Low-velocity impact on fibre-metal laminates

PhD Candidate: Freddy Morinière
Department: ASM
Section: Structural Integrity & Composites
Supervisor: R.C. Alderliesten
Promoter: R. Benedictus
Start date: 01-10-2009
Funding: TU Delft
Cooperation: NL Agency

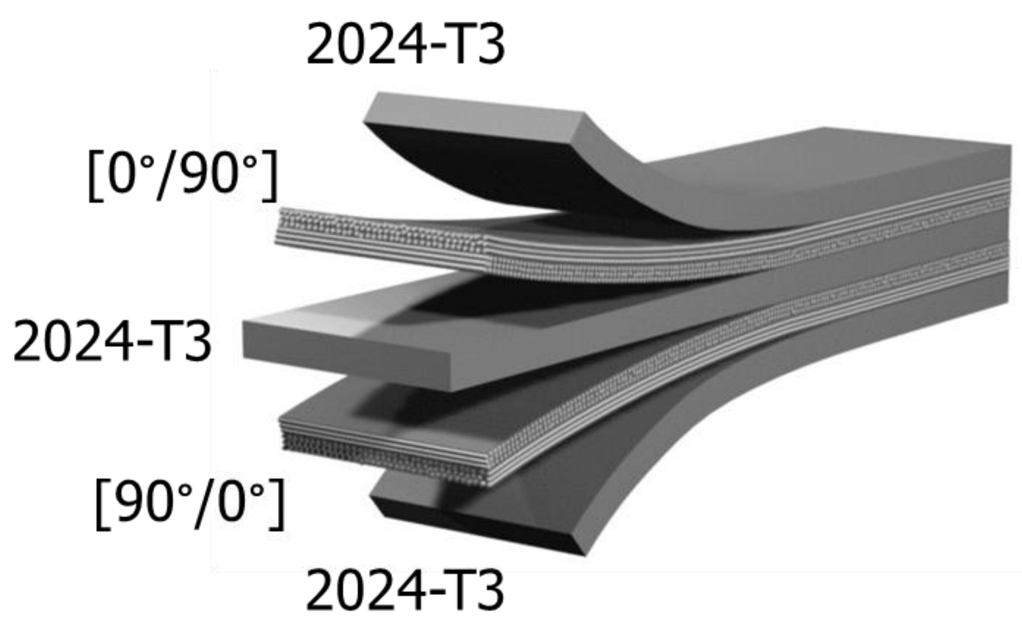
Aerospace Engineering

Background

Low maintenance costs and high reliability are key aspects for lightweight aircraft structures.

Cargo interiors suffer from many impacts on the floors and walls during ground handling operations. It is therefore necessary to develop enhanced material/manufacturing concepts for low-cost and "care free" cargo interior panels with improved impact performance.

The damage tolerant GLARE fibre-metal laminate and its derivatives can face this challenge for current aircraft and successors.



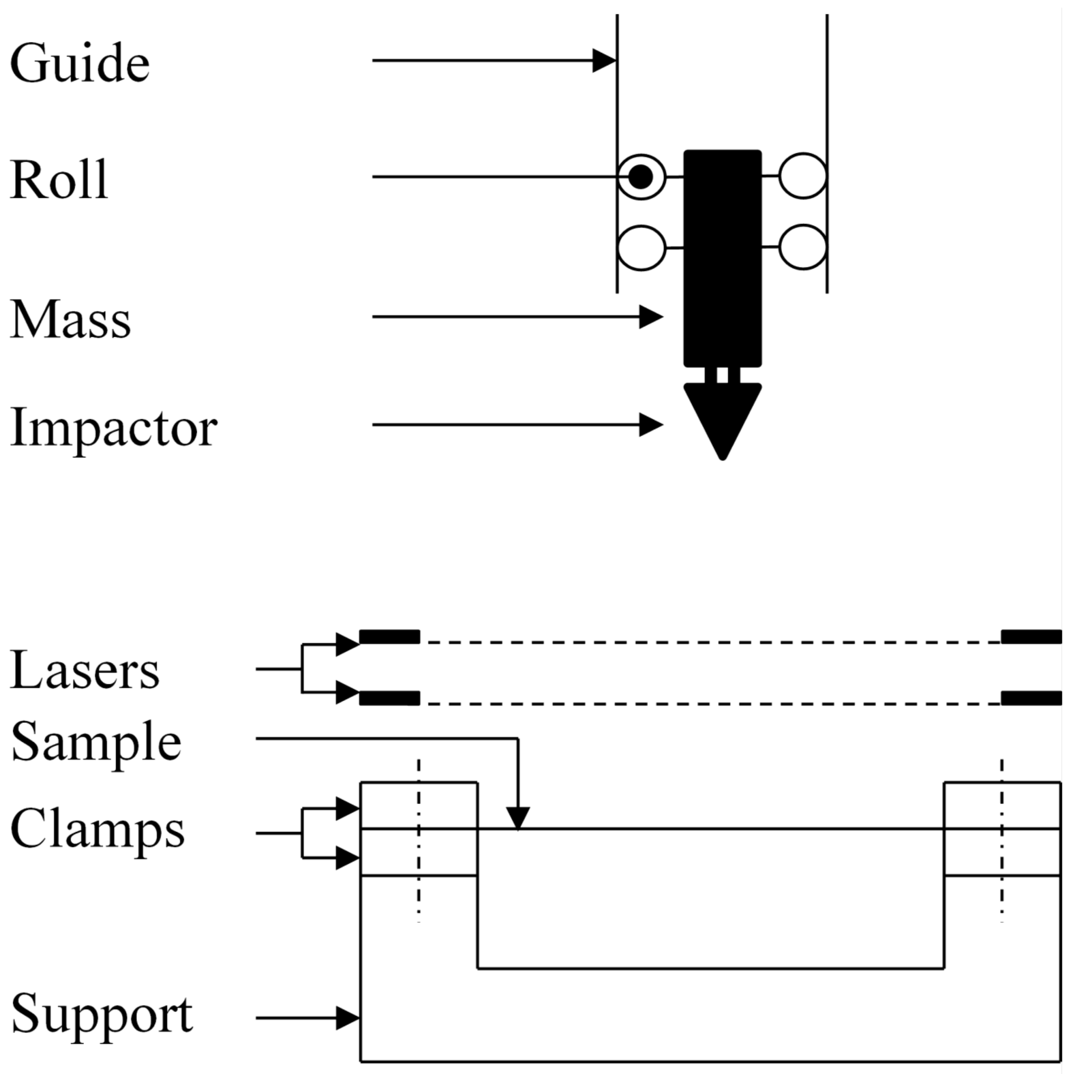
Example of a GLARE 3-3/2-0.4 lay-up

Test method

Below is illustrated the in-house instrumented drop-weight test set-up.

The velocity of the impactor nose prior to impact was measured as it interrupted the two laser beams separated by a known distance. The contact force F(t) between impactor and sample was measured by a load cell located inside the impactor nose. This force signal was integrated numerically to obtain the velocity V(t), displacement D(t), and absorbed energy E(t). The measuring and processing program is based on the Fasanella data filtering technique.

Rectangular plates were clamped between two square frames of 160 mm by 160 mm with a 125 mm by 75 mm opening. A conical-shaped steel mass of 1 kg with a hemispherical nose hit the centre of the samples.



Schematic of the drop-weight tower

Modelling approach

Despite abundant numerical impact models, the way of using this modelling technique reflects the limited knowledge on the impact mechanics of FMLs. The role of the materials constituents and their interaction with impact conditions are yet to be clarified.

Explicit formulations are preferred to develop an analytical model. The Classical Laminate Theory is integrated into an energy balance model.

Model development

From the transverse displacement of a plate, it is possible to estimate internal strain energy and derive force.

This energy is balanced with the energy due to failure modes to obtain the absorbed energy.

Deformation profile of membrane stretching:

$$w(x,y) = \Delta(2x/a-1)^2(2y/b-1)^2$$

Strain energy form:

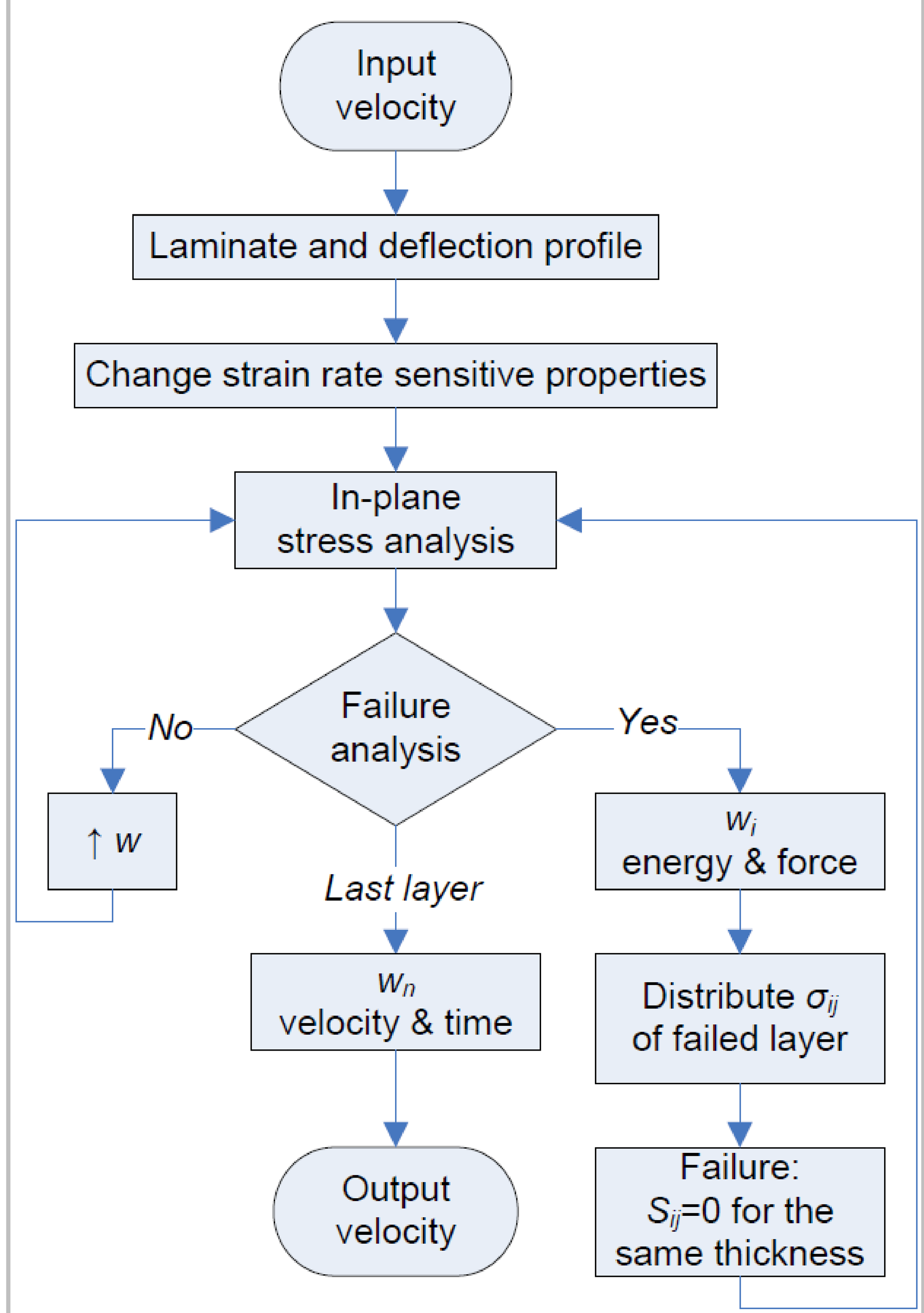
$$E_{deform} = \Delta^4 K_A + \Delta^3 K_B + \Delta^2 K_D$$

Derived impact load:

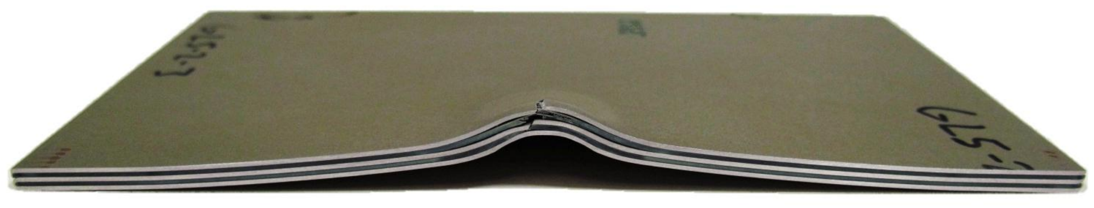
$$F = 4\Delta^3 K_A + 3\Delta^2 K_B + 2\Delta K_D$$

Energy balance between deformation and failure modes:

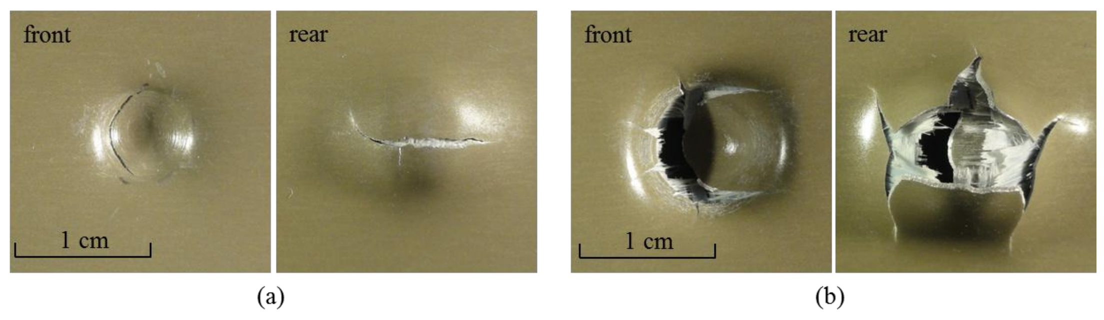
$$E_{deform} + E_{fail} = \frac{1}{2} M V_0^2$$



Failure process model



Out-of-plane deformation of GLARE



Damage stages in GLARE

Progress and Objectives

During 3.5 years, I performed research and engineering activities to answer this question:

How do the material constituents of FMLs contribute to the low-velocity impact energy absorption?

Research dissemination:
3 published scientific articles + 2 submitted
2 international conferences + 1 to be attended

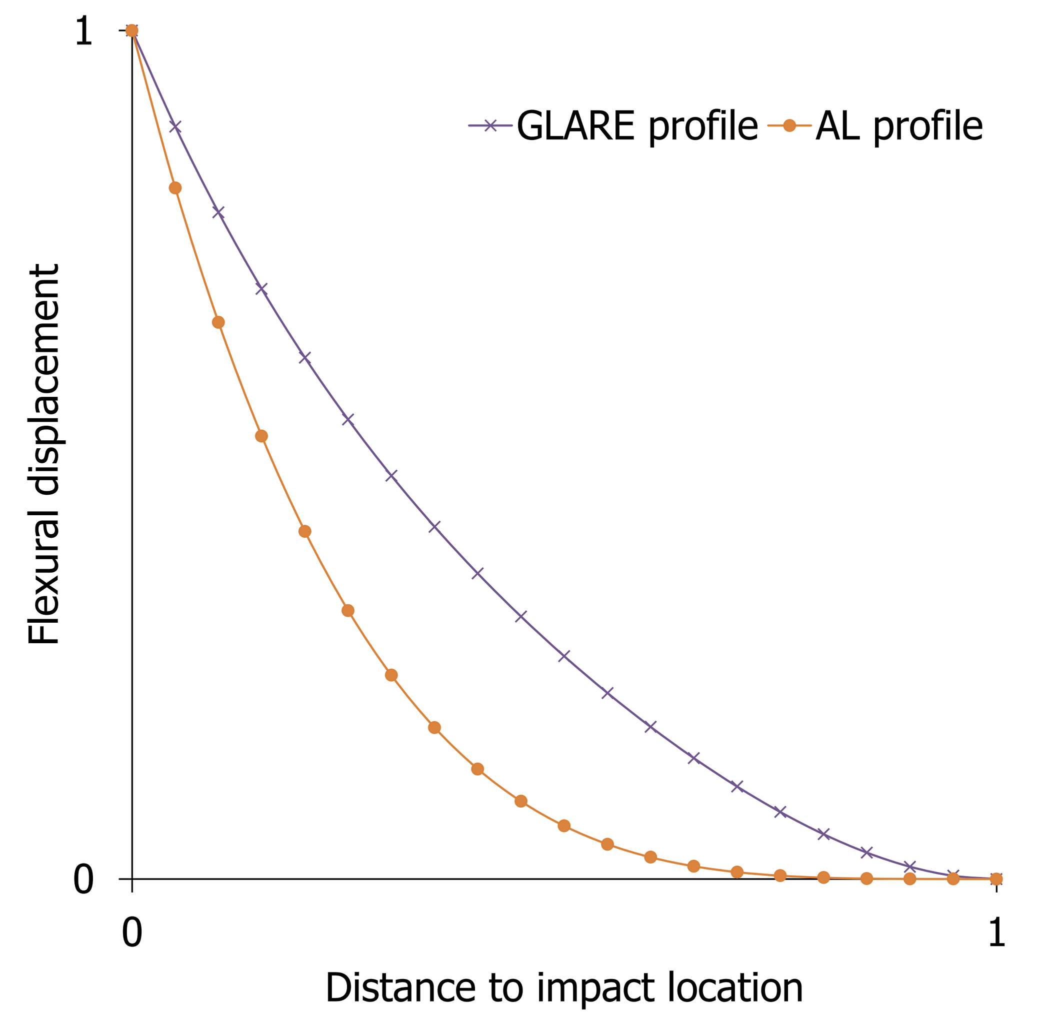
I expect to graduate next September 2013!

Research results

Successful analysis of aluminium, FML, and FML-sandwich. The generic method was verified with test results.

The high impact resistance of FMLs is due to the interaction between composite and metal:

- composite directs the impact load in the plate's plane;
- metal undergoes large displacement before fracture.



The disclosed secret of the durability of FMLs

Engineering results

Designing FMLs for impact resistance is becoming reality. Based on the developed technique, a concept offers 30% higher impact performance and is 10% lighter than its standard GLARE counterpart.

Publications

- C.D. Rans, F.D. Morinière, R. Rodi, R.C. Alderliesten, R. Benedictus, (2011) "Fatigue behaviour of Fiber Metal Laminate panels containing internal carbon tear straps," *Journal of Aircraft*, **48**(6), pp 2122-129
- F.D. Morinière, R.C. Alderliesten, R. Benedictus, (2012) "Development of fibre-metal laminates for improved impact performance," *The European Physical Journal - Special Topics*, **206**(1), pp79-88
- F.D. Morinière, R.C. Alderliesten, M. Yarmohammad Tooski, R. Benedictus, (2012) "Damage evolution in GLARE fibre-metal laminate under repeated low-velocity impact tests," *Central European Journal of Engineering*, **2**(4), pp 603-611, 2012
- F.D. Morinière, R.C. Alderliesten, M. Sadighi, R. Benedictus, (2013) "An integrated study on the low-velocity impact response of the GLARE fibre-metal laminate," *Composite Structures*, **100**(0), pp 89-103
- F.D. Morinière, R.C. Alderliesten, R. Benedictus, (2013) "Low-velocity impact energy partition in GLARE," *Mechanics of Materials*, submitted
- F.D. Morinière, R.C. Alderliesten, R. Benedictus, (2013) "Modelling of impact damage and dynamics in fibre-metal laminates – A review," *International Journal of Impact Engineering*, submitted

TU Delft — Delft University of Technology

Challenge the future