DAMAGE TOLERANCE – FACTS AND FICTION

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Design, analysis and verification of damage tolerant structures embrace both structural characterizations and damage detection assessments. This review is focused on continued airworthiness challenges in terms of evolution of design and verification requirements, analysis methods and examples of lessons learned.

Design of structures is fundamentally a guided interactive process aimed at achieving a practical balance between the state of the art and the intended usage requirements. These capabilities and requirements are typically evaluated against each other through a disciplined design process comprising regulations, methods and analysis, data bases, validation tests, etc. Static design of structures has evolved since the infancy of aviation towards widely accepted analysis methods and allowables design and verification procedures reflecting cumulative service experience.

Methods to determine fatigue performance, residual strength and crack growth of complex details have improved significantly since the introduction of commercial jet transports. Development of disciplined design and analysis methods comparable to static design processes has suffered due to the absence of widely accepted and practical evaluation procedures. This has at times prevented timely and systematic improvements through feedback of experience into standardized procedures for structural evaluations of damaged structure. Less industry technology development has occurred on integrating structural characteristics in establishing structural inspection program recommendations that reflect the value of normal operator maintenance activities.

Development of Boeing technology standards over the last three decades has been focused on a practical balance between simplicity and technical credibility aimed at providing structural engineers with useful and service/test validated analysis tools. Damage detection considerations required for flexible maintenance programs without compromising structural safety are addressed in this review.

Regulatory implementation of damage tolerance principles in 1978 encouraged application of contemporary engineering methods to determine inspection thresholds and intervals. Most manufacturers included dependent damage at multiple sites in early damage tolerance assessments. Independent damage at multiple sites in areas with many similar structural details subjected to similar stresses have provided additional challenges to verify continued airworthiness of aging commercial jet transports.

It is prudent to recognize the USAF contributions to damage tolerance implementation. These military requirements differ in details but not in principle. Prior to 1958, military airplane designs were based on static strength requirements. The Aircraft Structural Integrity Program (ASIP), initiated in 1958, was based on a fatigue initiation approach and moderately successful. This safe-life approach was replaced in 1975 by the fracture mechanics approach, which essentially embraces the damage tolerance concepts but with strong emphasis on the assumption that imperfections are present in an early stage of airplane service. This ASIP philosophy has been extremely effective in ensuring structural safety by significantly reducing hull losses.