An Engineering Approach for Damage Growth Analysis of Sandwich Structures Subjected to Combined Compression and Pressure Loading

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ABSTRACT

Fluid-ingression phenomenon in composite structures is a concern for sandwich structural details. Inadequate design details and/or poor material selections can result in microcracks during ground-air-ground (GAG) cycling that consequently coalesce to form transverse matrix cracks that lead to moisture ingression into the subsequent composite and adhesive layers and finally into the core. Impact damages on sandwich structures exacerbate the fluid-ingression phenomenon as a result of localized transverse cracks, delaminations, disbonds, and core damages. Thermo-mechanical loads during GAG cycling could cause the local buckling on compression side of a sandwich structure that result in localized mode I stresses that may result in further delamination/disbond growth creating more passageways for fluid migration. Additionally, the trapped water in sandwich cells translate into vapor during high temperatures and increase the internal pressure and cause core disbond and/or fracture. In some cases, the damage growth due to the above-mentioned two mechanisms is stable and occurs over a period of several flights, but may not be readily detected on the ground, when the thermo-mechanical and internal vapor pressure loads are released. Although the damage size continues to grow in such cases, the structure continues to carry loads until it reaches a critical damage threshold (CDT), where the unstable damage growth triggers the catastrophic failure. Unless such damage is detected and repaired prior to reaching CDT, GAG effects will further the damage size and threaten the structural integrity and safety of the aircraft. Current phase of the research focus on investigating the effects of ground-air-ground (GAG) cycling on damage growth behavior of sandwich structures with synchronized temperature, pressure and mechanical loads; investigate the conditions for onset of damage growth and damage growth rates. Also, a standardize procedure and test apparatus for GAG testing for simulate damage growth due to mixed-mode stress state caused by pressure differential at high altitude coupled with in-plane mechanical loads is developed. Furthermore, predictive capabilities of onset of damage growth and progressive failure mechanisms using virtual crack closure technique and cohesive zone modeling couple with multi-scale material models were evaluated. The information gathered through this research will be instrumental in developing analytical methods and validating finite element analysis procedures to further investigate the damage growth mechanics of sandwich composite structures.