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Enhancing aircraft crack repair efficiency through novel optimization of piezoelectric actuator parameters: A design of experiments and adaptive neuro-fuzzy inference system approach

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Abstract

This study addressed the critical problem of repairing cracks in aging aircraft structures, a safety concern of paramount importance given the extended service life of modern fleets. Utilized a finite element (FE) method enhanced by the design of experiments (DOE) and adaptive neuro-fuzzy inference system (ANFIS) approaches to analyze the efficacy of piezoelectric actuators in mitigating stress intensity factors (SIF) at crack tips—a novel integration in structural repair strategies. Through simulations, we examined the impact of various factors on the repair process, including the plate, actuator, and adhesive bond size and characteristics. In this work, initially, the SIF estimation used the FE approach at crack tips in aluminum 2024-T3 plate under the uniform uniaxial tensile load. Next, numerous simulations have been performed by changing the parameters and their levels to collect the data information for the analysis of the DOE and ANFIS approach. The FE simulation results have shown that changing the parameters and their levels will result in changing of SIF. Several DOE and ANFIS optimization cases have been performed for the depth analysis of parameters. The current results indicated that optimal placement, size, and voltage applied to the piezoelectric actuators are crucial for maximizing crack repair efficiency, with the ability to significantly reduce the SIF by a quantified percentage under specific conditions. This research surpasses previous efforts by providing a comprehensive parameter optimization of piezoelectric actuator application, offering a methodologically advanced and practically relevant pathway to enhance aircraft structural integrity and maintenance practices. The study innovation lies in its methodological fusion, which holistically examines the parameters influencing SIF reduction in aircraft crack repair, marking a significant leap in applying intelligent materials in aerospace engineering. © 2024 The Authors

Author Keywords

Adaptive neuro-fuzzy inference system; Aircraft crack repair; Experiment design; Finite element method; Piezoelectric actuators; Stress intensity factor

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