8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

MORPHOLOGICAL CHARACTERIZATION OF WOOD/POLYMER INTERPHASE IN WOOD-PLASTIC COMPOSITES USING ADVANCED IMAGING TOOLS

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ABSTRACT:

1. INTRODUCTION

Bio-fiber/polymer composites are complex, anisotropic, and heterogeneous materials. In most composite models, the internal bond area is assumed a clearly defined interface, an imaginary surface forming a common boundary between the phases (a wood particle and the surrounding polymer matrix). Such assumption is a good approximation for composites reinforced with glass or carbon fibers – solid, impermeable and of regular cross sections. Such assumption can hardly be made valid for wood plastic composites, where wood particles are porous, permeable and irregular. Thus in WPCs, the internal bond is believed to be dispersed in the interphase [1]. As opposed to interface, interphase is a three dimensional region on one or both sides of the imaginary contact surface where the phases coexist dispersed in one another, and a more or less gradual change of properties from one phase to another can be observed. Because of its transient nature, the precise location of interphase is not easy to determine. The presence of interphase may also pose a non-trivial difficulty for clear identification of the interface and consequently for precise morphological characterization of the composite.

High-resolution X-ray computed tomography (CT) scanning techniques created new opportunities for nondestructive, in situ analysis of particulate composites. X-ray CT scanners are capable of returning digital images carrying spatial information coded in discrete grayscale values representing densities and X-ray attenuations assigned to millions of voxels arranged in arrays [2, 3]. The combination of high-resolution nondestructive imaging techniques with machine vision tools provides the means for a quantitative characterization of the internal structure of heterogeneous composites. Although many researchers to-date have demonstrated various ways in which advanced imaging tools are being used to obtain qualitative understanding of the interaction between bio-particles and polymer matrix, quantitative characterization of statistical significance is rarely offered or even attempted.

In this study high-resolution X-ray computed tomography (CT) scanning, optical and electron scanning (ESM) microcopy were combined with digital image analysis and statistical tools to examine wood/polymer interphase in wood particle/PVC composite. Preliminary analysis of the CT scans revealed that apparent volumetric wood content in the CT images of the composite may be significantly underestimated when the existence of the interphase is apriori ignored. The objective of this study was to establish an effective analytical methodology for quantitative morphological characterization of WPCs that would properly account for the existence of interphase between the wood particles and the polymer matrix.

2. EXPERIMENTAL PROCEDURES

2.1 Materials and methods

Samples of pine wood flour and laboratory compounded 40/60 wood/PVC composite were used in this investigation. CT scans and microscopic images of pine wood flour (40-50 mesh), before compounding and embedded in PVC matrix were examined. Automated particle analysis of low-resolution digital micrographs was used to determine distribution of particle sizes and aspect ratios. The peripheral zones of individual free wood particles as well as of the particles embedded in the matrix were also examined with a high-resolution electron scanning microscope (ESM). Further, color micrographs of the embedded particles were used for quantitative assessment of the extent of the wood/polymer interphase (Figure 1a). A high resolution X-ray CT scanner was used to generate three dimensional images of the composite volumes, which were then subjected to advanced image analysis.

2.2 Results

Results of the automated particle analysis are shown in Figure 1b. The dominant aspect ratio of wood particles was between 2 and 4. High-resolution ESM images of individual wood particles revealed extensive peripheral zones with the external cells squeezed and crushed due to the mechanical processing. Micrographs of particles embedded in PVC matrix showed that these peripheral zones were relatively easily penetrated by the polymer during compounding. Digital analysis of the color micrographs allowed effective phase segmentation and a quantitative assessment of the relative volume fraction of the interphase in the composite at approximately 50% of the total particle volume. This observation allowed for a refined evaluation of apparently binomial histograms of the volumes generated with the X-ray CT scanning of wood/PVC composite samples. Phases separated using the adjusted histogram segmentation method revealed three component distributions, with the middle one consistent with the interphase volume. Accounting for the interphase allowed for much more realistic assessment of the volume content of the components in the compounded material and improved morphological definition of the phases from the CT scans.

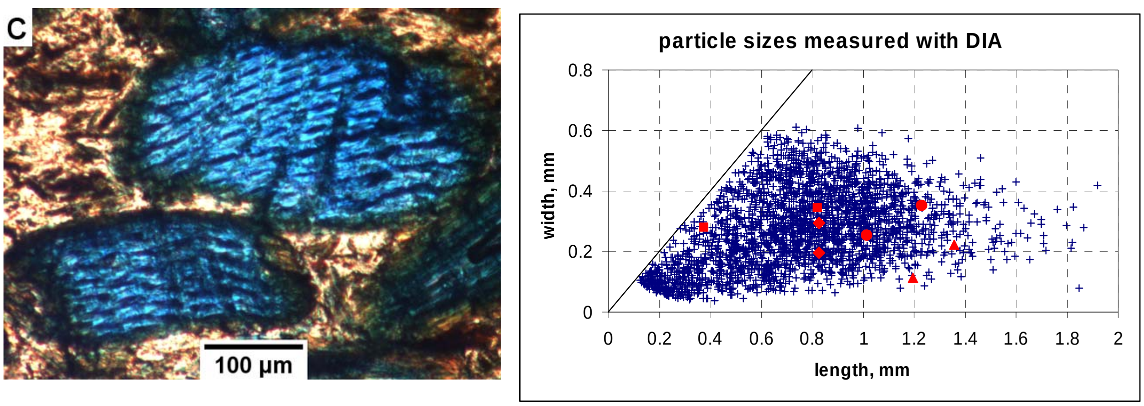

Figure 1- Color micrographs of the embedded wood particles (a) and the results of the automated measurement of wood flour characteristics (b).

3. REFERENCES

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