

cracks can cause the degradation of matrix-dominated properties. For laminates designed to transmit loads with their fibers (fiber dominant), only a slight reduction of properties is observed when the matrix is severely damaged. Matrix cracks, or microcracks, can significantly reduce properties dependent on the resin or the fiber-resin interface, such as interlaminar shear and compression strength. Micro-cracking can have a very negative effect on properties of high-temperature resins. Matrix imperfections may develop into delaminations, which are a more critical type of damage.

Delamination and Debonds

Delaminations form on the interface between the layers in the laminate. Delaminations may form from matrix cracks that grow into the interlaminar layer or from low-energy impact. Debonds can also form from production nonadhesion along the bondline between two elements and initiate delamination in adjacent laminate layers. Under certain conditions, delaminations or debonds can grow when subjected to repeated loading and can cause catastrophic failure when the laminate is loaded in compression. The criticality of delaminations or debonds depend on:

- Dimensions.
- Number of delaminations at a given location.
- Location—in the thickness of laminate, in the structure, proximity to free edges, stress concentration region, geometrical discontinuities, etc.
- Loads—behavior of delaminations and debonds depend on loading type. They have little effect on the response of laminates loaded in tension. Under compression or shear loading, however, the sublaminates adjacent to the delaminations or debonded elements may buckle and cause a load redistribution mechanism that leads to structural failure.

Combinations of Damages

In general, impact events cause combinations of damages. High-energy impacts by large objects (e.g., turbine blades) may lead to broken elements and failed attachments. The resulting damage may include significant fiber failure, matrix cracking, delamination, broken fasteners, and debonded elements. Damage caused by low-energy impact is more contained, but may also include a combination of broken fibers, matrix cracks, and multiple delaminations.

Flawed Fastener Holes

Improper hole drilling, poor fastener installation, and missing fasteners may occur in manufacturing. Hole elongation can occur due to repeated load cycling in service.

In-Service Defects

In-service defects include:

- Environmental degradation
- Impact damage
- Fatigue
- Cracks from local overload
- Debonding
- Delamination
- Fiber fracturing
- Erosion

Many honeycomb structures, such as wing spoilers, fairings, flight controls, and landing gear doors, have thin face sheets which have experienced durability problems that could be grouped into three categories: low resistance to impact, liquid ingress, and erosion. These structures have adequate stiffness and strength but low resistance to a service environment in which parts are crawled over, tools dropped, and service personnel are often unaware of the fragility of thin-skinned sandwich parts. Damages to these components, such as core crush, impact damages, and disbonds, are quite often easy to detect with a visual inspection due to their thin face sheets. However, they are sometimes overlooked or damaged by service personnel who do not want to delay aircraft departure or bring attention to their accidents, which might reflect poorly on their performance record. Therefore, damages are sometimes allowed to go unchecked, often resulting in growth of the damage due to liquid ingress into the core. Nondurable design details (e.g., improper core edge close-outs) also lead to liquid ingress.

The repair of parts due to liquid ingress can vary depending on the liquid, most commonly water or Skydrol (hydraulic fluid). Water tends to create additional damage in repaired parts when cured unless all moisture is removed from the part. Most repair material systems cure at temperatures above the boiling point of water, which can cause a disbond at the skin-to-core interface wherever trapped water resides. For this reason, core drying cycles are typically included prior to performing any repair. Some operators take the extra step of placing a damaged but unrepaired part in the autoclave to dry to preclude any additional damage from occurring during the cure of the repair. Skydrol presents a different problem. Once the core of a sandwich part is saturated, complete removal of Skydrol is almost impossible. The part continues to weep the liquid even in cure until bondlines can become contaminated and full bonding does not occur. Removal of contaminated core and adhesive as part of the repair is highly recommended. [Figure 7-21]