Case Study: Alenia Aermacchi

Accounting for Successive ply Failure in Composite Laminates

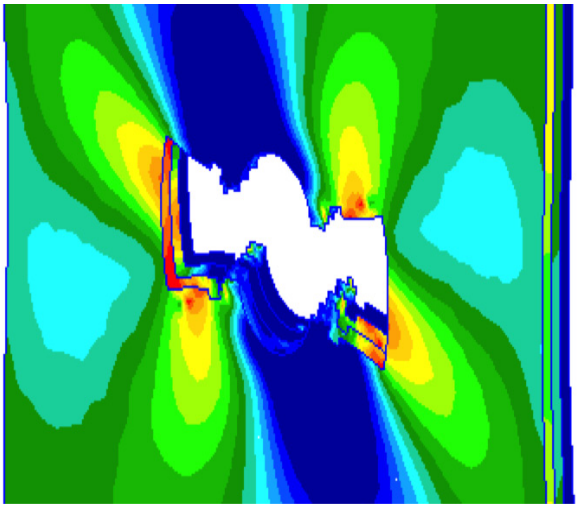
Challenge

Continuous fiber composites are much more complex than metal, with respect to failure in particular. If they are so-called unidirectional (UD), they involve stacks of several plies, each ply being characterized by a single fiber orientation.

Hence they fail because of various mechanisms taking place at the ply level (matrix cracking, fiber breakage, fiber-matrix debonding) or between the plies (delamination). These mechanisms are investigated often through costly and time consuming experimental testing and can be now studied also with virtual testing.

This complexity is usually not captured by simulation so that UD composite material properties are currently obtained only from physical testing, requiring high investments in time and money.

Alenia Aermacchi, as a leader in the aerospace industry, faces these issues and has successfully applied a progressive failure model to the simulation of an open-hole tensile test on a carbon-epoxy composite.



Towards virtual coupon testing with Digimat and MSC Nastran

"The integration of progressive damage models, like Matzenmiller-Lubliner-Taylor model, in nonlinear multi-scale homogenization methods available in Digimat enables to predictively take into account constituent's properties and microstructure influences over material performance and accurately compute stresses in these constituents."

- Salvatore Russo, Stress analyst, Airframe, Alenia Aermacchi

Solution

Digimat, effective modeling solution

To accurately predict the properties of UD composites, Digimat advantageously combines micromechanics, deriving composite properties from constituent properties through mean-field homogenization, and progressive failure.

At the constituent level, Digimat is employed to define and reverse-engineer the matrix – e.g. epoxy – and fiber – e.g. carbon – stiffnesses. At the ply level, it uses a Hashin failure criterion to compute damages in matrix and fiber constituents In addition, it enables a stiffness reduction according to the Matzenmiller-Lubliner-Taylor model.

Typically it is employed to build material models on nominal constituent properties and then calibrated on measured lamina properties, usually tension/compression tests on 0° /90° coupons. Digimat is then coupled to a finite element solver to provide the solver with the material properties. Such coupled analyses can be run for implicit or explicit solvers.

Digimat interfaces with all major FEA solvers and bridges the gap between the manufacturing process and the structural performances of parts. For instance, fiber orientation computed when simulating the manufacturing process can be given as an input to the structural simulation and serves Digimat at computing accurately the local properties of the composite material based on the local orientation of the fibers. With information given by the FE solver, such as strain increments, Digimat calculates stress increments according to above-described material model.

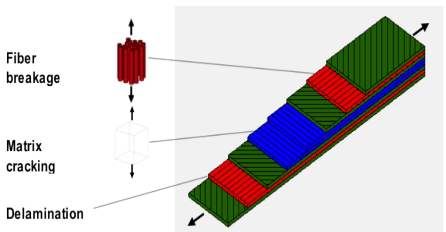


Figure 1: Failure a UD laminate under tensile loading. Various mechanisms occur in and between plies

Taking into account the specific requirements of test standards and the systematic collection of experimental data, Digimat enables a high level of automation for the purpose of computing material properties.

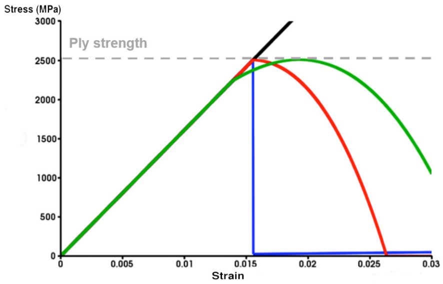


Figure 2: Stiffness reduction according to different damage laws fo Matzenmiller-Lubliner-Taylor model

Results/Benefits

Compute stresses accurately

In the example of a quasi-isotropic open-hole tensile test simulation, Digimat's progressive failure model enables to account for the ply failure sequence. This sequence involves first damage initiation in 90° plies, then in 0° plies. It yields a stress-strain response whose maximum reaches the experimental tensile strength. The pattern of maximum principal stresses is different between transverse and longitudinal oriented plies. Damage evolves following the increase of the load and material stiffness is reduced accordingly from one time step to the other.

Key Highlights:

Digimat:
Digimat-MF, Digimat-CAE

Customer:
Alenia Aermacchi

CAE Technology:
MSC Nastran, Marc, Abaqus...

Industry:
Aerospace

Application:
Virtual Property Prediction

Performances:
Stiffness & failure

The use of Digimat's progressive failure modeling has proven to be very effective in capturing the actual end behavior of continuous fiber composite laminate failure.

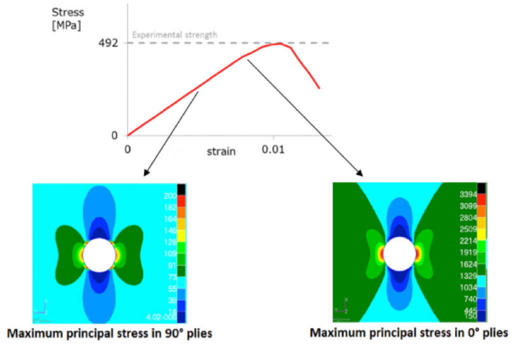


Figure 3: Progressive failure enables to account for the failure sequence involving damage initiation in 90° plies and ultimate failure after failure of 0° plies

For more information on Digimat and for additional Case Studies, please visit www.e-Xstream.com

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