DLR German Aerospace Center
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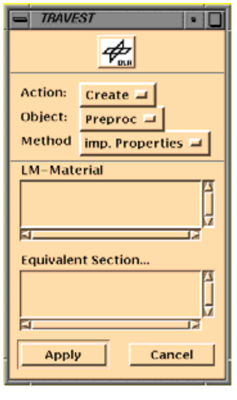
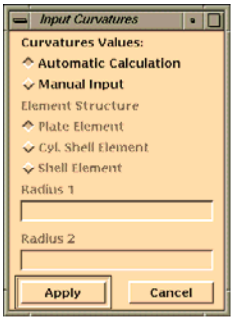
Institute of Composite Structures and Adaptive Systems

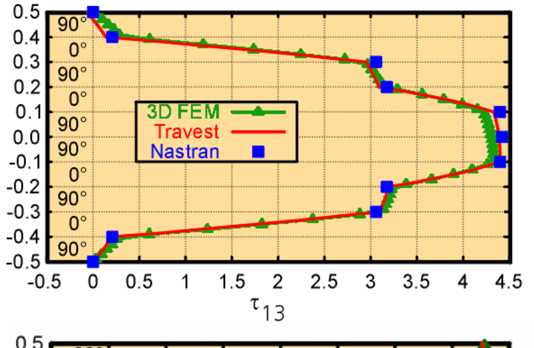
TRAVEST

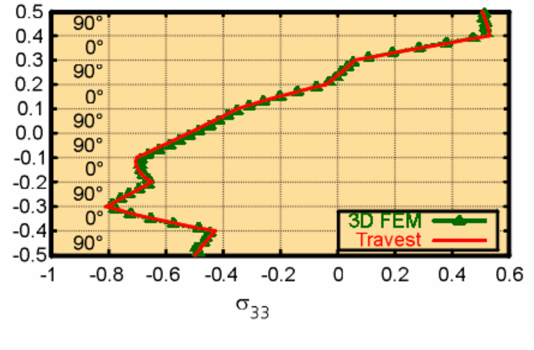
A computational tool for TRAnsVErse STress and failure calculations of composite structures based on a 2D shell analysis

Design and calculation of modern fibre reinforced composite structures require efficient tools. Furthermore, the consideration of failure plays an important role in the dimensioning process. TRAVEST establishes a fast and accurate methodology to calculate the full 3D stress tensor needed for the failure analysis, based on a 2D shell analysis. In addition to mechanical loading, thermal loads can be considered. For general and easy use the procedure is embedded in the MSC.PATRAN environment.









Improved transverse stiffness

In order to get most accurate results using standard shell elements, improved transverse shear stiffness is needed. For laminated composites this is an involved task. TRAVEST starts at pre-processing level to calculate the improved transverse shear stiffness which is subsequently assigned to the corresponding elements and stored in the MSC.PATRAN database. Then the global Finite Element calculation is started to determine the global displacement field.

Stresses

The full stress tensor is calculated using the global displacement field as input. The method is based on the “First Order Shear Deformation Theory” and uses equilibrium conditions for determining the transverse components within each Finite Element. The transverse shear stresses are calculated from the transverse shear forces whereas the transverse normal stress is evaluated from the transverse shear forces derivatives.

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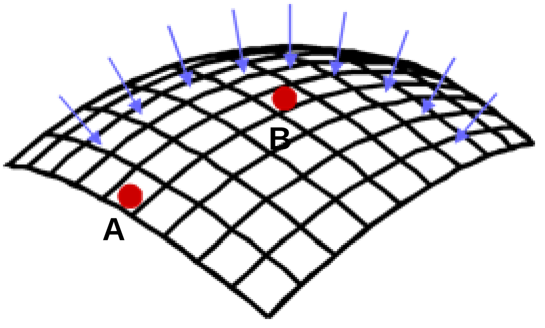


Loads and boundary conditions

Loads and Boundary Conditions have an effect on the transverse stress results calculated by TRAVEST. Standard functionality should be used to generate the required restraints and loadings. Additionally thermal loads can be defined. TRAVEST uses the following thermal distribution:

T(x,y,z) = T0(x,y) + z t(x,y)

where T0(x,y) is the temperature of the middle plane and t(x,y) the gradient in transverse direction.

Failure criteria

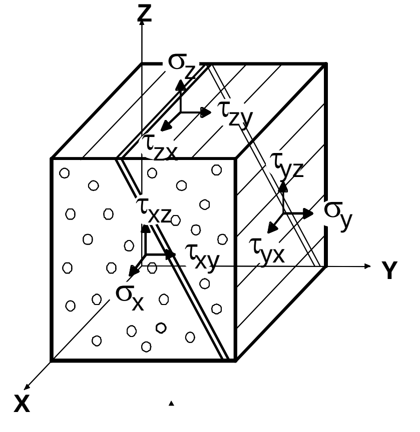
Currently 5 failure criteria for unidirectional composite layers under 3D stress are implemented in this version of TRAVEST:

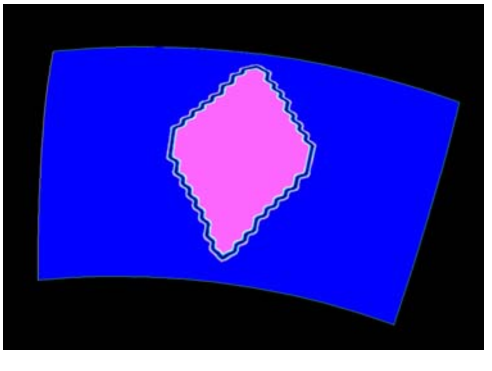
1. **Ts**ai-**W**u criterion (**TSW**),

which does not determine the failure mode and

2. Criterion of **Has**hin (**HAS**)
3. **I**nvariant **A**pproach of **C**untze (**IAC**)
4. **P**arabolic **C**riterion of **P**uck (**PCP**)
5. **S**imple **P**arabolic **C**riterion (**SPC**),

which distinguish between the failure modes
Fiber **F**racture (**FF**) and
Inter **F**iber **F**racture (**IFF**).





Margin of Safety

The failure criteria are macro-mechanical stress-based. Failure occurs for $F(f_R(\sigma)\cdot\sigma) \geq 1$, $f_R(\sigma)$ is computed as the reserve factor by which a stress state has to be multiplied to make the left side of equal to 1. Since the reserve factor becomes infinite for the numerically more advantageous reciprocal failure index or material effort of is used. The well known **M**argin **o**f **S**afety (**MoS**) links to both parameters:

$$MoS = f_R - 1 = 1/f_i - 1$$