Risks of Initial Assumptions in Fatigue and Damage Tolerance of Small Aircraft Development Programs

Dejan Romančuk [1], Juan Ocampo [2]
[1]*Institute of Mechanical Engineering, HSLU, Switzerland*
[2]*St. Mary's University, USA*

Design and certification of aircraft structures require a large set of initial assumptions before the structural sizing and design process can get started and certification analysis and testing can take place. Within the starting phase most of the key assumptions are defined and the overall program risks are related to these initial assumptions. This review paper outlines assumptions in fatigue and damage tolerance (FDT) and the associated risks. Understanding and managing the risks of these assumptions is paramount to the success of every structural integrity program.

Aircraft certified under the requirements of Part 23 are considered as "small". The selected certification basis defines the fatigue evaluation requirement where different concepts are applicable depending on the type of component, the design, and the material. The structural development process involves the steps of mission and usage assumptions, spectrum development for every component that includes principal structural elements (PSE), fatigue load derivation, material selection, and material data derivation as part of the building block testing approach. This includes development, certification and qualification tests. Damage tolerance analyses require software tools and adequate libraries of Stress Intensity Factors (SIF). The selection of scatter factors and life improvement factors for interference fit fasteners, cold worked holes or shot peened structure, the definition of initial and detectable crack sizes with their probability of detection (POD), are important parameters.

Every step above involves assumptions and simplifications with associated risks. One example is the deployment of fracture mechanics models by using existing SIF libraries like the ones existing in AFGROW or NASGRO, where the plate model with a hole with offset can solve many of the load transfer problems in an acceptable manner at relatively low costs. In conjunction with good quality FEM models the SIF solution may lead to satisfactory results in the range of ligament crack sizes. Beyond this range the predictions may be too conservative when applying continued growth in a plate. The understanding of the full chain of assumptions, the limitations and conservatism in this approach may allow to size towards a Reserve Factor (RF) = 1.00, although, for production support a slightly higher RF is desired. The related risks are often covered by conservatism and described by judgement, however, when quantification becomes inevitable, probabilistic approaches may be employed to justify possible corrective actions in the fleet.

Keywords: fatigue and damage tolerance, structural integrity program, crack growth, fracture mechanics, probabilistic