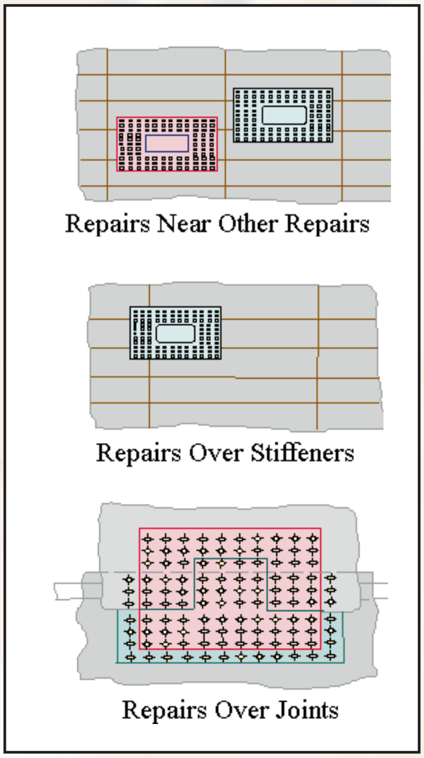
Repair Assessment Procedure and Integrated Design (RAPID)

A critical issue identified by the aviation industry (civilian and military) is the need to examine the effects of repairs on the structural integrity of aircraft.

The incorporation of damage tolerance methodologies in aircraft maintenance and repair practices is required in order to insure their continued airworthiness and operational safety. The resources needed for damage tolerance designs of repairs are lacking for small operators, independent repair facilities, and military repair depots. In an effort to address this need, a task was undertaken under the joint sponsorship of the United States Air Force (USAF) and the Federal Aviation Administration (FAA) to develop a new, user-friendly software tool, Repair Assessment Procedure and Integrated Design (RAPID), capable of static strength and damage tolerance analyses of fuselage skin repairs.

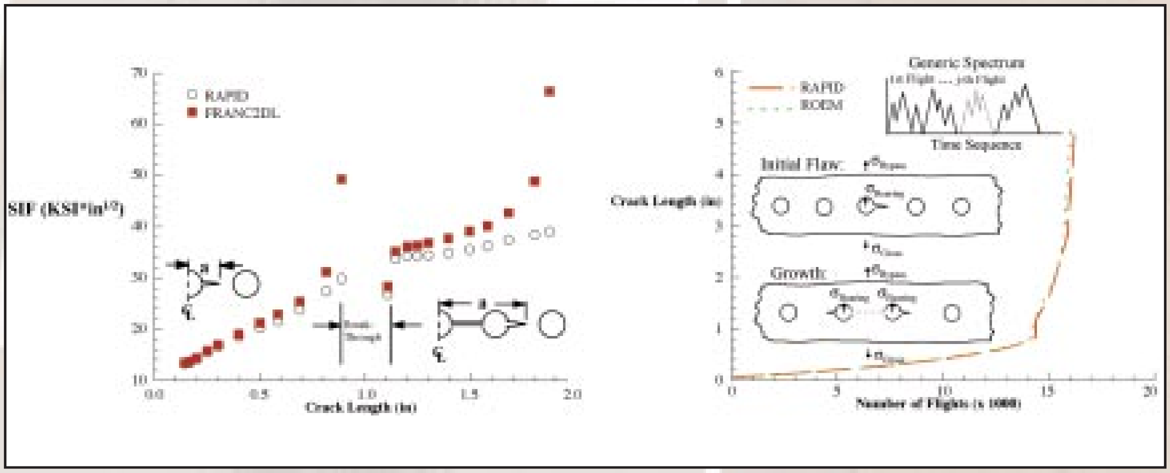
RAPID is a simple, PC-based repair tool with a modularized open system architecture to provide easy implementation of upgrades and new features. In the development of this tool, emphasis has been placed on using generic engineering approaches for use in a Windows-based, user-friendly software tool that can run on a PC computer with minimal hardware and software requirements. The targeted audience for RAPID are people in the aircraft repair industry in need of analysis tools to conduct damage tolerance analysis of repairs such as third-party repair facilities, independent designated engineering representatives (DERs), FAA aircraft certification offices (ACOs), and USAF repair depots.



The fuselage skin repairs considered in RAPID consist of a rectangular skin cut out of the damaged area and doublers mechanically fastened to the skin. Complex fuselage skin repairs found in actual operating conditions can be assessed using RAPID, including repairs near other repairs, repairs of splice joints, and repairs over stiffeners, as shown above. RAPID assesses fuselage skin repairs for static strength and damage tolerance requirements.

The static strength analysis is based on the margin of safety calculated using the allowables of the doublers and the fastener joints. The methodology includes shear and compression analysis capabilities of the repairs. Inter-rivet buckling between adjacent fasteners and the panel buckling of the repair doubler are examined against the compression strength allowables of the materials.

Safety



The damage tolerance analysis (DTA) in RAPID is based on a procedure which involves several steps including the calculation of fastener loads, assumption of the initial flaw geometry and growth, and calculations of stress-intensity factors, crack growth, residual strength, and inspection schedule. The DTA is conducted at the center and corner fastener holes in the skin on each side of the repair. The center fastener is analyzed since inspections at that location can be difficult; the corner fastener is analyzed since it is typically the highest loaded fastener. The two analyses are conducted on all sides since there may be an asymmetric condition due to substructure or adjacent repairs.

Two crack growth models are available: a simplified approach based on Walker's equation and a cycle-by-cycle approach. The load spectra database includes a generic narrow-body and wide-body load spectra. The corresponding stress spectra are determined based on the location of the repair on the aircraft. An equivalent stress cycle spectrum can be derived from any stress spectrum history and can be used in the simplified crack growth analysis. In addition, a user-defined stress spectrum can be input to RAPID to be used in an analysis.

The analysis methodology in RAPID has been validated using in-house and commercial finite element programs. In the figures above, RAPID generated results for the stress-intensity factor (SIF) solutions and the crack growth analysis are compared to other solutions.

In general, there is good agreement in the SIF calculations made using RAPID and FRANC2DL (a two-dimensional finite element analysis) for the initial crack growth. As the crack tip approached a boundary, i.e., a rivet hole or specimen edge, there is a noticeable difference between the two analyses; however, this occurs over a very short crack extension length. After the first breakthrough condition, the difference increases as the crack length increases. The finite width of the finite element model contributes to this increasing difference. To validate the crack growth calculations, the crack growth was determined for a generic spectrum using the cycle-by-cycle crack growth model in RAPID and compared with a representative original equipment manufacturer (ROEM) approach. In general, the results are in good agreement.

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