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TERFENOL-D CARBON FIBER REINFORCED POLYMER (CFRP) EMBEDDED SENSING FOR EARLY DAMAGE DETECTION

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Carbon Fiber Reinforced Polymers (CFRPs) have become an essential part of designing and engineering lightweight rigid bodies; predominantly in the aerospace and automotive industries. Typical epoxy-based CFRPs exhibit virtually no plasticity with minimal strain to failure. Although CFRPs have high specific strengths and elastic moduli, the brittle fracture mechanism presents unique challenges in failure detection for the Army's vertical lift vehicles since failure occurs catastrophically. Current real-time state of the art structural health monitoring (SHM) systems for aerospace structures are intrusive to the surface of the part and/or requires electrical connectivity. The Army uses a "safe-life" interval-based service methodology where components are replaced with regards to a usage spectrum rather than the component's actual state of structural health. This paper explores a method for solving this problem by investigating the possibility of embedding Terfenol-D (~100 microns in diameter), a magnetostrictive material, into the CFRPs for embedded non-contact structural health monitoring. For baseline results, the change in localized (32 mm^2 field of view) magnetic flux was only 0.02% for an applied load of 0-100% of the material's ultimate tensile strength (UTS). For quasi-static testing procedure of specimen 5714 (15 wt.% Terfenol-D embedded CFRP) on a 0-40% loading interval of the material's UTS, there was an observed localized (32 mm^2 field of view) magnetic flux gradient of more than 5 mT (4%) with a reversible flux of 100%. For quasi-static testing procedure of specimen 5714 (15 wt.% Terfenol-D embedded CFRP) on a 0-70% loading interval of the material's UTS, there was an observed localized (32 mm^2 field of view) magnetic flux gradient of more than 3 mT (2%) with a reversible flux of only 25%. Terfenol-D embedded CRFPs have shown promising results for detecting instantaneous levels of degradation. Acoustic emission (AE), X-ray computed tomography (CT) scanning, Finite Element Analysis (FEA) and analytical modeling were used to validate the observed results.

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