World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:12, No:12, 2018

Multiaxial Stress Based High Cycle Fatigue Model for Adhesive Joint Interfaces

Authors : Martin Alexander Eder, Sergei Semenov

Abstract : Many glass-epoxy composite structures, such as large utility wind turbine rotor blades (WTBs), comprise of adhesive joints with typically thick bond lines used to connect the different components during assembly. Performance optimization of rotor blades to increase power output by simultaneously maintaining high stiffness-to-low-mass ratios entails intricate geometries in conjunction with complex anisotropic material behavior. Consequently, adhesive joints in WTBs are subject to multiaxial stress states with significant stress gradients depending on the local joint geometry. Moreover, the dynamic aero-elastic interaction of the WTB with the airflow generates non-proportional, variable amplitude stress histories in the material. Empiricism shows that a prominent failure type in WTBs is high cycle fatigue failure of adhesive bond line interfaces, which in fact over time developed into a design driver as WTB sizes increase rapidly. Structural optimization employed at an early design stage, therefore, sets high demands on computationally efficient interface fatigue models capable of predicting the critical locations prone for interface failure. The numerical stress-based interface fatigue model presented in this work uses the Drucker-Prager criterion to compute three different damage indices corresponding to the two interface shear tractions and the outward normal traction. The two-parameter Drucker-Prager model was chosen because of its ability to consider shear strength enhancement under compression and shear strength reduction under tension. The governing interface damage index is taken as the maximum of the triple. The damage indices are computed through the well-known linear Palmgren-Miner rule after separate rain flow-counting of the equivalent shear stress history and the equivalent pure normal stress history. The equivalent stress signals are obtained by self-similar scaling of the Drucker-Prager surface whose shape is defined by the uniaxial tensile strength and the shear strength such that it intersects with the stress point at every time step. This approach implicitly assumes that the damage caused by the prevailing multiaxial stress state is the same as the damage caused by an amplified equivalent uniaxial stress state in the three interface directions. The model was implemented as Python plug-in for the commercially available finite element code Abaqus for its use with solid elements. The model was used to predict the interface damage of an adhesively bonded, tapered glass-epoxy composite cantilever I-beam tested by LM Wind Power under constant amplitude compression-compression tip load in the high cycle fatigue regime. Results show that the model was able to predict the location of debonding in the adhesive interface between the webfoot and the cap. Moreover, with a set of two different constant life diagrams namely in shear and tension, it was possible to predict both the fatigue lifetime and the failure mode of the sub-component with reasonable accuracy. It can be concluded that the fidelity, robustness and computational efficiency of the proposed model make it especially suitable for rapid fatigue damage screening of large 3D finite element models subject to complex dynamic load histories.

Keywords : adhesive, fatigue, interface, multiaxial stress
Conference Title : ICFMPCA 2018 : International Conference on Fracture Mechanics, Polymers, Composites and Adhesives
Conference Location : Sydney, Australia
Conference Dates : December 03-04, 2018