WindSTAR

Wind-Energy Science, Technology, and Research
Industry/University Cooperative Research Center

Curing of Thick Adhesive Joints

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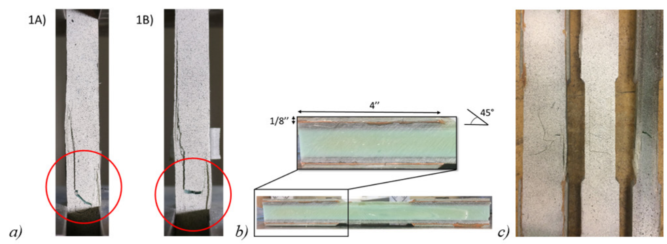
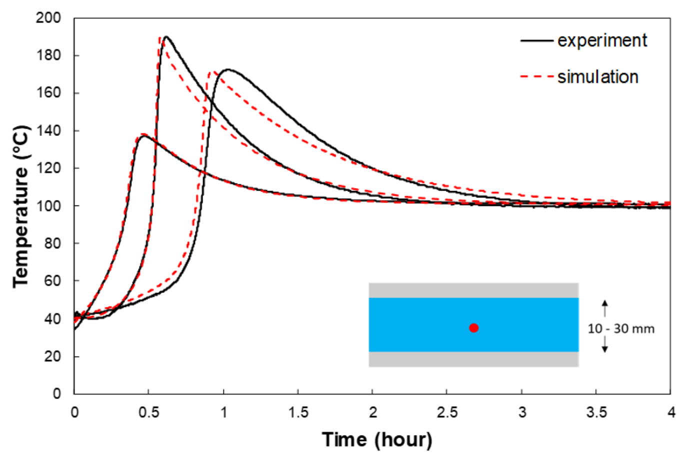
Bondline failure is a key critical failure mode in wind turbine blades. Substantial variation in bondline thickness can result in different thermal histories for the adhesive layer due to the exothermic curing of common adhesives. Predictive guidance regarding the impact of this variability in adhesive cure temperature cycles is extremely limited. Without guidelines of acceptable variability, excess resources may be placed into avoiding damage by processing at excessively low temperatures and longer processing cycles, which produce no discernible benefits. This project focuses on the characterization of adhesive bonded joints as a function of the curing temperature and adhesive thickness. In order to take into account the thickness influence, a series of experiments are conducted in a bonded joint configuration. Two sets of specimens for each thickness (10/20/30 mm) have been manufactured using recommended cure cycles and an elevated temperature cure cycle. A series of tensile and fatigue tests is performed on the joint specimens to determine the mechanical properties and the thickness-temperature influence on the bonded joint performance. Moreover, due to the exothermic nature of the cure of most adhesives, thicker regions result in elevated temperatures during curing which, beyond a critical threshold, lead to a degradation of adhesive properties. These regions with degraded properties are often visibly indiscernible from adhesive cured at recommended temperatures. Little research has been conducted to characterize the effect of temperatures and exothermic reaction levels on adhesive quality for thick joints. Additionally, the effect of bondline thickness on curing temperatures is also poorly understood, and predictive capabilities in this field are presently unavailable. Therefore, a finite element model capable of tracing the thermal and conversion histories in thick adhesive bondlines is presented. The cure kinetics of the bonding paste has been successfully characterized using isothermal DSC analysis. The finite element model is validated with experimental results from temperature sensors embedded in the adhesive centerline of 10, 20 and 30 mm specimens. Finally, an example of curing cycle optimization on a geometry representative of the trailing edge of a wind turbine blade is proposed.



Failure due to stress concentrations near the gripping area b) tabs geometry b) failure of 10, 20 and 30 mm thick adhesive specimens with tabs



Temperature sensor reading (continuous lines) vs. FE model predicted values (dashed lines) at adhesive centerline for 10/20/30 mm thick adhesive joint specimens.

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