KTH SOLID MECHANICS SEMINAR; Thursday, February 9^{th}, 15.15; KTH Solid Mechanics Seminar room

Leif A. Carlsson "WATER UPTAKE IN FIBER-COMPOSITES WITH VOIDS"

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Long-term durability assessment of polymer matrix composite materials exposed to humid air or liquid water requires a firm understanding of the mechanisms governing water uptake and the chemical interactions involved in degradation of the matrix and the fiber/matrix interface. A good adhesion between the fiber and matrix is the most desirable in composite structures. The added mass of water will cause swelling of the matrix, which tends to degrade bonding between fiber and matrix. The water present in the composite may also chemically degrade of the fiber/matrix interface. Furthermore, although the presence of voids is undesirable, it is difficult to manufacture void-free composites. Factors such as insufficient resin flow, extensive resin cure shrinkage, and outgassing of volatiles in the resin contribute to the formation of voids and an imperfect fiber/matrix interface. Improper chemistry of the fiber sizing will further elevate the material mismatch between two very dissimilar materials. As a result, many types of composite materials suffer from poor fiber/matrix adhesion and voids enclosed in the material.

Voids provide space where water may accumulate, and if they are located at the fiber/matrix interface, the accumulated water may cause hydrolysis. Voids, furthermore, are geometrical irregularities that cause stress concentration, and reduction of strength. Hence quantification of void content in the composite is an important quality control issue. Characterization of the voids in a composite traditionally employs techniques such as Archimedes density method, analysis of cross section micrographs, and ultrasonic C-scan. Furthermore, micro-CT techniques have recently been used to characterize the voids in three dimensions, and reveal large elongated voids along the fibers.

Fickian diffusion is considered valid to analyze the moisture uptake in polymers and void-free composites. For composites containing voids, however, deviations from Fickian diffusion are observed. Voids in the form of capillaries along the fibers define flow channels and promote 'wicking', which is a rapid water uptake mechanism. Experimental studies on water uptake in polymer matrix composites show a strong dependence of voids. A composite containing even a small volume fraction voids will absorb moisture in excess of that contained in the matrix resin.

The moisture uptake in a composite with interfiber voids has been modeled using a combination of diffusion of moisture in the matrix resin, combined with capillary flow in the voids. Both the diffusion and capillary flow models predict increased time of saturation with increasing panel size, although the diffusion model predicts much longer times, and the capillary model much shorter times than observed experimentally. The results suggest that a more detailed characterization of the void structure and improved flow modeling are required to accurately predict the dynamics of water uptake in a composite.