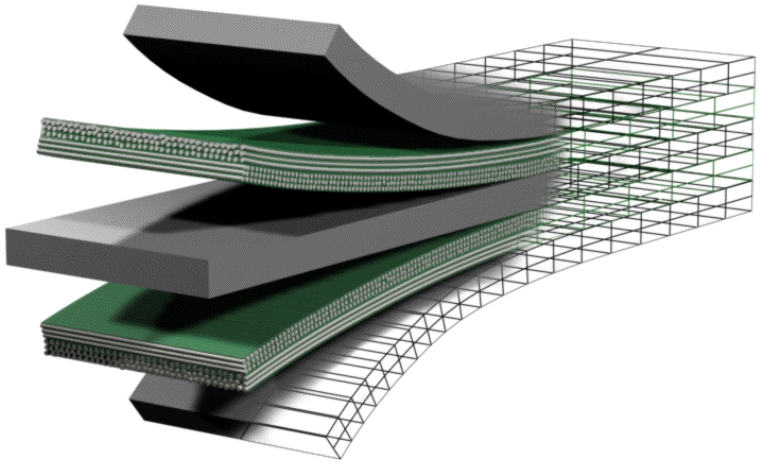
Numerical modelling of Glare



Implementation of the thermo-mechanical solid-like shell element in B2000

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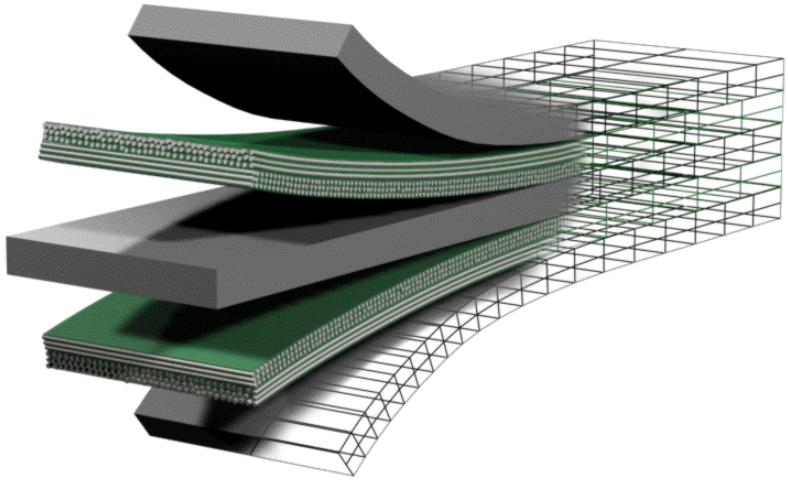
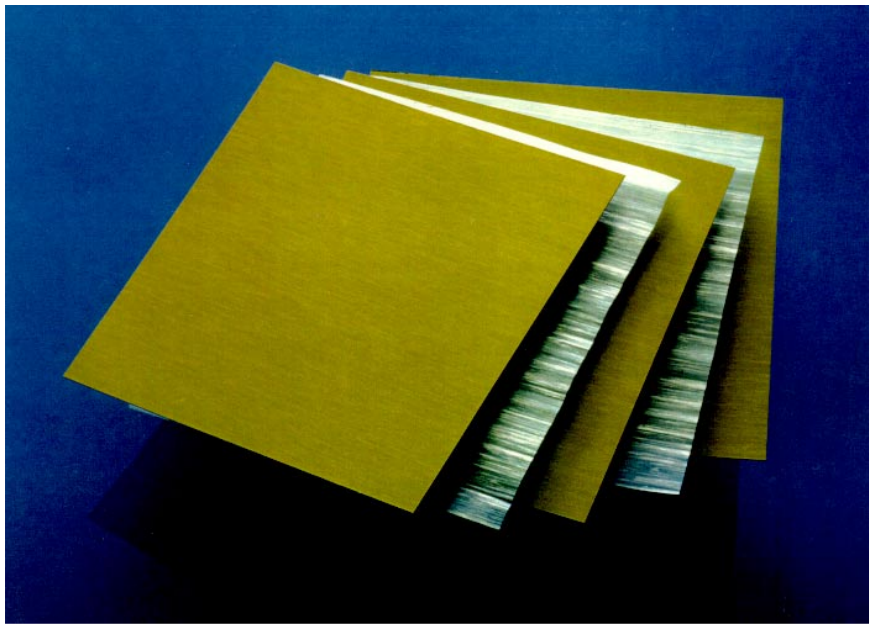


The Fibre Metal Laminate Glare

Glare, glass reinforced aluminium, consists of alternating layers of aluminium and glass fiber prepreg



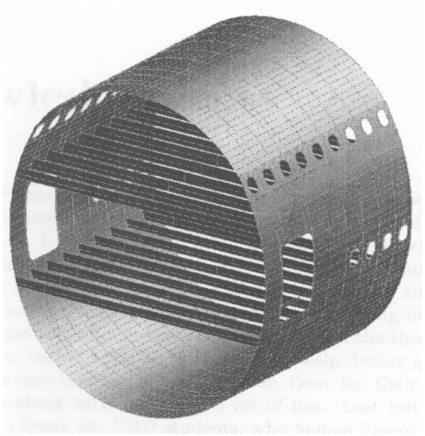
Main advantages:

- Damage tolerance
  - fatigue
  - impact
  - Corrosion
- Reduced weight
- Fire resistance

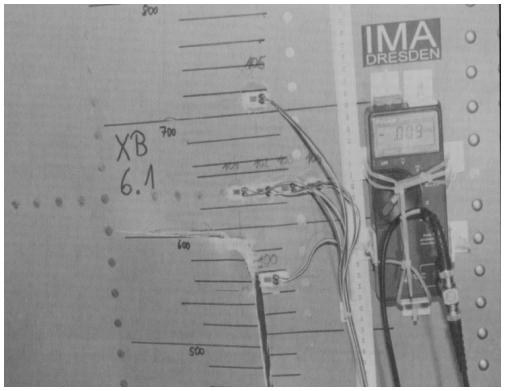
Scale of modelling

Three modelling scales

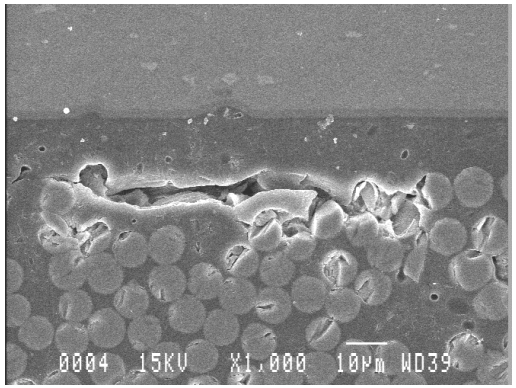
Macroscopic



Mesoscopic



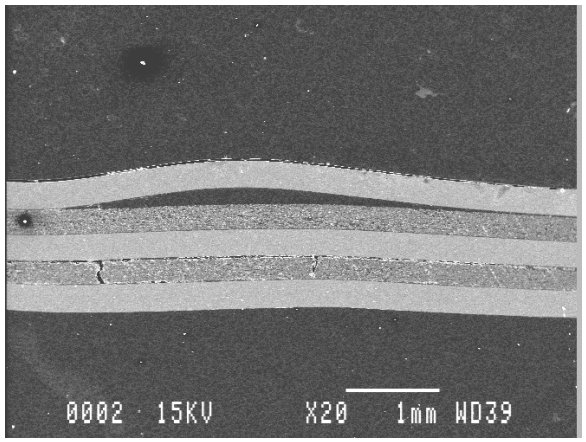
Microscopic

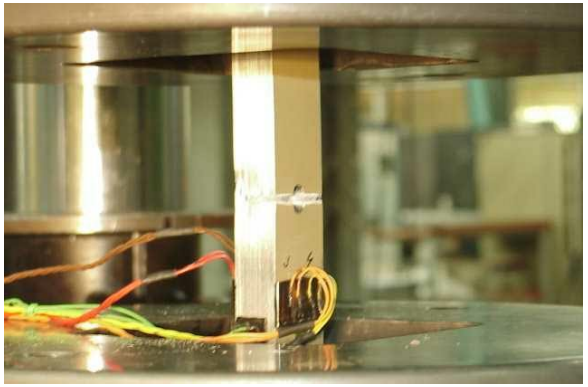


10 m — 10 µm

Scale of modelling

Mesoscopic scale





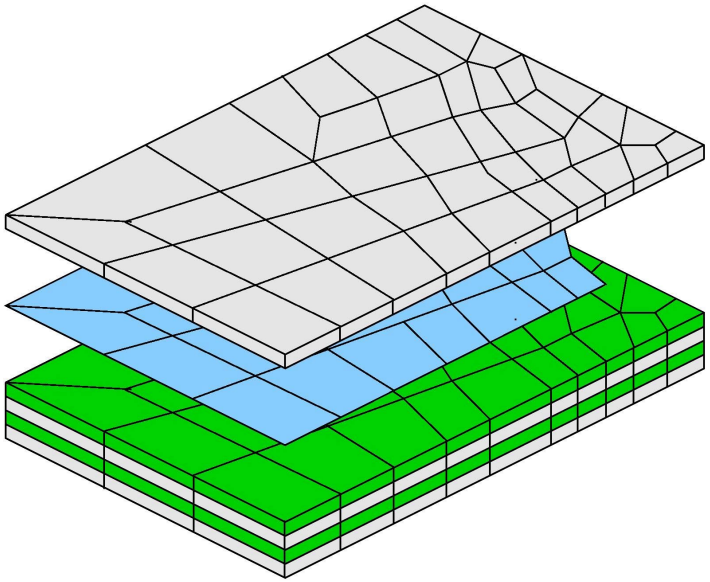
‘Intermediate’ level

- Length scale: 0.1 mm - 1 m
- Meeting ground of failure mechanisms and structural effects
- Finite element model
  - geometrically nonlinear
  - physically nonlinear

Examples

- Delamination buckling
- Blunt notch simulations
- Thermo-mechanical coupling

Mesoscopic model



Continuum elements

- Aluminium layers
  - orthotropic plasticity model
- Prepreg layers
  - orthotropic damage model

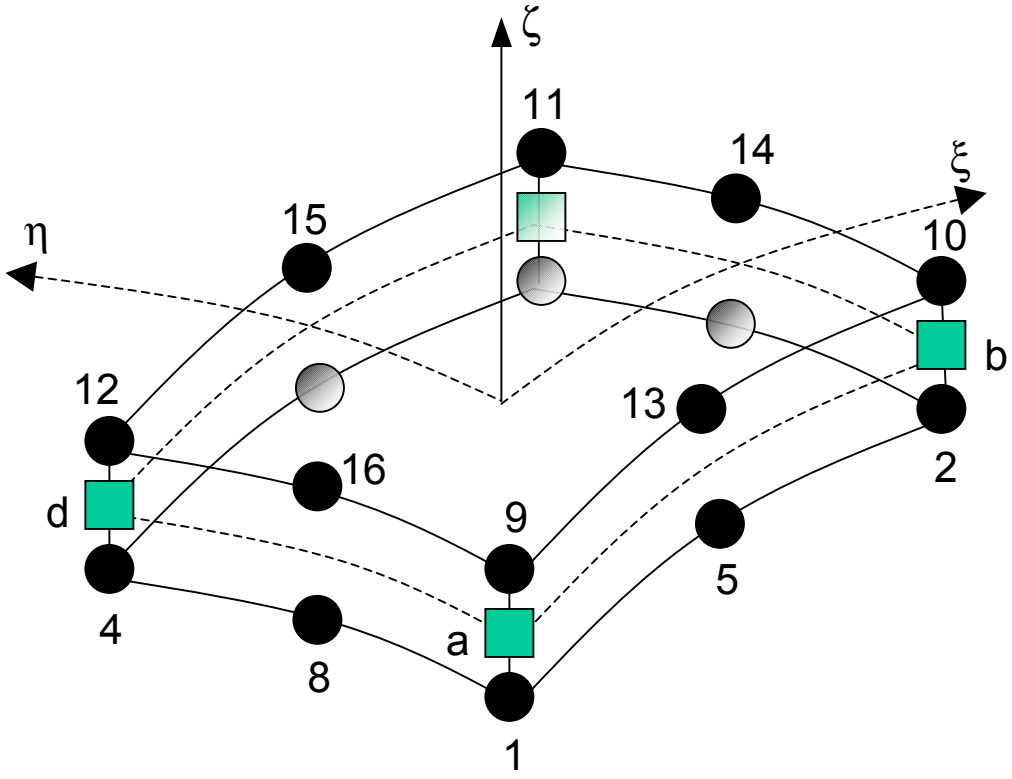
Interface elements

- Delamination
- Crack growth in aluminium

Static analysis

[Hashagen 1998]

The solid-like shell element



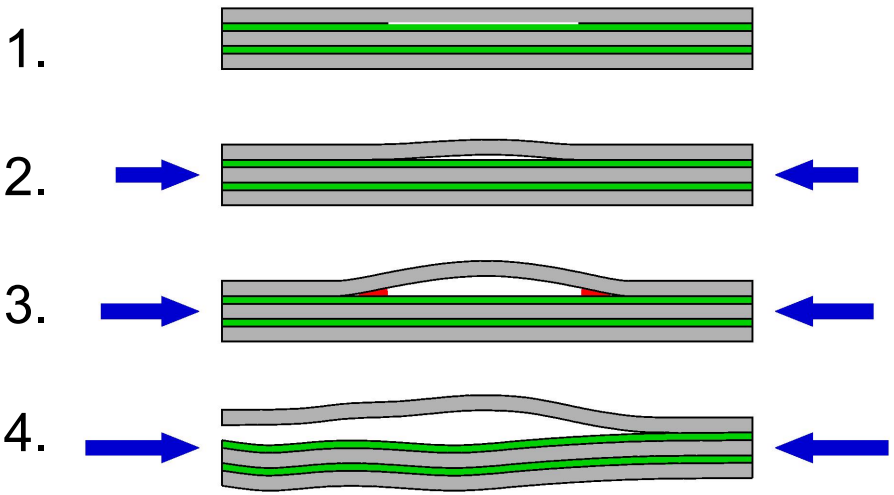
Properties:

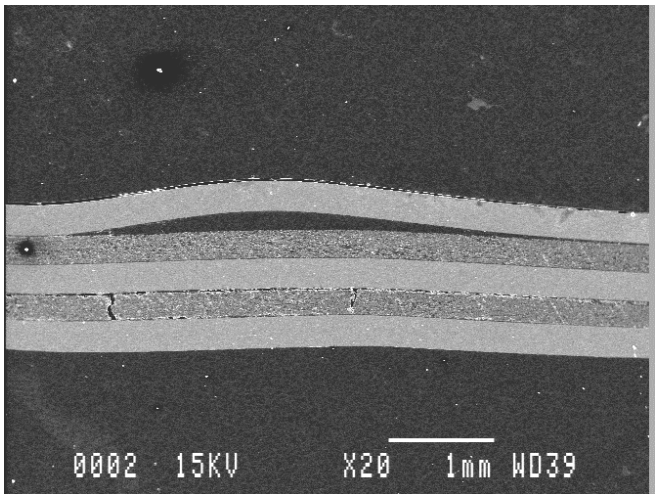
- 8 or 16 noded element
- 4 internal nodes:
  - quadratic displacement field in thickness direction

Main advantages:

- Modelling of delamination
  - with interface elements
- High aspect ratio
- No shear locking

Delamination buckling theory

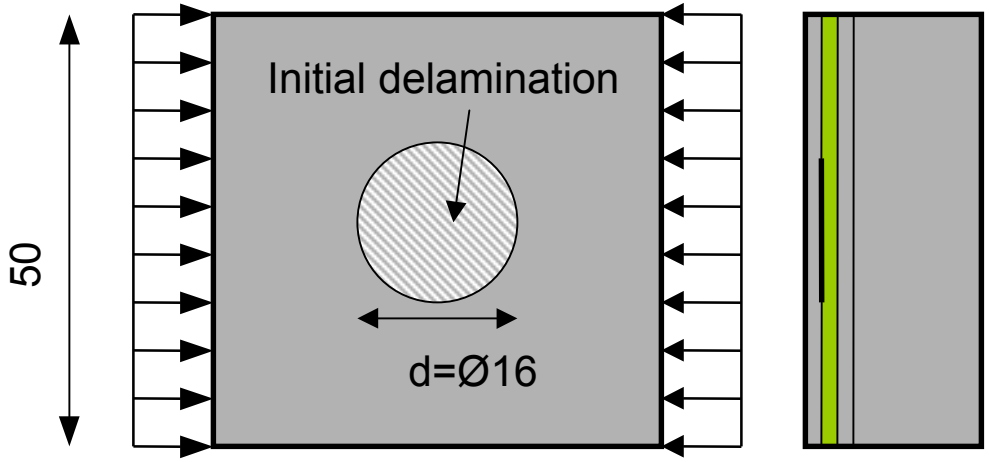


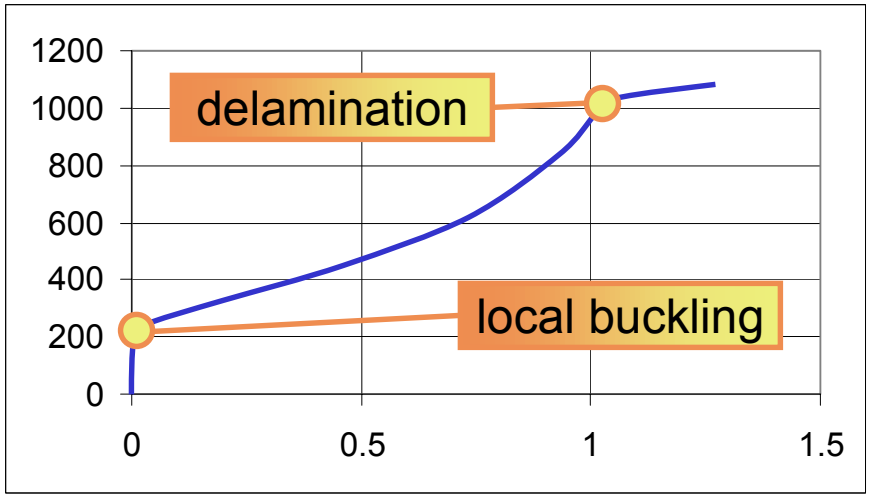


1. Initial delamination
   - production errors
   - impact damage
2. Buckling
3. Delamination growth
4. Failure

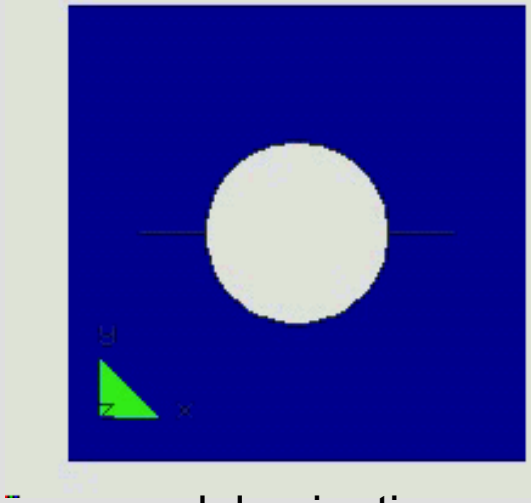
Applications

Delamination buckling analysis

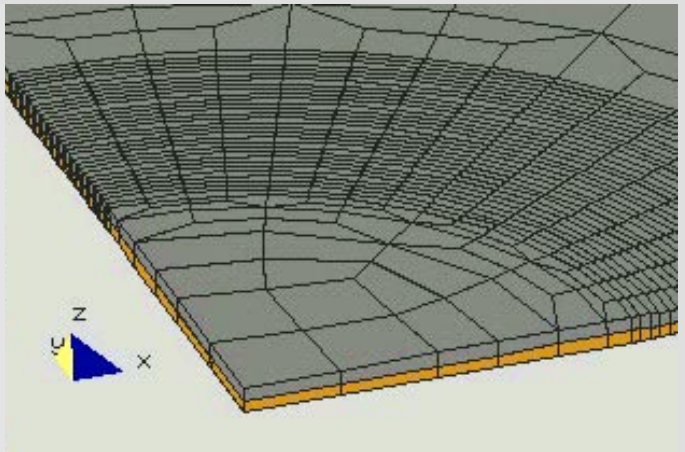




load vs. lateral displacement



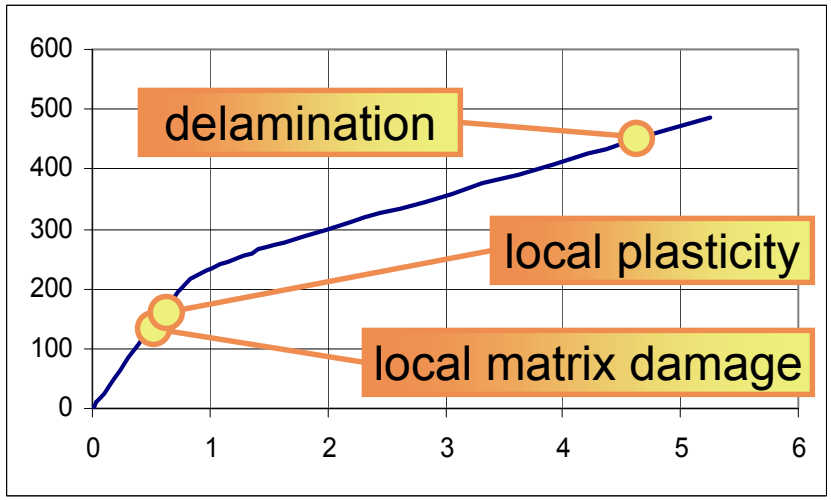
delamination



deformation

Applications

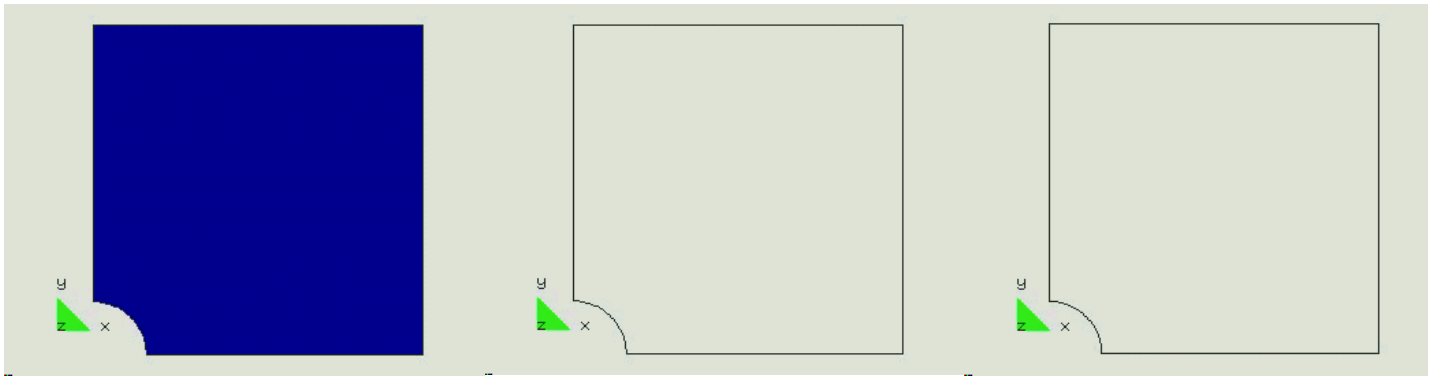
Blunt notch simulation



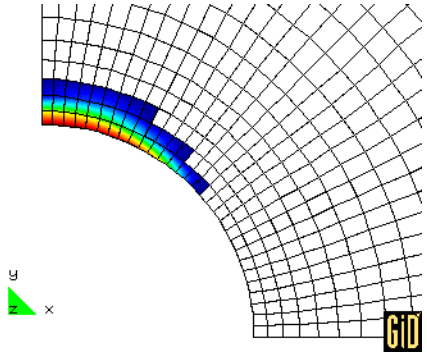
load-displacement curve

Output

- Load-displacement curve
- Stress field in all layers
- Damage in prepreg
- Interface tractions
- Delamination

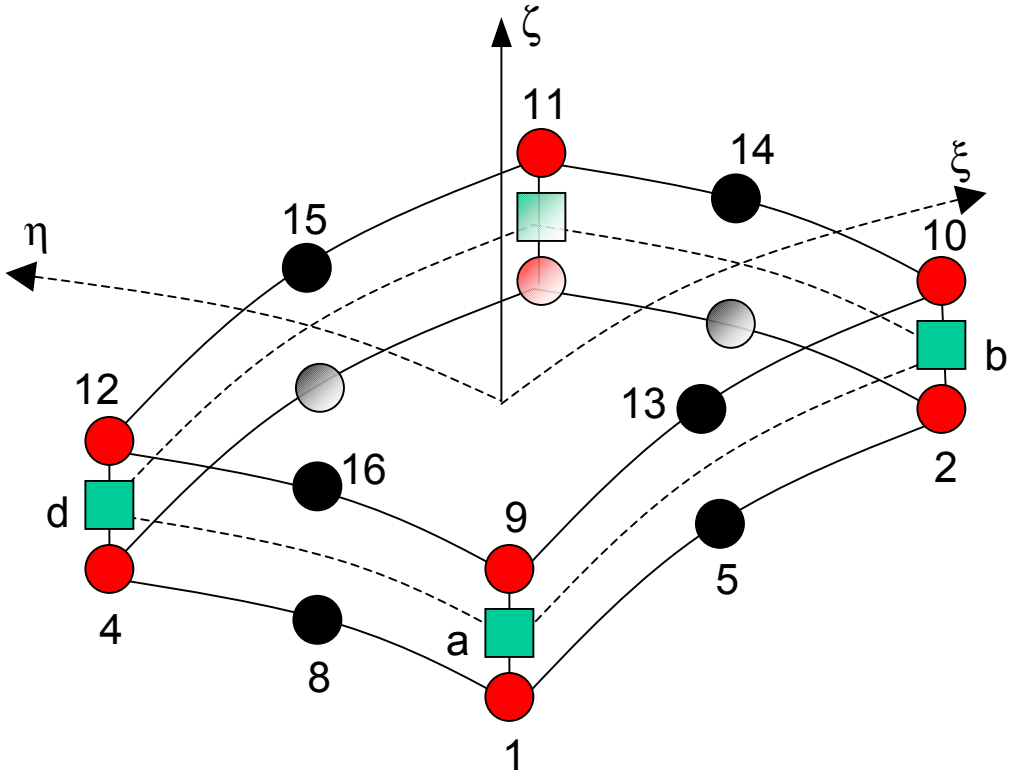


stresses in Al. | plastic strains | damage in prepreg



delamination

The extended solid-like shell element



Mechanical node

Thermo-Mechanical node

Internal node

Extended element properties:

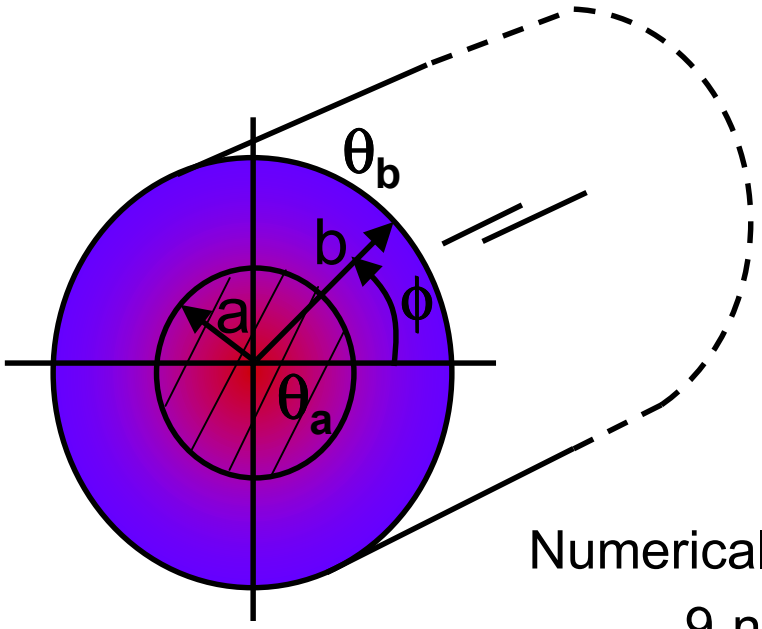
- 8 or 16 noded element
- Temperature at corner nodes
- Thermal expansion included
- Heat transfer due to conduction
  - T.B.D.

Main advantages:

- Thermal field calculation
- Effect of thermal field on mechanical properties:
  - Expansion
  - Degradation

Thick wall cylinder subjected to temperature

Analytical solution:



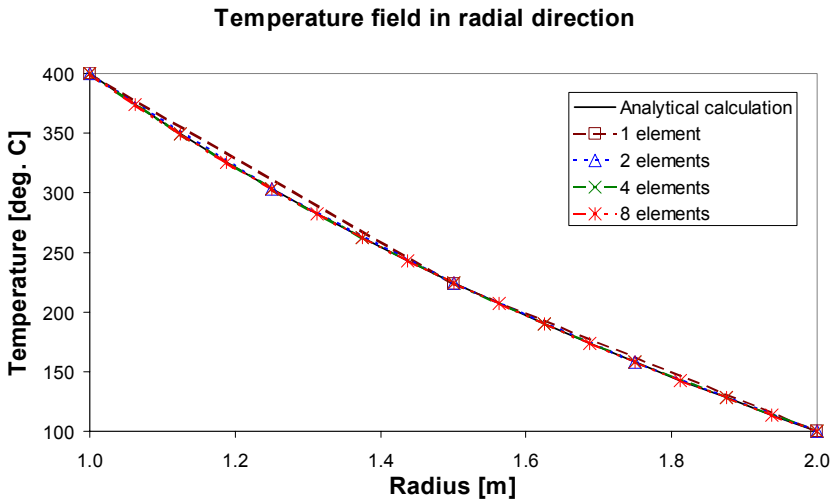
$$\theta(r) = \frac{1}{\ln b/a}\left(\theta_a \ln\frac{b}{r} + \theta_b \ln\frac{r}{a}\right)$$

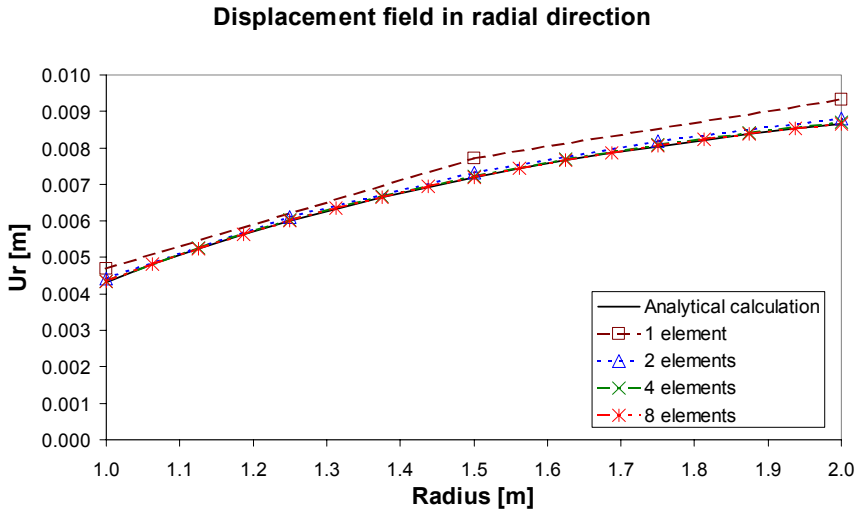
$$u_r = D_1 r + D_2 r \ln r + D_3 \frac{1}{r}$$

Numerical solution with B2000:

- 9-node thermo-mechanical element implemented
- Thermal expansion and heat conduction included

Numerical modelling | 9-noded continuum element





Comparison of solutions:

- Numerical solution in agreement with analytical solution
- Two elements already give accurate results for temperature and displacement field in the cylinder

Future research

Further extension of thermo-mechanical solid-like shell element:

- Implementation of heat conduction
- Verification with thick-wall cylinder subjected to temperature
- Temperature dependency of material properties will be included

Questions?