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Detection of Barely Visible Damage in a CFRP Thermoplastic Tilt-Rotor Flaperon Demonstrator Using an Ultrasonic Guided Wave-Based SHM System

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Ensuring the structural integrity of aircraft flaperons is crucial for flight safety and performance. To enable continuous monitoring and early damage detection, Structural Health Monitoring (SHM) systems have become indispensable in aerospace applications. This study focuses on detecting and localizing barely visible damages (BVDs) on the slightly curved surface of a flaperon demonstrator, made of carbon-fibre-reinforced composite with a thermoplastic matrix, enhancing recyclability. The flaperon, a critical component of the aircraft control surfaces, features variations in material thickness due to a protective cold spray coating, and the incorporation of stiffeners. These modifications significantly affect the propagation mechanisms of guided ultrasonic waves, which are essential for assessing SHM system performance.

An SHM system based on ultrasonic guided waves (UGWs) is implemented within a finite element (FE) environment to model multiple BVD scenarios at different locations. An array of surface-mounted piezoelectric transducers (PZT) excites and captures UGWs, enabling signal comparison with the reference state. Key features are extracted from gathered signals to assess their sensitivity to BVDs, ensuring accurate detection and localization.

To enhance the diagnostic capabilities of the developed SHM system, this study integrates a comprehensive numerical-experimental investigation, systematically validating numerical simulations against experimental data from a dedicated test campaign incorporating non-destructive evaluation (NDE) techniques. This approach establishes a robust correlation between numerical predictions and experimental outcomes, improving SHM system reliability and applicability. The findings contribute to advancing SHM technologies for early-stage damage identification in complex aerospace structures, aligning with the highest level of the building block approach.

Additionally, this research supports the transition of the SHM system towards operational deployment by enhancing damage detection accuracy and efficiency. By integrating advanced composite engineering with state-of-the-art monitoring technologies monitoring technologies, this study promotes sustainability in aerospace engineering while refining maintenance strategies for next-generation aircraft.

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