ID contributo: **100**

Tipo: **Presentazione orale**

Damage Tolerance and Non-Destructive Evaluation of Low-Velocity Impact Damage in CFRP under Fatigue Loading

mercoledì 3 settembre 2025 12:30 (15 minuti)

The damage tolerance approach enables the design of lightweight composite structures, provided that damage progression remains controlled throughout their operational life. However, the fatigue-driven growth of delaminations resulting from low-velocity impact (LVI) remains poorly understood. The prevailing no-growth design philosophy assumes that delaminations in the high-cycle fatigue regime exhibit an extended plateau phase with negligible propagation. However, recent findings suggest that this plateau phase may stem from the limitations of conventional non-destructive evaluation (NDE) techniques, rather than an actual absence of damage evolution. In particular, C-SCAN ultrasonic inspections, commonly employed for damage assessment, may fail to detect internal delaminations encapsulated within outer ones due to the shadowing effect, potentially leading to an underestimation of fatigue-driven damage progression. This raises concerns about the reliability of traditional inspection methods for monitoring damage in critical composite structures.
As part of the TU-LEARN (Structural Life Extension Enhanced by Artificial Intelligence) project, funded by Unione Europea –Next Generation EU under the PRIN 2022 PNRR –D.D. n. 1409 del 14-09-2022 program, this study aims to enhance the understanding of LVI damage propagation mechanisms under fatigue loading.
An experimental campaign was conducted on Carbon Fibre Reinforced Polymer (CFRP) coupons with a $[(45,-45,90,0)]_2s$ stacking sequence, representative of aerospace-grade laminates. The methodology involved LVI tests following the ASTM D7136 standard, performed at an impact energy of 15 J using a 4.567 kg drop mass to induce a representative damage state. The post-impact behavior was assessed through compression after impact (CAI) fatigue tests, in accordance with the ASTM D7137 standard, under compressive-compressive cyclic loading with a stress ratio R = 0.1 and frequency f = 4 Hz.
To monitor damage progression at multiple fatigue stages, an ultrasonic guided wave (UGW)-based Structural Health Monitoring (SHM) system was integrated, complementing conventional C-SCAN inspections. This multi-sensor approach enabled a more detailed assessment of delamination growth, highlighting potential limitations in the conventional no-growth assumption. The UGW-SHM system demonstrated the capability to track internal damage progression, even in regions where C-SCAN proved insufficient.
The findings underscore the need for advanced NDE techniques to ensure a more reliable assessment of fatigue-driven damage evolution in composite structures. The integration of UGW-based SHM enhances the detection capabilities beyond traditional ultrasonic inspections, offering a more comprehensive evaluation of internal damage progression. These results contribute to refining damage tolerance strategies and improving predictive maintenance frameworks for aerospace and other safety-critical applications.

Autore principale: DE LUCA, Alessandro (Università della Campania Luigi Vanvitelli, Dipartimento di Ingegneria)

Coautore: Prof. MINARDO, Aldo (Università della Campania Luigi Vanvitelli, Dipartimento di Ingegneria); PERFETTO, Donato (Università degli Studi della Campania Luigi Vanvitelli); Dr. CATALANO, Ester (Università della Campania Luigi Vanvitelli, Dipartimento di Ingegneria); Prof. CAPUTO, Francesco (Università della Campania Luigi Vanvitelli, Dipartimento di Ingegneria); LAMANNA, Giuseppe (Università degli Studi della Campania "Luigi Vanvitelli")

Relatore: DE LUCA, Alessandro (Università della Campania Luigi Vanvitelli, Dipartimento di Ingegneria)

Classifica Sessioni: Compositi

Classificazione della track: Materiali Compositi