Fatigue characterization of continuous fiber reinforced polymers

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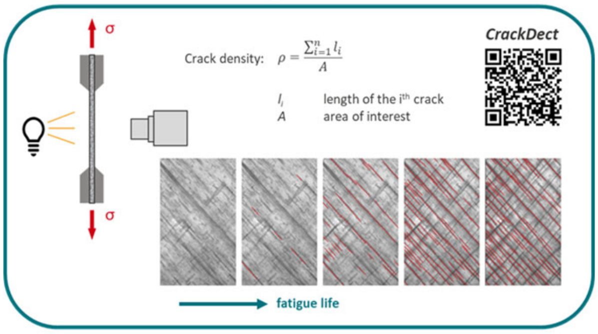
In-situ detection of damage evolution using automated optical crack detection and acoustic emission analysis

Fiber reinforced polymer laminates exhibit a series of complex damage mechanisms throughout their lifetime. In order to accurately model their fatigue behavior, it is essential to characterize damage evolution and its effects on the mechanical properties. During the initial stage of fatigue life, the dominating mechanism is cracking in off-axis plies, typically leading to a significant decrease of stiffness. For semi-transparent laminates a source of light shining through the specimen can be used to visualize those cracks, because they scatter the light and therefore appear as dark lines. With the help of an automated algorithm crack density during fatigue life can be determined (Fig. 1).

Automated optical crack detection



Correlation of crack density with stiffness degradation

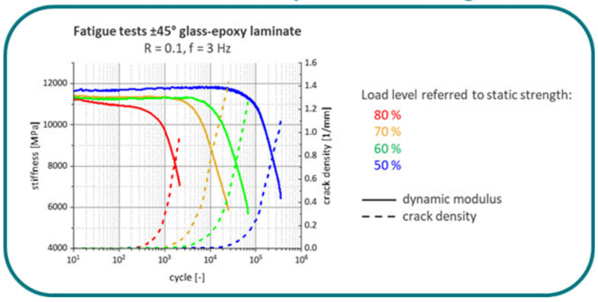
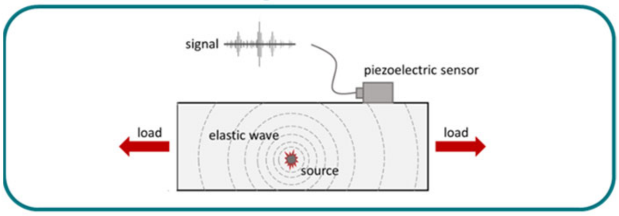


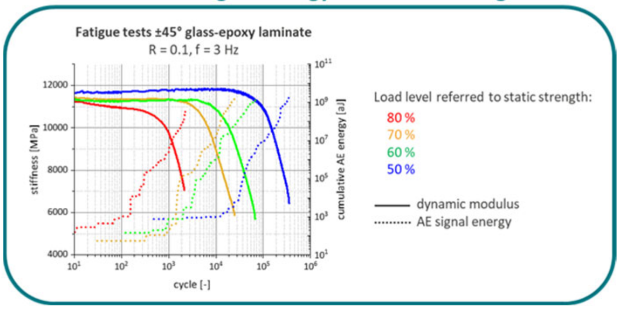
Fig.1

Use of automated optical crack detection during fatigue testing of a ±45° glass-epoxy laminate. The detected crack initiation correlates with stiffness decrease. For higher load levels crack initiation/ stiffness decrease is shifter to lower cycles.

AE signal detection



Correlation of AE signal energy with stiffness degradation



Another method for the in-situ detection of damage is acoustic emission (AE) analysis. Thereby, each occurring damage event generates an elastic wave, that propagates through the material, and is detected by a piezoelectric sensor as vibration of the specimen's surface (Fig. 2). Compared to the optical crack detection, AE is not limited to semi-transparent laminates.

Fig. 2

Use of AE during fatigue testing of a ±45° glass-epoxy laminate. The increase in cumulative AE energy indicates the accumulation of damage inside the laminate, which is also reflected in a decrease of stiffness.

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