Fatigue performance of glass fibre – vinyl ester composite at ambient and sub-zero temperature

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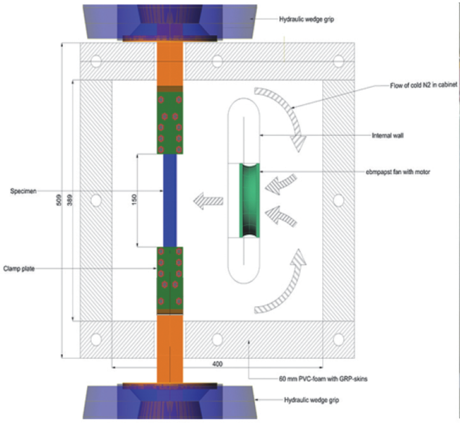
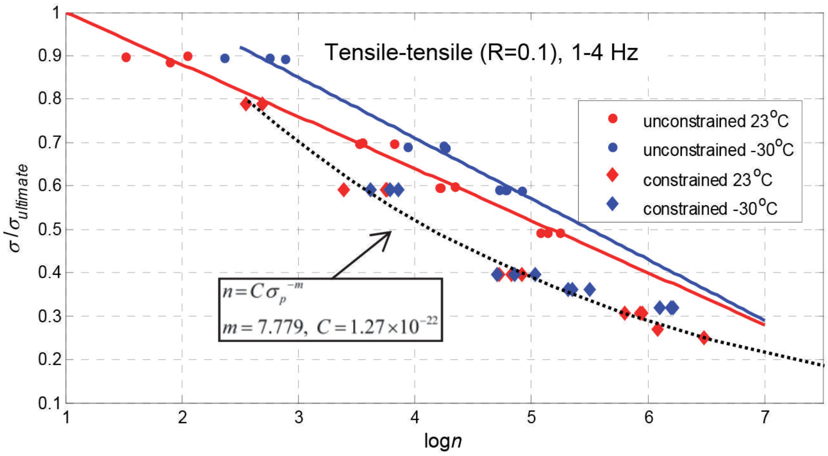
Composite material stiffness and fatigue performance are important design parameters for the structural design of wind turbine blades. Composite materials in wind turbines consist in general of a fibers and a thermoset polymer resin that has temperature dependent mechanical properties. This evidently leads to temperature dependence of the composite material. In relation to the deployment of wind energy in cold regions it is important to attain knowledge of the mechanical behavior of composite materials at sub-zero temperature. We here present results of fatigue test of a typical blade composite material.

Equipment: Tests where performed on an Instron 100 kN fatique test machine equipped with a custom-built chamber for convection cooling with liquid nitrogen.

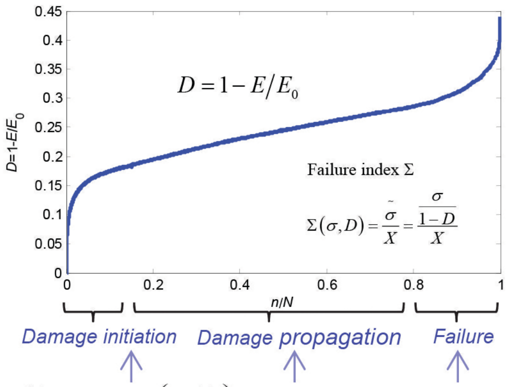
Material: Devold AMT DBLT 850 in a Reichhold Dion 9102 vinyl ester matrix with reinforcement structure $[0°,-45°, 90°, 45°]_4$.
The layup is asymmetric giving rise to stretch – twist coupling. If twisting is constrained interlaminar shear and out of plane stresses are increased. The effect of this on fatigue life was investigated by performing test both allowing and constraining twisting around the load axis of the sample during testing.

Results: In the unconstrained test case allowing twisting fatigue life increase slightly with decreasing temperature. However this difference tends to decrease with decreasing load. Constraining the sample from twisting reduces the lifetime and reduces the temperature dependence of the results. In addition the load dependence changes from exponential to power law. This indicates different dominating damage modes in the two cases.

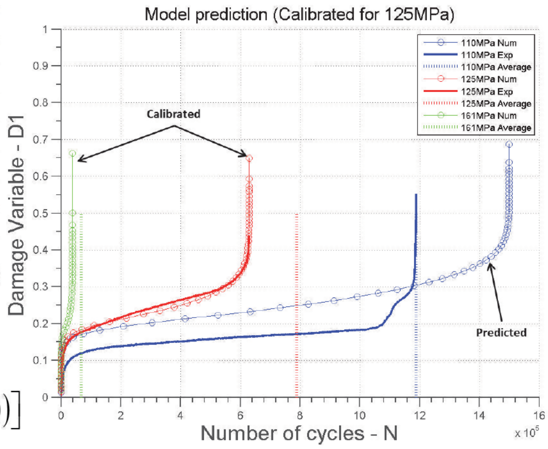




Modelling: The relative stiffness degradation is a commonly used parameter to describe development of damage in composites. The stiffness degradation of the samples presented here shows a typical stiffness decrease curve that can be divided in three stages: Initiation, damage propagation and failure. This can be modelled using a phenomenological damage model proposed by Van Papegem and Degrieck*



$$\frac{dD}{dn} = c_1 \cdot \Sigma \cdot \exp\left(c_2 \frac{D}{\sqrt{\Sigma}}\right) + c_3 \cdot D \cdot \Sigma^2 \left[1 + \exp\left(c_5 (\Sigma - c_4)\right)\right]$$



Conclusion: The tested composite material shows a weak dependence of temperature on fatigue performance when tested at 23 ° C and -30 °C. The matrix is well below T_g in both cases, which could explain the limited temperature dependence. These result do not indicate that low temperature should be of special concern for composites.

** W. Van Paepegem, J. Degrieck, A new coupled approach of residual stiffness and strength for fatigue of fibre-reinforced composites, International Journal of Fatigue, Volume 24, Issue 7, July 2002, Pages 747-762*

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