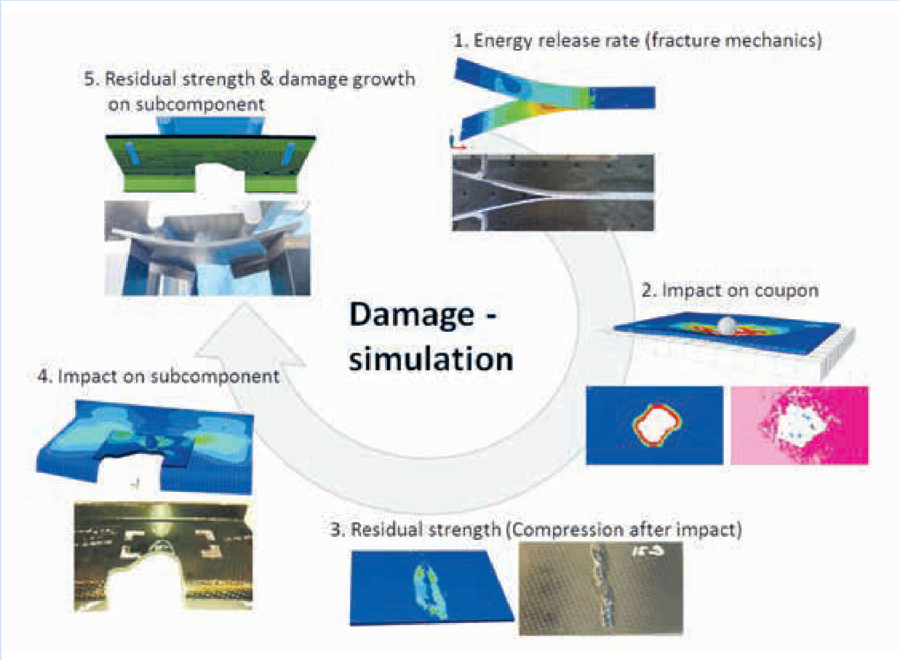
HOW TO SIMULATE DAMAGE

Damage simulation methods and their industrial applications for aircraft structures

Aircraft industry is striving for lightweight structures which often results in complex composite parts. Corresponding simulation methods are evolving constantly, and their industrial applications are stretching from well-known strain criteria to latest, sophisticated delamination and fatigue predictions.

The damage and failure behaviour of composite structures is complex and not yet fully characterized. This is especially true for multi-directional loading conditions, post-failure behaviour and damage propagation. Nevertheless, developers want to keep pace with demanding requirements and, if engineered with appropriate methods, composite can be the superior material.



Airbus-Systematic comparison of damage simulation and physical test

A small history of damage simulation

Classical composite simulation with Finite Element Methods (FEM) is performed with shell elements and laminate theory together with stress or strain based failure criteria. Stability failure modes can also be captured. Such methods allow sizing of thin walled structures, mostly loaded in-plane. Typical structures like airplane fuselages are mainly sized with these methods.

To allow the prediction of post failure behaviour of composite structures, damage models have been developed that use a set of failure criteria for different damage modes in each ply. Once failure occurs, the in-plane stiffness matrix of each ply is degraded. These methods have been implemented in many commercial FEM programs in the recent years and are used in the aerospace industry. Examples are bird strike and crash simulations of helicopters.

Composites are different

The above mentioned methods do not allow simulating delamination of composite structures. Although this failure mode should be avoided by appropriate design, it is relevant for damage tolerant aircraft structures because inevitable impacts from various sources are causing delamination. Industry is still relying on tests to predict these failure modes. However, in recent years, adhesive contact models together with fracture mechanic models have been developed for commercial FEM codes and promising results have been generated.

Inside and outside

While carbon composites have excellent in-plane fatigue resistance, out-of plane cyclic loading should be avoided. Delamination caused by fatigue has hardly been studied in composites but there are some industrial applications where this phenomenon becomes a driving factor

An example is the rotor head of the Airbus Helicopters H160. It is a relatively thick part, loaded by cyclic bending and shear. A thermoplastic matrix has been chosen because of its better fatigue resistance compared to epoxy. There is no established simulation method available to predict the damage growth and lifetime of such a part.

But inter-laminar stresses can be predicted accurately. Based on tests with simple specimens loaded by representative stress, the service live can be estimated and certification is accomplished by full component test.

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