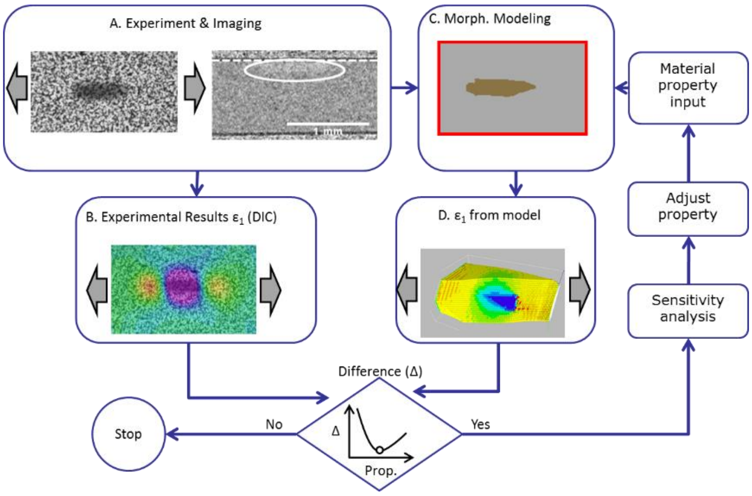

Figure 2. Diagram summarizing the data flow in the inverse problem approach as implemented in this project.

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