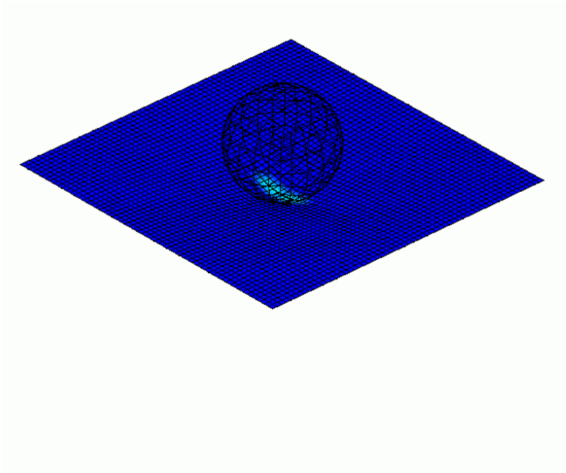
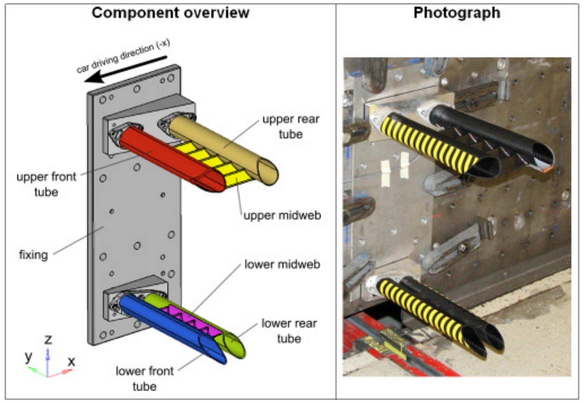
Materialmodellierung und Auslegung von Composite Strukturen für die Crash- und Impactsimulation

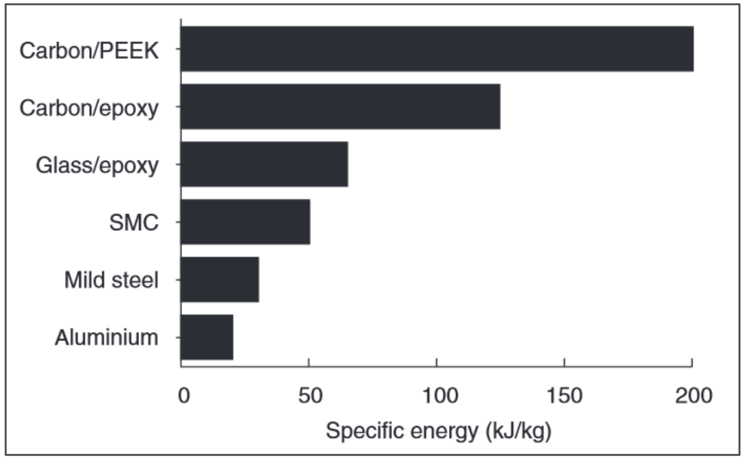


Agenda

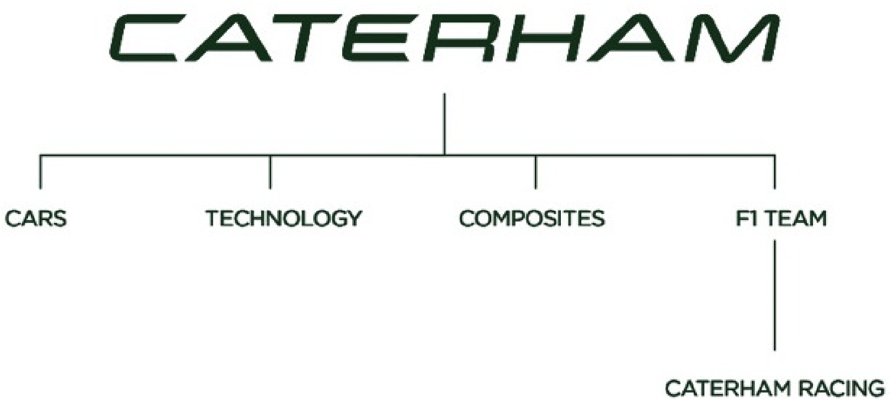
- **Materialmodellierung**
  - **Validierung einer Crashberechnung**
- Auslegung von Composite Strukturen
  - Beschnitt: Optimierung Size/Shape/Shuffling
  - Fertigung: Drapiersimulation



$$SEA = \frac{E_{absorbiert}}{m_{benötigt}}$$



Partner Caterham Composites

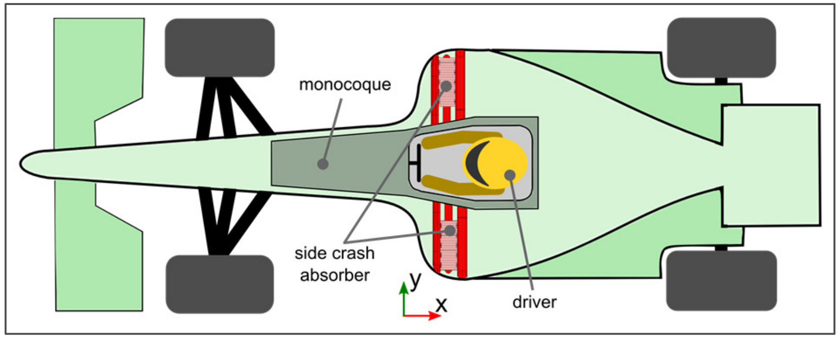


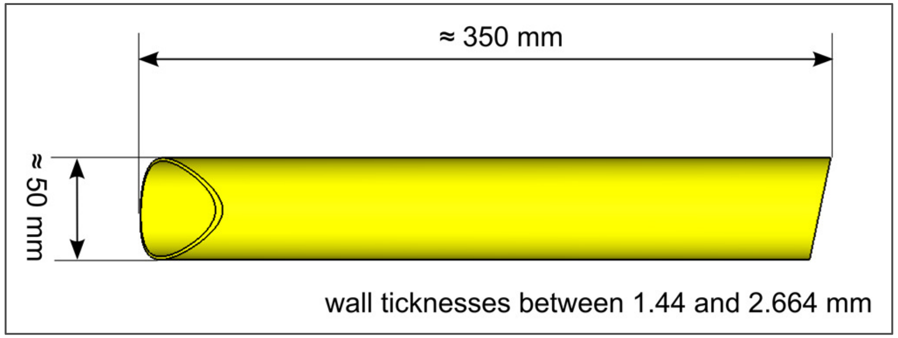
Lotus T127 Formel 1
Simulation dynamischer Seitencrash

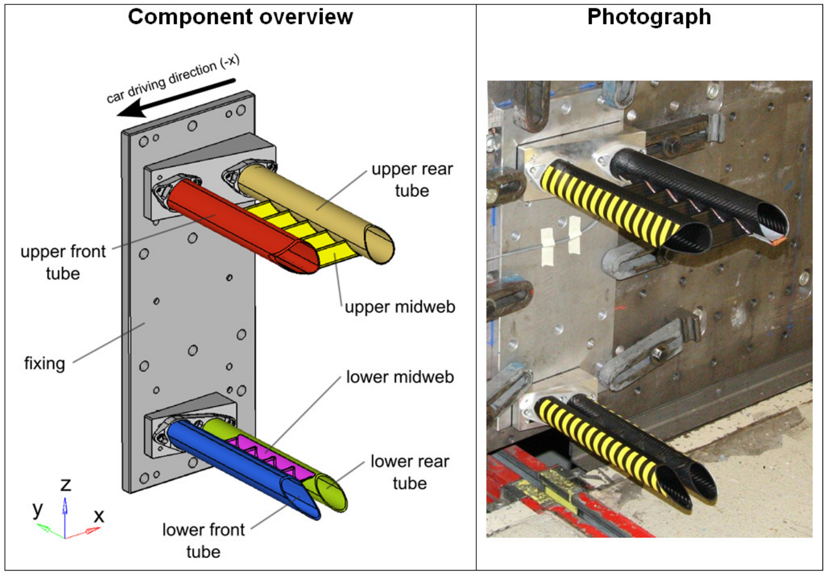
Gegenstand der Untersuchung

Paul Schischkin

Seitencrash-Absorber aus Kohlenstofffaser-Kunststoff-Verbund

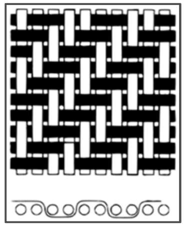


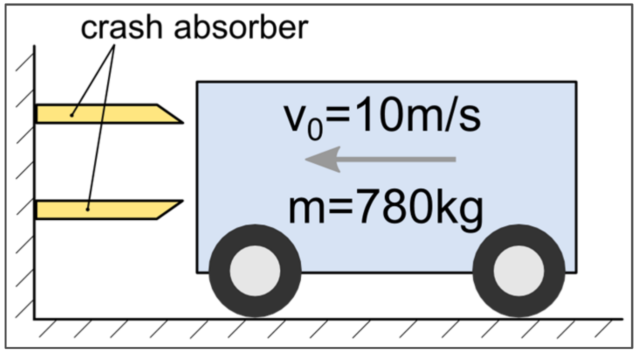




Laminatmaterial

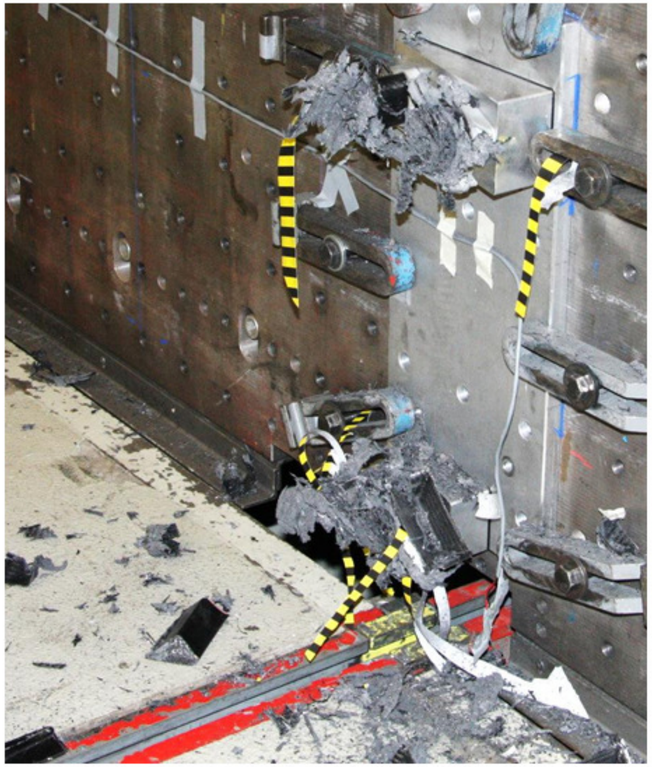
- **2x2 Twill Gewebe**





Gegenstand der Untersuchung

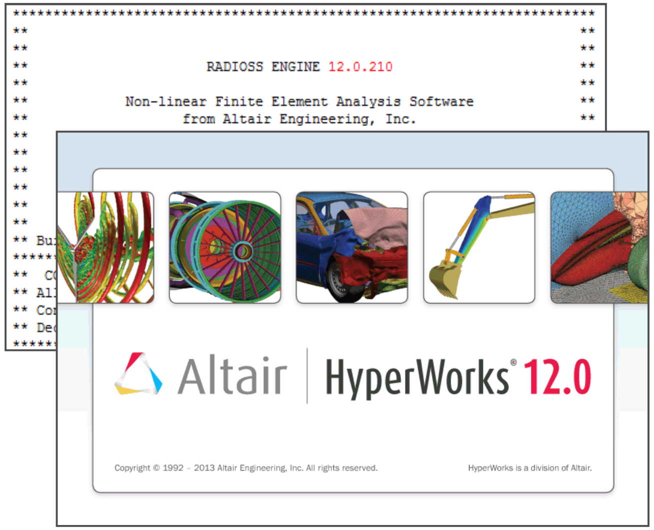
Realversuch Seitencrash: Vorher-Nachher-Vergleich

Before Impact	After Impact
	

Modellaufbau

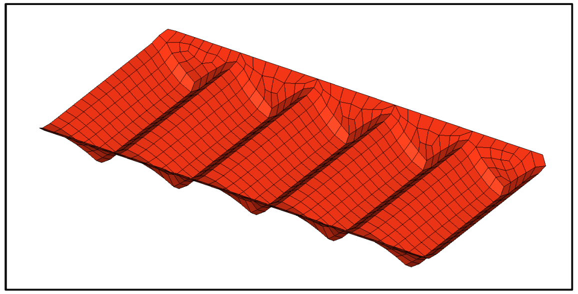
Paul Schischkin

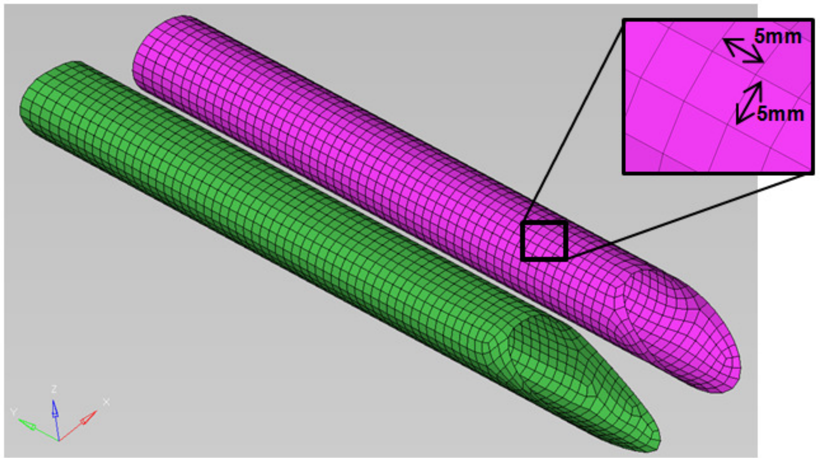
Solver: RADIOSS V12.0.210



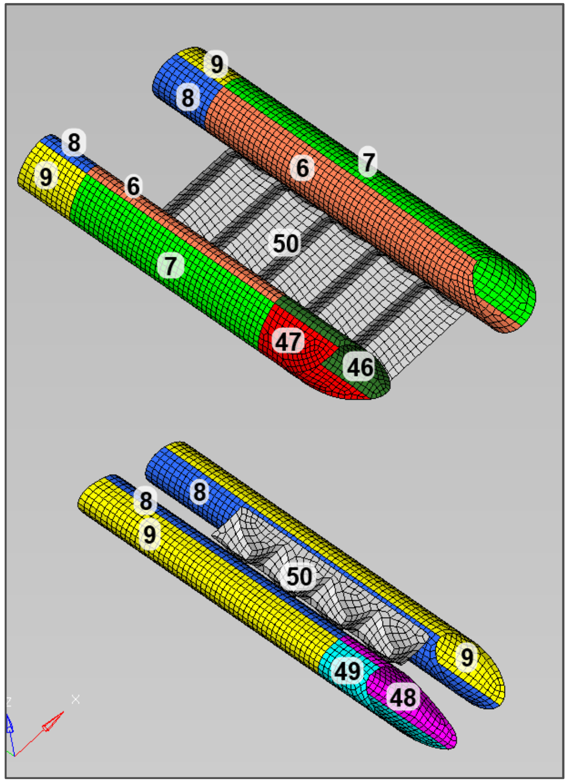
Vernetzung der Geometrie:

- Grundlage: CAD-Model
- 5x5mm 4-Knoten-Schalenelemente (quads)
- eine Schale pro Laminatdicke
- Anzahl: insgesamt ca. 7500 Elemente



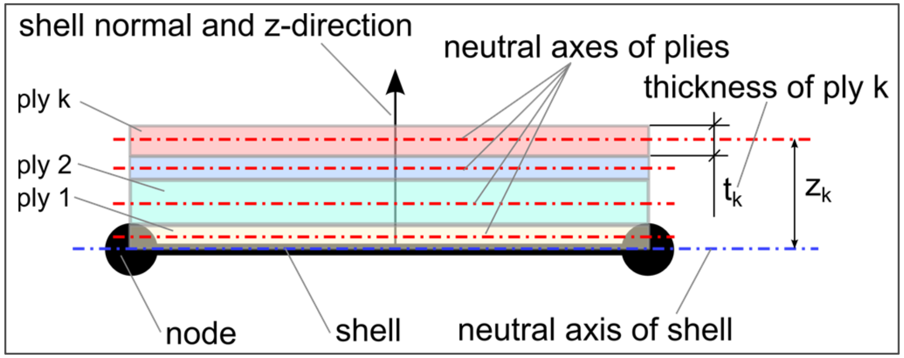


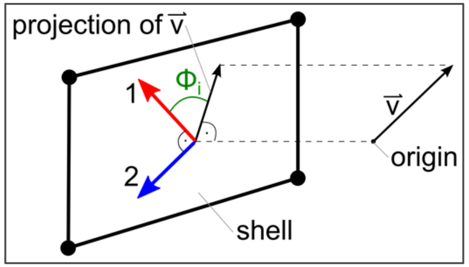
Modellaufbau



Elementeigenschaften (*properties*)**:**

- Definition des Laminataufbaus durch den Sandwich Schalen Ansatz
- Jede *property* erhält Informationen zu **Anzahl** der Lagen, sowie ihre jeweilige **Position, Dicke, Orientierung** und **Material**

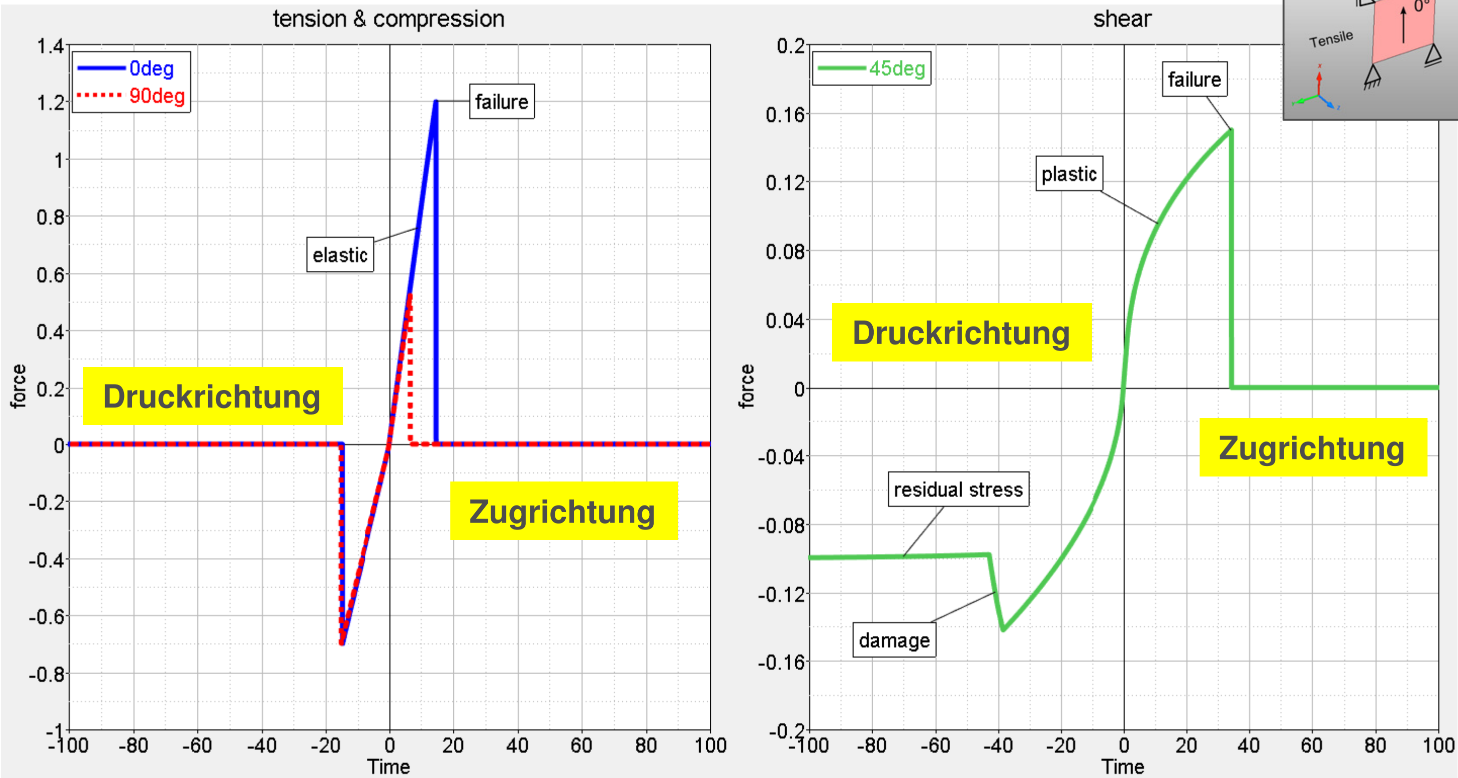


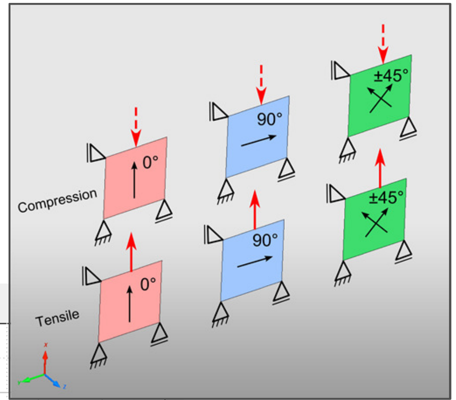


Modellaufbau

Materialmodell:

Elasto-plastisch-orthotrop (exemplarisch)





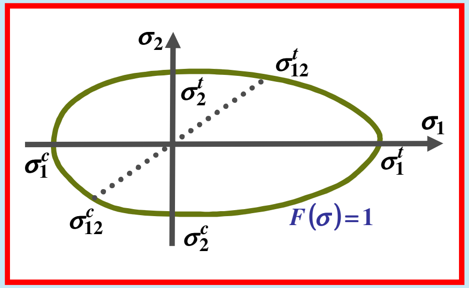
Radioss Composite Material Model

Linear

Nonlinear

```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/COMPSH/10
Altair composite material
#        Init. dens.          Ref. dens.
          1.5000E-6                    0
#              E11                  E22                  NU12    IFLAG               E33
                42                   40                   .05        1              0.50
#              G12                  G23                   G31                EPSF1               EPSF2
               3.4                    3                     3                    0                   0
#            ESPT1                EPSM1                 EPST2                EPSM2                Dmax
                 0                    0                     0                    0               .9999
#            Wpmax                Wpref      Ioff
                 0                    0         5
#                C                  EPS                 ALPHA                                      Icc
                 0                    0                     0                                        0
#       sig_trac_1                 B_1T                  N_1T           SIGMA_1MAXT               C_1T
               0.1                   25                   .10                    0                   0
#          EPS_1T1              EPS_2T1           SIGMA_RST1          Wpmax_trac_1
                 0                    0                     0                    0
#       sig_trac_2                 B_2T                  N_2T           SIGMA_2MAXT               C_2T
               0.1                   20                   .10                    0                   0
#          EPS_1T2              EPS_2T2           SIGMA_RST2          Wpmax_trac_2
                 0                    0                     0                    0
#       sig_comp_1                 B_1C                  N_1C           SIGMA_1MAXC               C_1C
             .0050                 2000                    .5                    0                   0
#          EPS_1C1              EPS_2C1           SIGMA_RSC1          Wpmax_comp_1
                 0                    0                     0                    0
#       sig_comp_2                 B_2C                  N_2C           SIGMA_2MAXC               C_2C
             .0050                 2000                    .5                    0                   0
#          EPS_1C2              EPS_2C2           SIGMA_RSC2          Wpmax_comp_2
                 0                    0                     0                    0
#           sig_12                B_12T                 N_12T          SIGMA_12MAXT              C_12T
             .0040                 83.0                   .31                    0                   0
#         EPS_1T12             EPS_2T12          SIGMA_RST12         Wpmax_trac_12
             0.075                0.085                  0.05                    0
#        GAMMA_INI            GAMMA_MAX                  Dmax
              1E31                 1E31                 .9999
#  Fsmooth              Fcut
         0                 0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```

Composite Material Model: Yield Stress

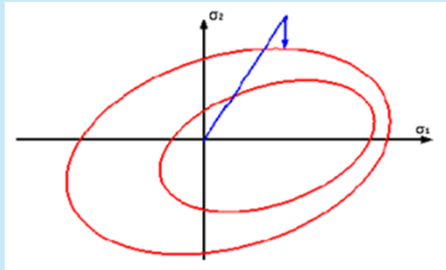



```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/COMPSH/10
Altair composite material
#        Init. dens.          Ref. dens.
          1.5000E-6                    0
#              E11                  E22                 NU12     IFLAG
                42                   40                  .05         1
#              G12                  G23                  G31                 EPSF1
               3.4                    3                    3                     0
#            ESPT1                EPSM1                EPST2                 EPSM2
                 0                    0                    0                     0
#            Wpmax                Wpref      Ioff
                 0                    0         5
#                C                  EPS                ALPHA                                     Icc
                 0                    0                    0                                       0
#      sig_trac_1                  B_1T                 N_1T          SIGMA_1MAXT               C_1T
             1e+30                    0                    0                    0                  0
#          EPS_1T1              EPS_2T1          SIGMA_RST1          Wpmax_trac_1
                 0                    0                    0                    0
#      sig_trac_2                  B_2T                 N_2T          SIGMA_2MAXT               C_2T
             1e+30                    0                    0                    0                  0
#          EPS_1T2              EPS_2T2          SIGMA_RST2          Wpmax_trac_2
                 0                    0                    0                    0
#      sig_comp_1                  B_1C                 N_1C          SIGMA_1MAXC               C_1C
             1e+30                    0                    0                    0                  0
#          EPS_1C1              EPS_2C1          SIGMA_RSC1          Wpmax_comp_1
                 0                    0                    0                    0
#      sig_comp_2                  B_2C                 N_2C          SIGMA_2MAXC               C_2C
             1e+30                    0                    0                    0                  0
#          EPS_1C2              EPS_2C2          SIGMA_RSC2          Wpmax_comp_2
                 0                    0                    0                    0
#           sig_12                B_12T                N_12T         SIGMA_12MAXT              C_12T
             .0040                 67.0                  .29                    0                  0
#         EPS_1T12             EPS_2T12         SIGMA_RST12         Wpmax_trac_12
              0.00                 0.00                 0.00                    0
#        GAMMA_INI            GAMMA_MAX                 Dmax
              1E31                 1E31                .9999
#  Fsmooth                Fcut
        0                    0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```

Yield Stress

Composite Material Model: Plasticity

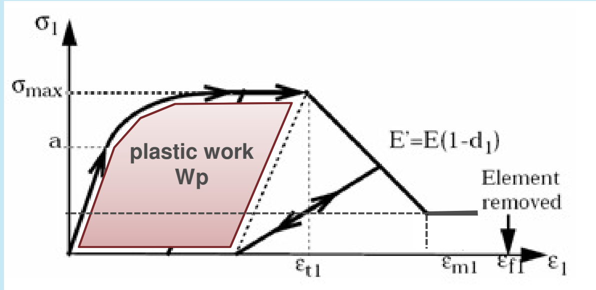
```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/COMPSH/10
Altair composite material
#        Init. dens.          Ref. dens.
          1.5000E-6                   0
#                 E11                 E22                NU12     IFLAG
                   42                  40                 .05         1
#                 G12                 G23                 G31               EPSF1
                  3.4                   3                   3                   0
#               ESPT1               EPSM1               EPST2               EPSM2
                    0                   0                   0                   0
#               Wpmax               Wpref      Ioff
                    0                   0         5
#                   C                 EPS               ALPHA                                     Icc
                    0                   0                   0                                       0
#          sig_trac_1                B_1T                N_1T         SIGMA_1MAXT                C_1T
                1e+30                   0                   0                   0                   0
#             EPS_1T1             EPS_2T1          SIGMA_RST1        Wpmax_trac_1
                    0                   0                   0                   0
#          sig_trac_2                B_2T                N_2T         SIGMA_2MAXT                C_2T
                1e+30                   0                   0                   0                   0
#             EPS_1T2             EPS_2T2          SIGMA_RST2        Wpmax_trac_2
                    0                   0                   0                   0
#          sig_comp_1                B_1C                N_1C         SIGMA_1MAXC                C_1C
                1e+30                   0                   0                   0                   0
#             EPS_1C1             EPS_2C1          SIGMA_RSC1        Wpmax_comp_1
                    0                   0                   0                   0
#          sig_comp_2                B_2C                N_2C         SIGMA_2MAXC                C_2C
                1e+30                   0                   0                   0                   0
#             EPS_1C2             EPS_2C2          SIGMA_RSC2        Wpmax_comp_2
                    0                   0                   0                   0
#              sig_12               B_12T               N_12T        SIGMA_12MAXT               C_12T
                .0040                67.0                 .29                   0                   0
#            EPS_1T12           EPS_2T12          SIGMA_RST12       Wpmax_trac_12
                 0.00                0.00                0.00                   0
#           GAMMA_INI           GAMMA_MAX                Dmax
                 1E31                1E31               .9999
#  Fsmooth                Fcut
         0                   0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```



Plasticity,
Strain
Rates

Composite Material Model: Damage and Failure

```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/COMPSH/10
Altair composite material
#        Init. dens.          Ref. dens.
           1.5000E-6                   0
#                E11                 E22                 NU12     IFLAG
                  42                  40                  .05         1
#                G12                 G23                  G31
                 3.4                   3                    3
#              ESPT1               EPSM1                EPST2
                   0                   0                    0
#              Wpmax               Wpref     Ioff
                   0                   0        5
#                  C                 EPS                ALPHA                                     Icc
                   0                   0                    0                                       0
#         sig_trac_1                 B_1T                 N_1T         SIGMA_1MAXT                C_1T
               1e+30                   0                    0                   0                   0
#            EPS_1T1             EPS_2T1          SIGMA_RST1         Wpmax_trac_1
                   0                   0                    0                   0
#         sig_trac_2                 B_2T                 N_2T         SIGMA_2MAXT                C_2T
               1e+30                   0                    0                   0                   0
#            EPS_1T2             EPS_2T2          SIGMA_RST2         Wpmax_trac_2
                   0                   0                    0                   0
#         sig_comp_1                 B_1C                 N_1C         SIGMA_1MAXC                C_1C
               1e+30                   0                    0                   0                   0
#            EPS_1C1             EPS_2C1          SIGMA_RSC1         Wpmax_comp_1
                   0                   0                    0                   0
#         sig_comp_2                 B_2C                 N_2C         SIGMA_2MAXC                C_2C
               1e+30                   0                    0                   0                   0
#            EPS_1C2             EPS_2C2          SIGMA_RSC2         Wpmax_comp_2
                   0                   0                    0                   0
#             sig_12                B_12T                N_12T        SIGMA_12MAXT               C_12T
               .0040                67.0                  .29                   0                   0
#           EPS_1T12            EPS_2T12         SIGMA_RST12        Wpmax_trac_12
                0.00                0.00                 0.00                   0
#          GAMMA_INI           GAMMA_MAX                 Dmax
                1E31                1E31                .9999
#  Fsmooth              Fcut
         0                 0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```



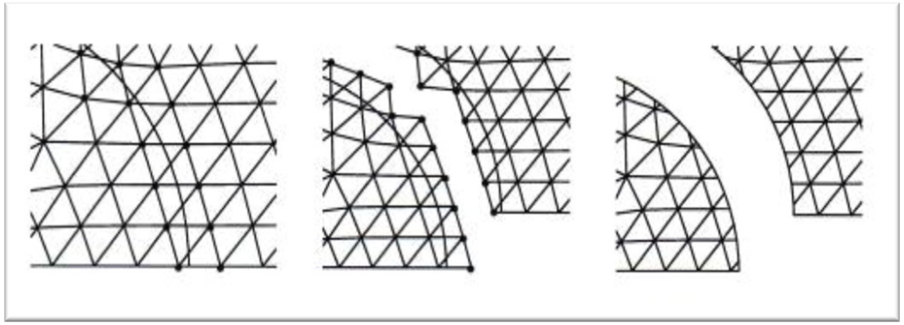
Damage & Failure

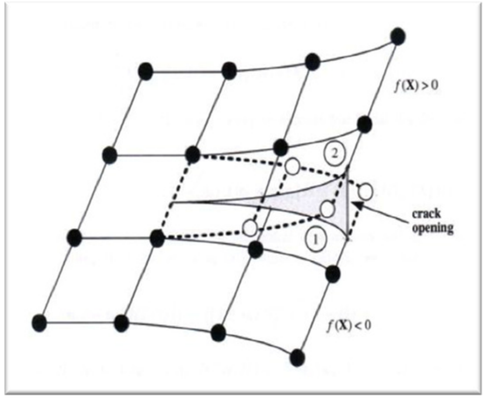
Composite Material Model: Advanced Failure Models

HyperWorks

Failure Model Keyword	Type	Description
CHANG	Chang-Chang model	Failure criteria for composites
CONNECT	Failure	Normal and Tangential failure model
ENERGY	Energy isotrop	Specific energy
FLD	Forming limit diagram	Fld
HASHIN	Composite model	Hashin model
JOHNSON	Ductile failure model	Johnson-Cook
LAD_DAMA	Composite delamination	Ladeveze delamination model
NXT	NXT failure criteria	Similar to FLD, but based on stresses
PUCK	Composite model	Puck model
SNCONNECT	Failure	Failure criteria for plastic strain
SPALLING	Ductile + Spalling	Spalling + Johnson-Cook
TAB1	Strain failure model	based on damage accumulation using user-defined functions
TBUTCHER	Tuler-Butcher model	Failure due to fatigue
TENSSTRAIN	Traction	Strain failure
USERi	User failure model	
WIERZBICKI	Ductile material	Bao-Xue-Wierzbicki model
WILKINS	Ductile failure model	Wilkins model
XFEM_FLD	Forming limit diagram	Fld
XFEM_JOHNS	Ductile failure model	Johnson-Cook
XFEM_TBUTC	Ductile (brittle) failure model	Modified Tuler-Butcher model

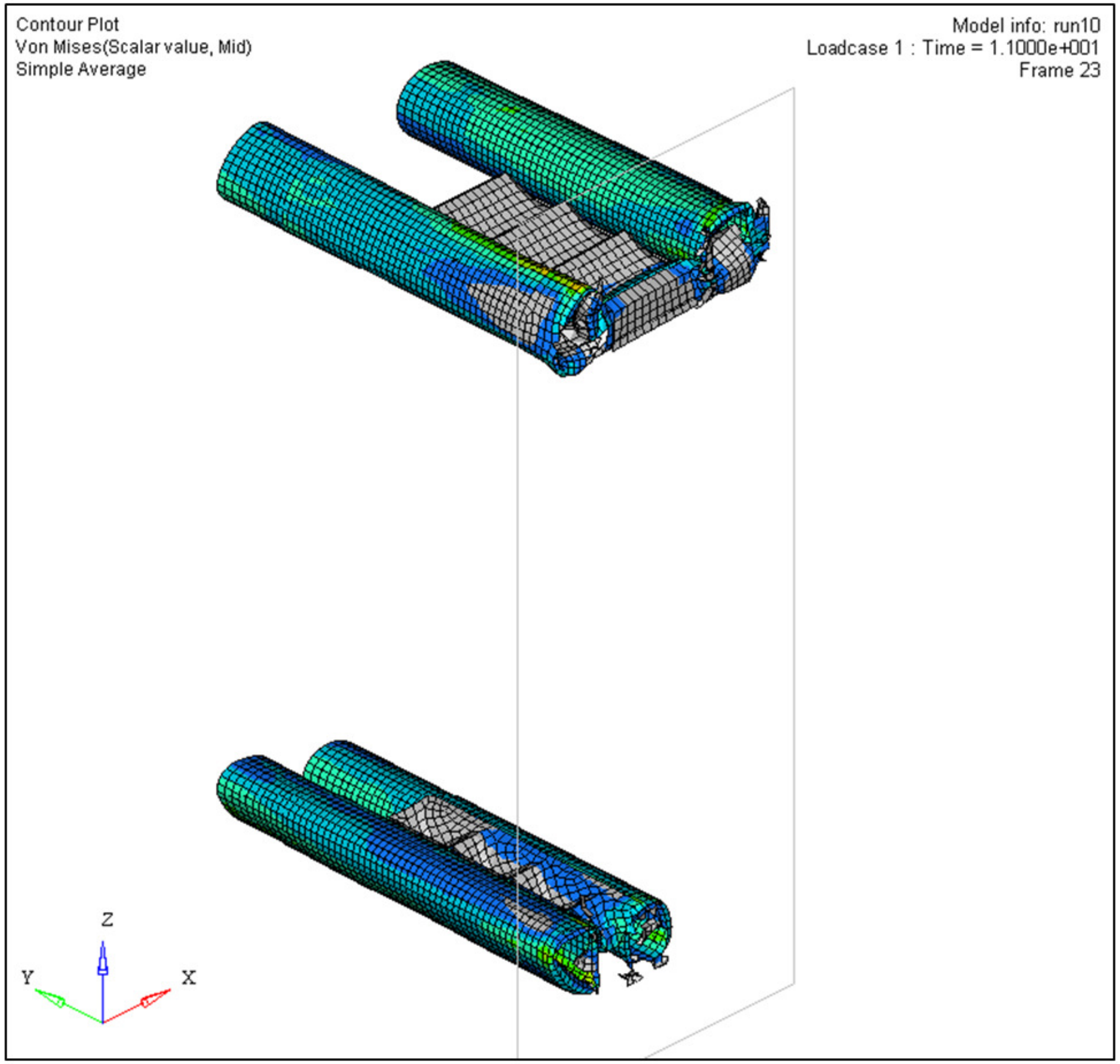
Failure models can be coupled with compatible material laws



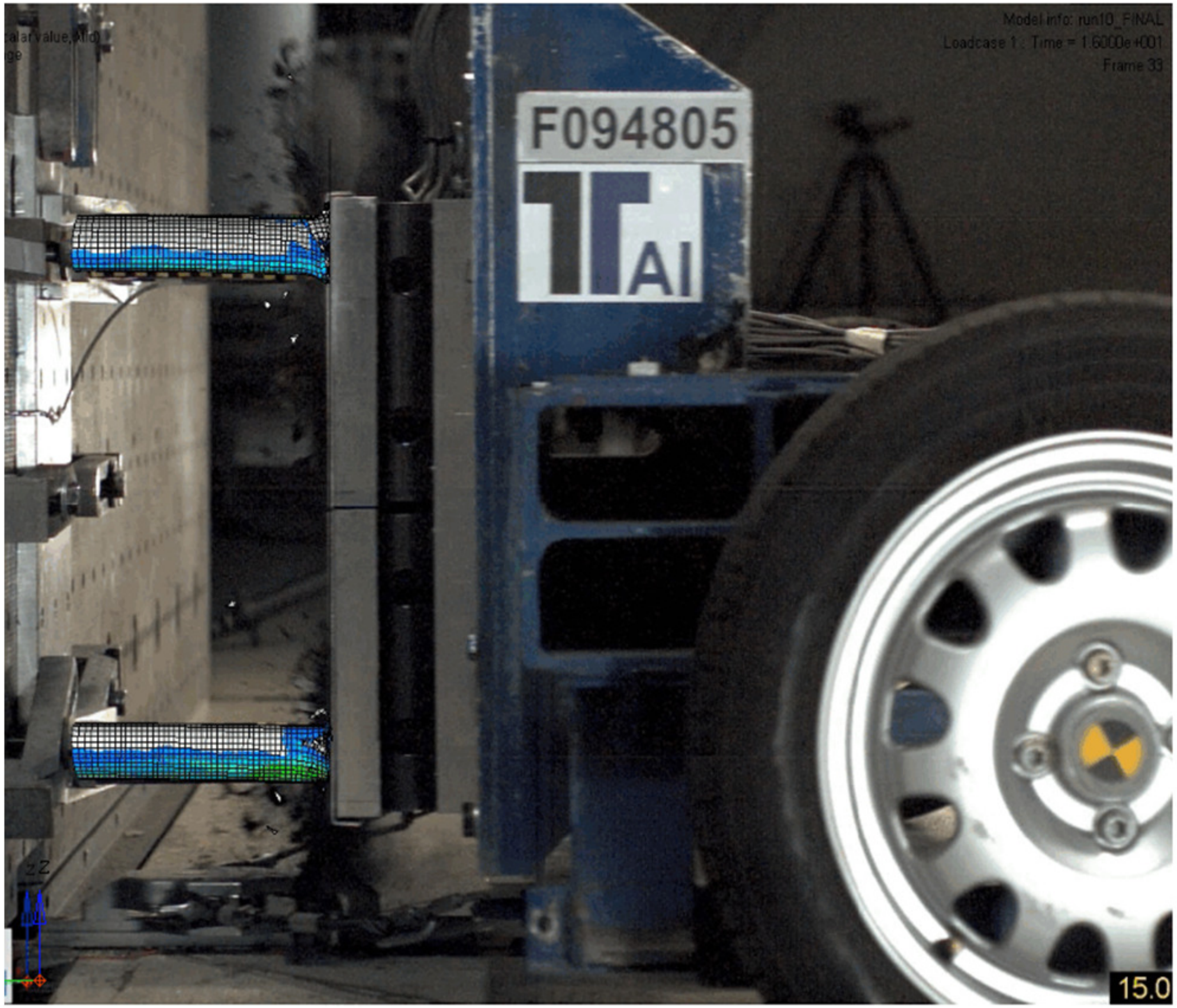


Ergebnisse

Paul Schischkin



Ergebnisse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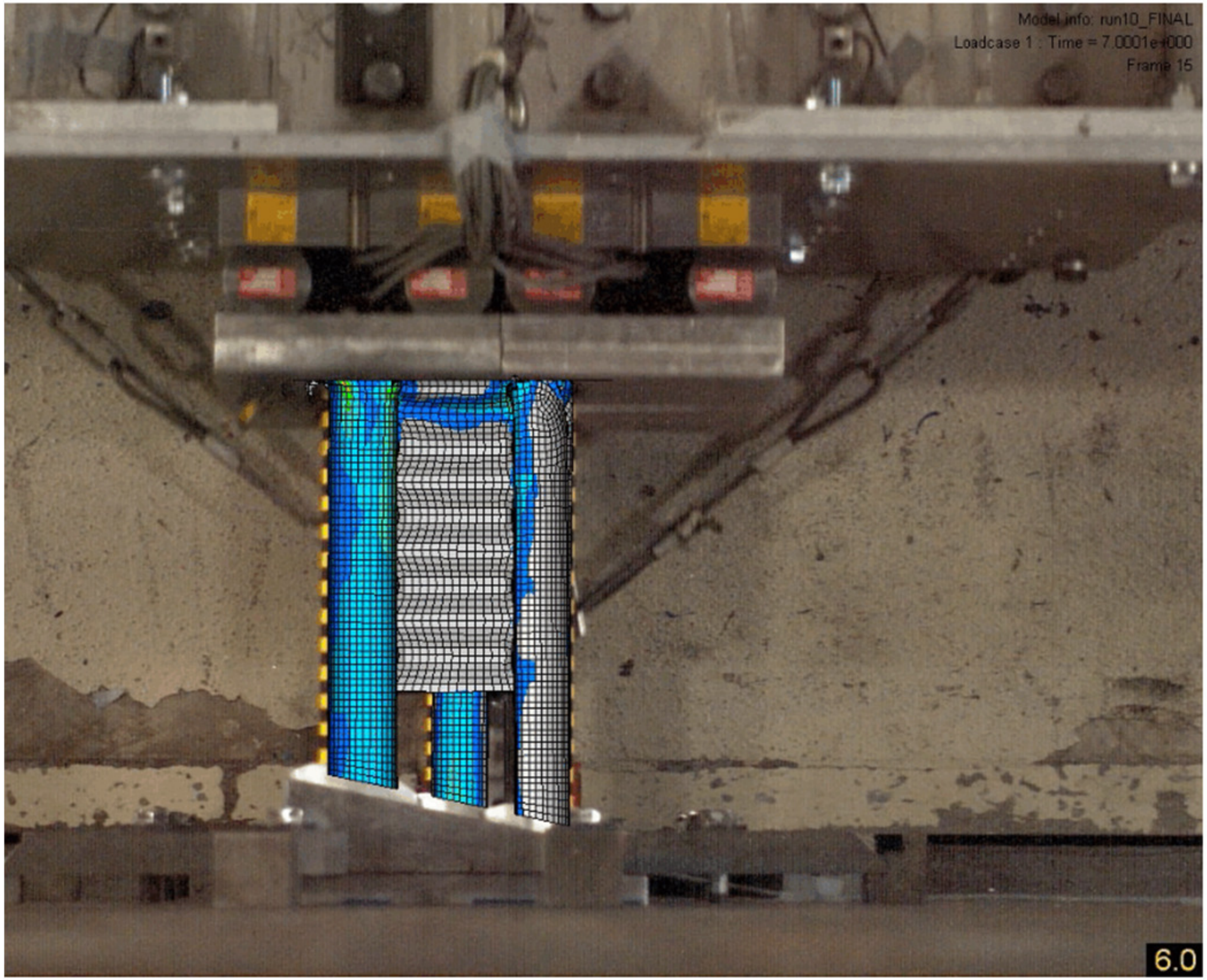
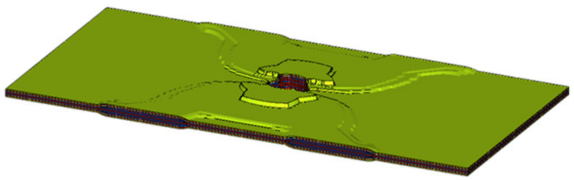
Loadcase 1 : Time = 1.6000e+001
Frame 33
F094805
AI
15.0

Ergebnisse


Model info: run10_FINAL
Loadcase 1 : Time = 7.0001e+000
Frame 15
6.0

Agenda

- Materialmodellierung
  - Validierung einer Crashberechnung
- **Auslegung von Composite Strukturen**
  - **Beschnitt: Optimierung Size/Shape/Shuffling**
  - **Fertigung: Drapiersimulation**



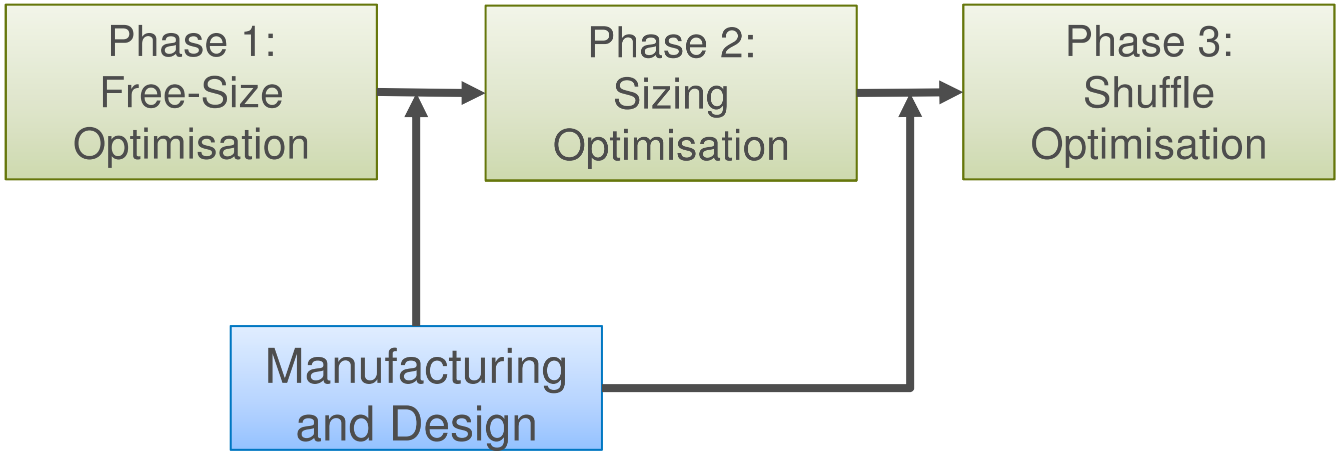
CAE Process Chain

What is known ?

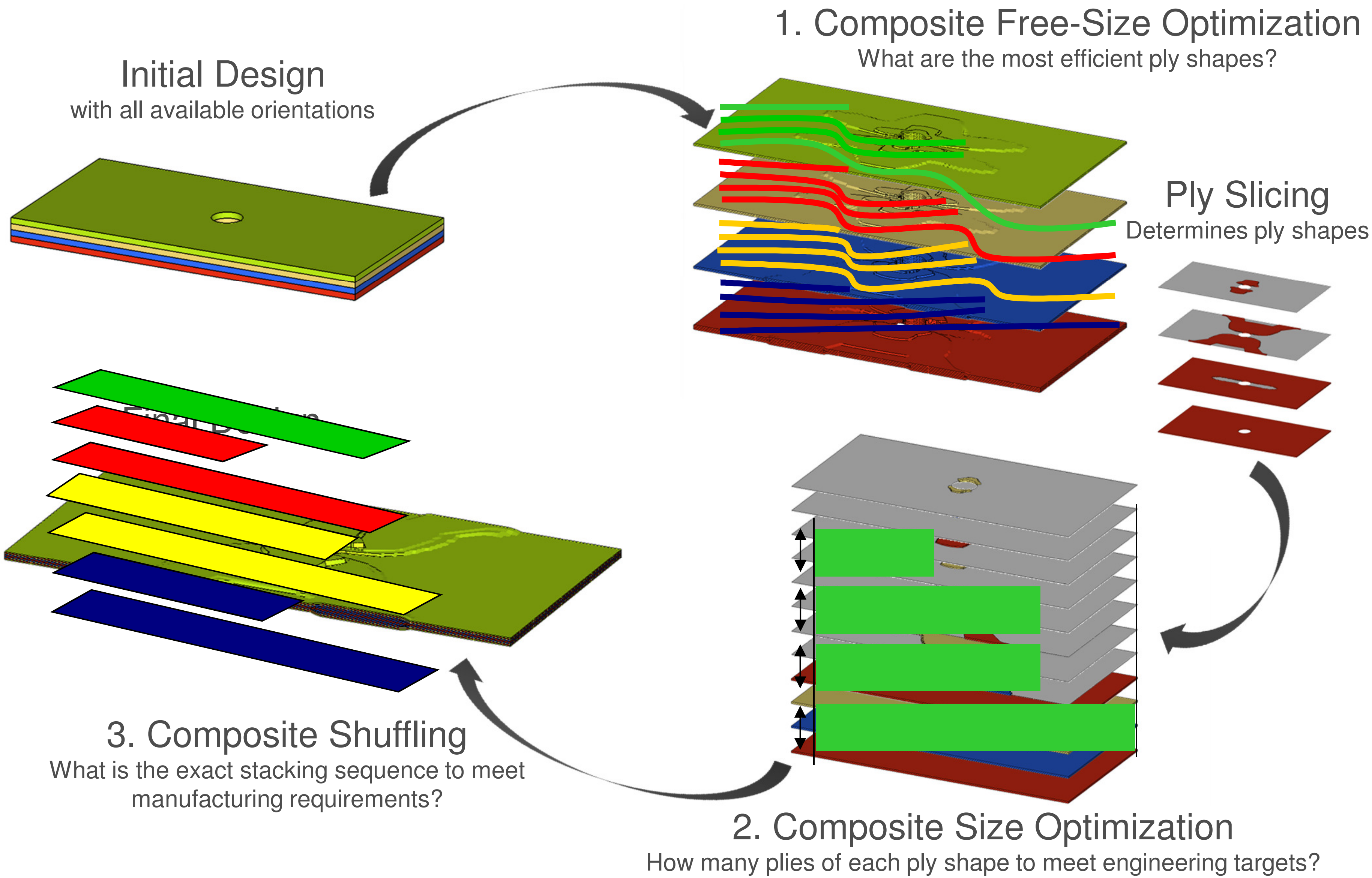
- Manufacturing process
- Design idea
- Available material (fabric, UD-layers, fiber/matrix)
- Possible fiber orientations

What is not known ?

- Distribution of material and fiber orientation
- Final lay-up of the laminate



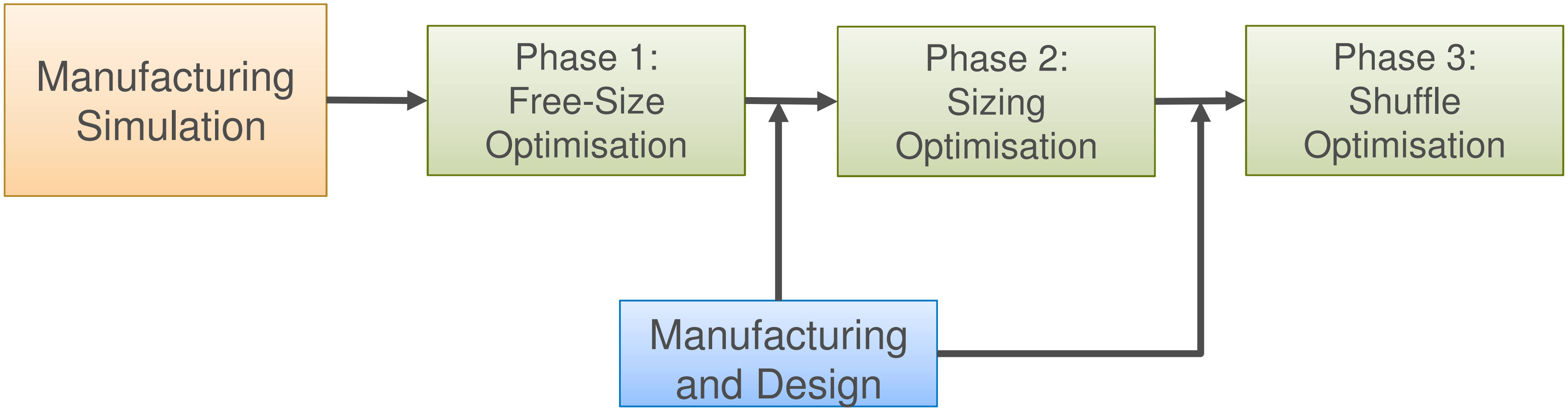
OptiStruct: Composite Design Process



CAE Process Chain

What is known ?
- Manufacturing process
- Design idea
- Available material (fabric, UD-layers, fiber/matrix)
- Possible fiber orientations

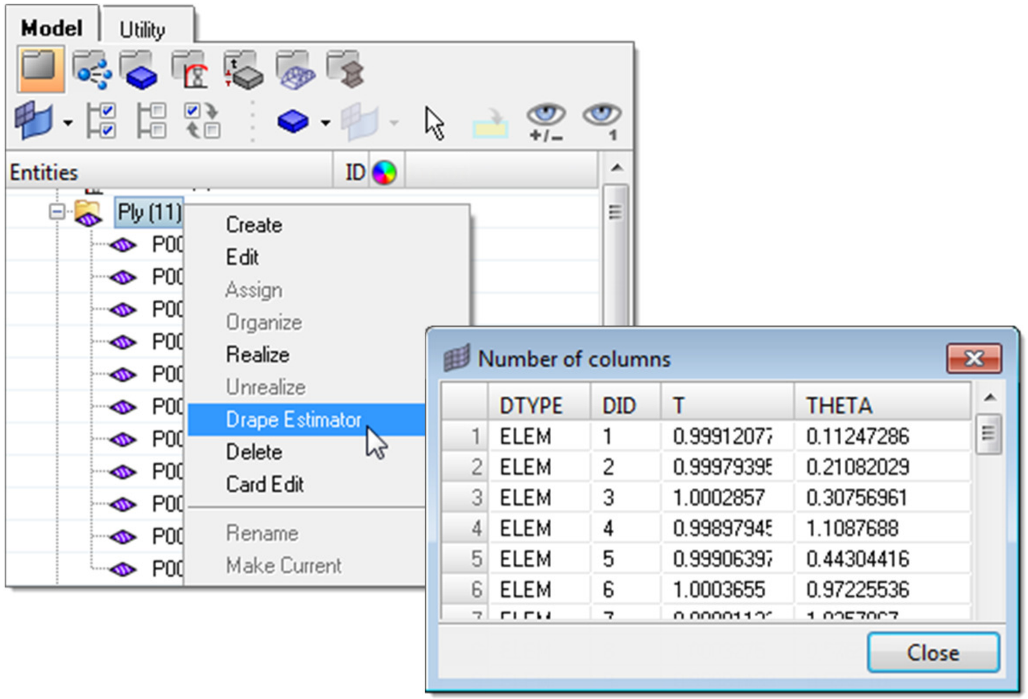
What is not known ?
- Distribution of material and fiber orientation
- Final lay-up of the laminate

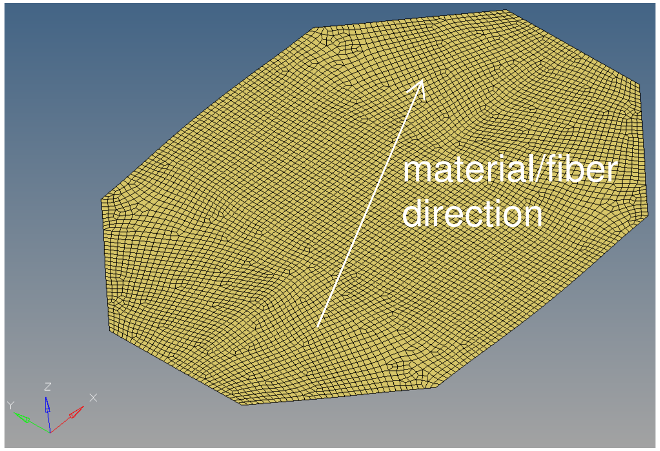


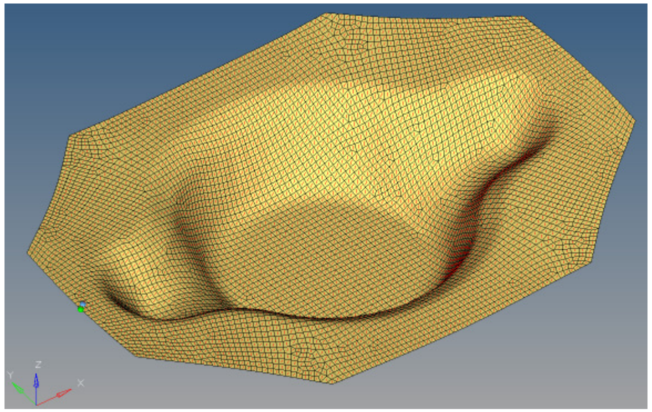
In addition, we can answer:
- Is it possible to manufacture my design at all?
- What is the influence of the manufacturing on the fiber orientation?
- Do I have local thickenning or thinning?

HyperMesh: Drape Estimator for Composite Fibers

- Calculate draping angles and thickness variation
- Geometry based, very fast (seconds)
- Good estimation for deviation of the fiber oriention, but feedback on manufacturability only indirect







Radioss: Draping Simulation

Sandwich method

1 Component
1 Material
1 Property

Sandwich material law

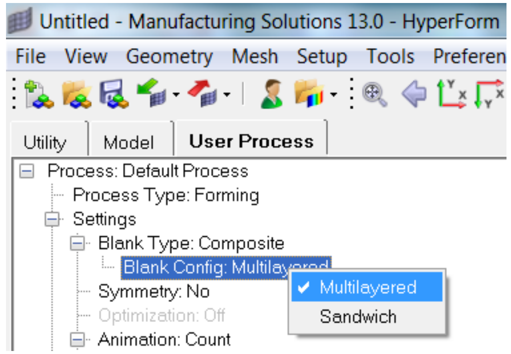
- All plies defined in the same property

Independant layers method

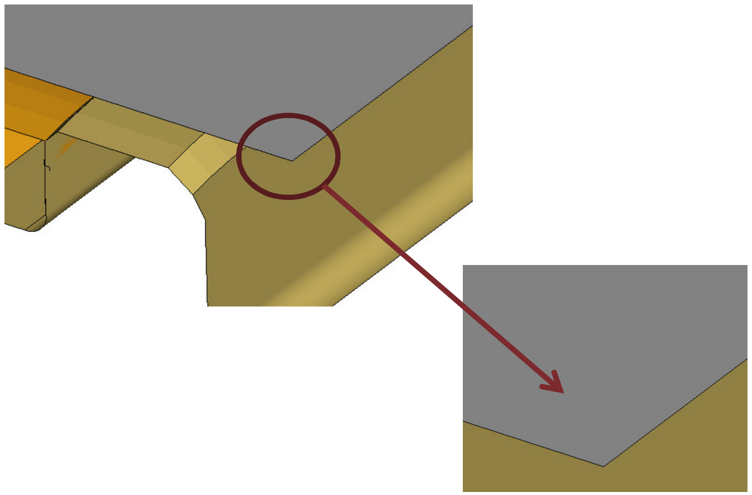
1 Component for each Ply
1 Material for each Ply
1 Property for each Ply

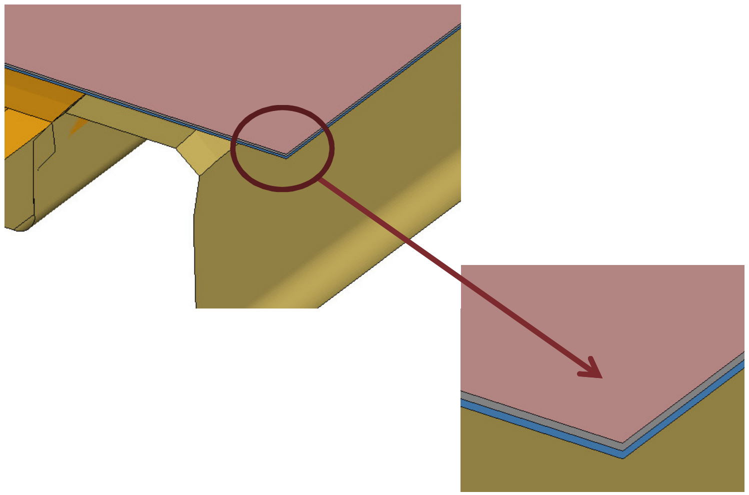
Fabric material law

- All layers defined independently
- Contact interface between the layers



Setup in HyperForm user process

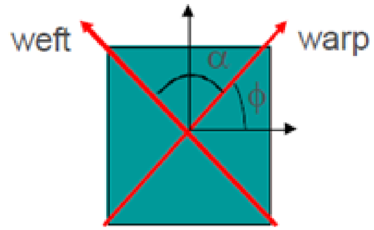


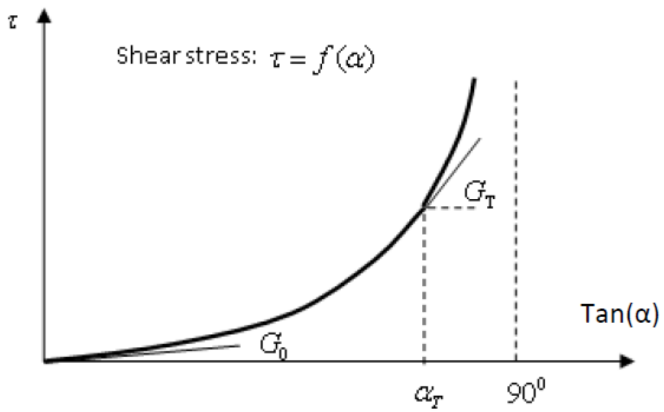


Radioss: Fabric Material Characterization

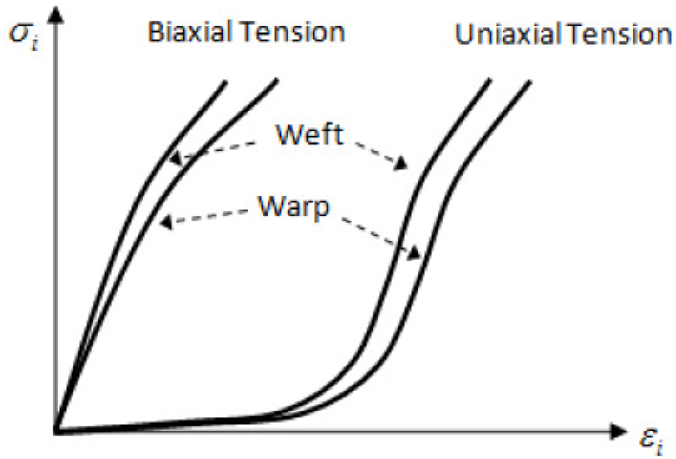
Capture complete physical ply behavior

- Stress-strain curve in warp and weft direction
- Shear stress as a function of shear angle
- …





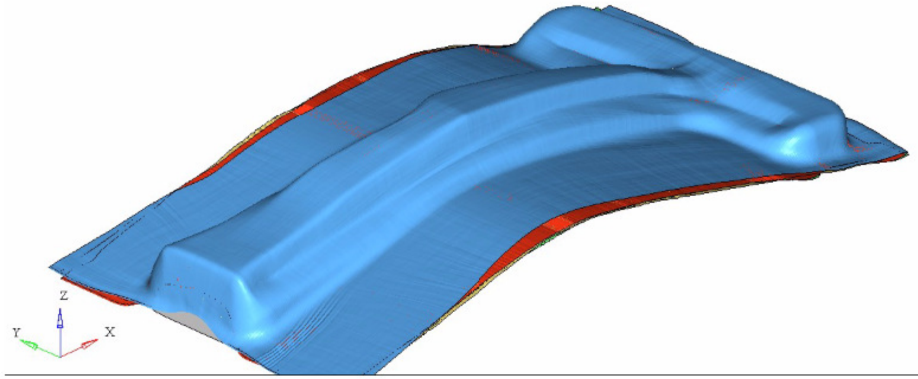
Shear stress – tangent shear angle

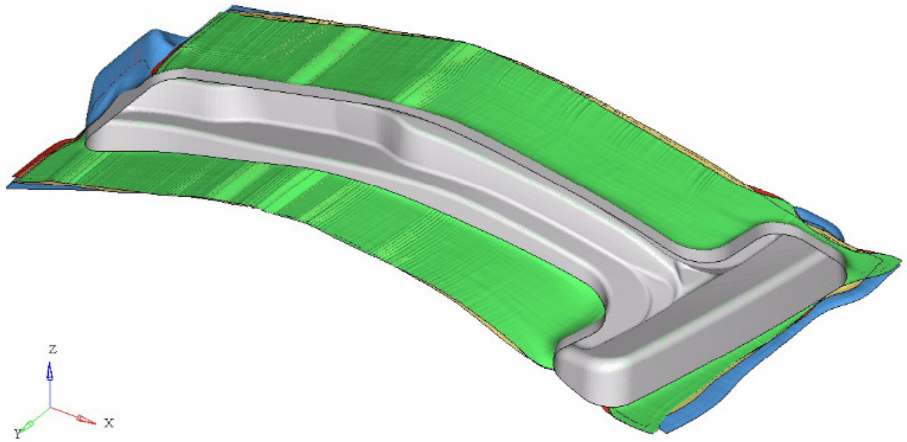


Radioss: Independent Layers Simulation

Sliding

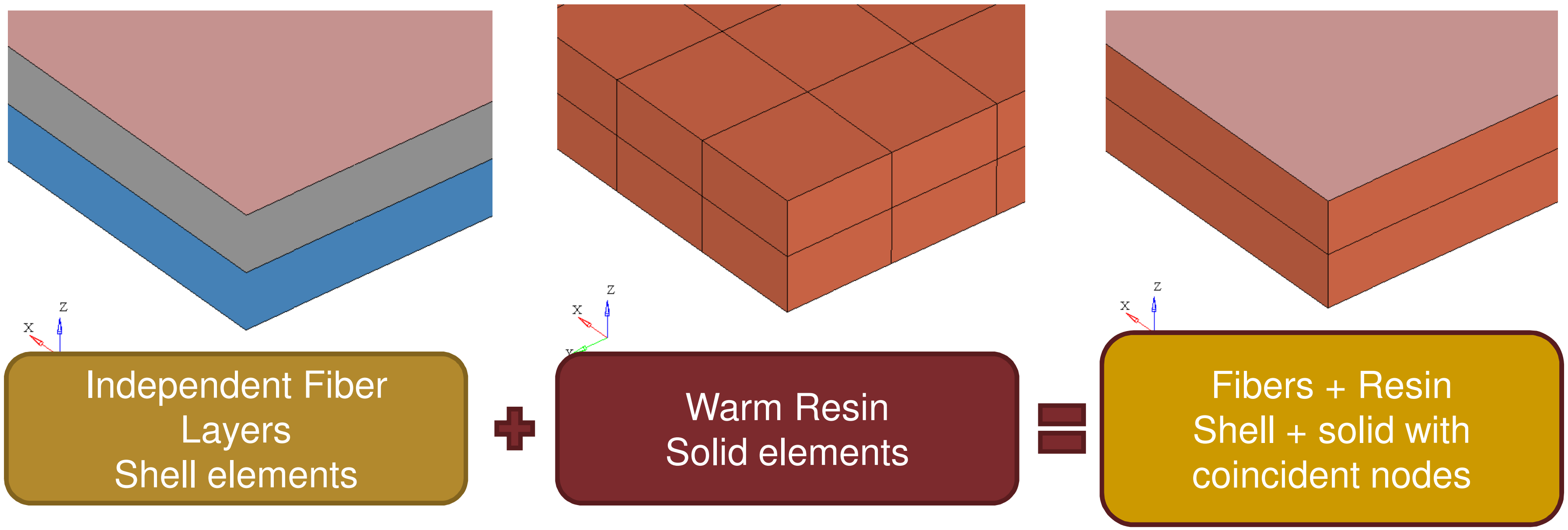
- Sliding effect between layers can be modeled by contact interface
- Each layer is free to slide over other layers
- In this example, fiber orientaions are 0, +45, 90 and -45° regarding X axis
- The behavior during stamping is different for each layer





Radioss: Independent Layers with Resin

Independant layers + resin method



Connect material is used to model resin :

- A plasticity domain is reached after a small yield stress value
- Strain rate dependancy available for user defined curves

Summary: CAE Process Chain with HyperWorks

Manufacturing Simulation

Phase 1: Free-Size Optimization

Phase 2: Sizing Optimization

Phase 3: Shuffle Optimization

Manufacturing and Design

Mapping and Assembly

Crash/Impact Model

Validation of test data

Validation of nonlinear material parameters