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Fatigue damage evolution in quasi-unidirectional non-crimp fabric based composite materials for wind turbine blades

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The fatigue failure of wind turbine blades is controlled by failure mechanisms on multiple scales spanning single fiber fatigue failure at the sub-micron scale, over the fiber bundle structure on the millimeter scale to the quasi-unidirectional non-crimp fabric on the meter scale. At the smaller scales, the 3D x-ray computer tomography technique is used non-destructive to observe the fatigue damage evolution on the fiber and bundle scale. Those observations are then linked to the larger scales through mechanical testing of representative volumes of the non-crimp fabric bundle structure. Numerically, those non-crimp fabric bundle structures extracted from the 3D x-ray scans can be used in a multi-scale based finite element models used for understanding the parameters controlling the fatigue damage evolutions. During tension-tension fatigue testing, the damage mechanism is shown to be controlled by local architecture of the so-called backing bundle structure present in the non-crimp fabric. This mechanism is demonstrated to be highly dependent on the presence of curing induced residual stresses. Residual stresses which for an epoxy matrix system can be controlled by the chosen cure profile and thereby the mold time during wind turbine blade manufacture.