Acoustic Emission Testing of Composite Laminates at Cryogenic Temperatures Using Cantilevered Phase-shifted Fiber Bragg Grating

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Conventional ultrasonic sensors are significantly affected by low temperatures. This results in the difficulty of acoustic emission (AE) detection of composite laminates at cryogenic temperatures. In this study, a phase-shifted fiber Bragg grating (PSFBG) ultrasonic sensor with superior temperature resistance and sensing performance was proposed and evaluated by both acousto-ultrasonic and AE test in liquid nitrogen (77 K). The results indicate that a PSFBG with a polyimide coating and installed by the cantilevered configuration can better retain its spectrum than that with an acrylate coating or bonded directly. Consequently, it is suitable for ultrasonic detection at cryogenic temperatures owing to its 1.42 MHz bandwidth and high sensitivity. Twenty seven small-energy and high-frequency AE signals generated by matrix cracks within a composite laminate during a three-point bending test were detected successfully by a cantilevered polyimide-coated PSFBG. The distributions of amplitude and frequency of the AE signals were evaluated, and compared to those detected at room temperature, showing that the composite become more brittle at low temperatures. This demonstrated the sufficient detection reliability of the sensor at cryogenic temperatures. This pioneering work of using an optical fiber sensor for AE detection provides a potential approach for composite evaluation at cryogenic temperatures that was difficult to achieve earlier.