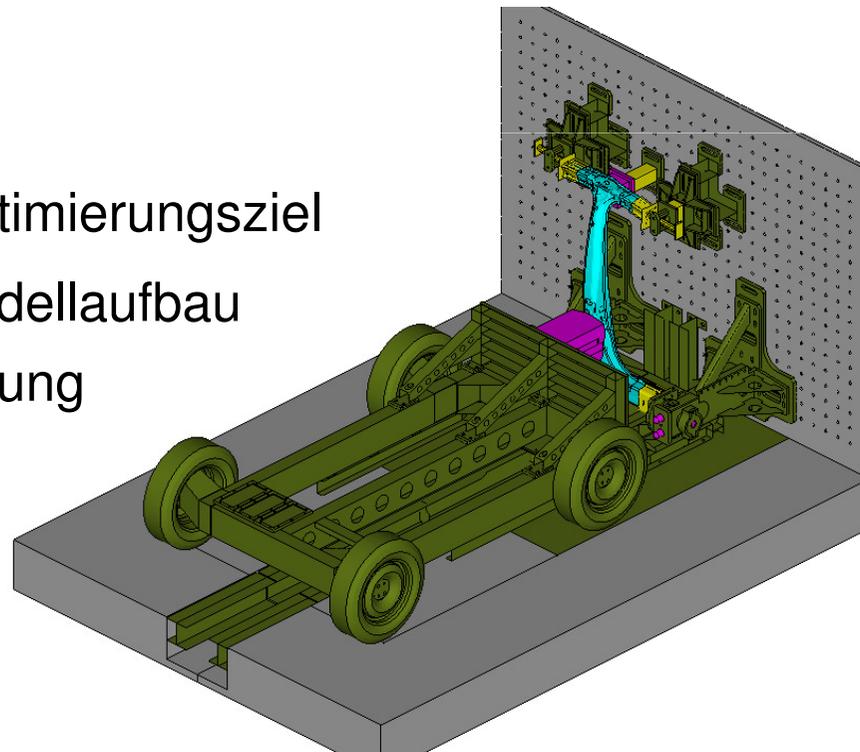


Optimierung des Impaktors eines B-Säulen Prüfstandes

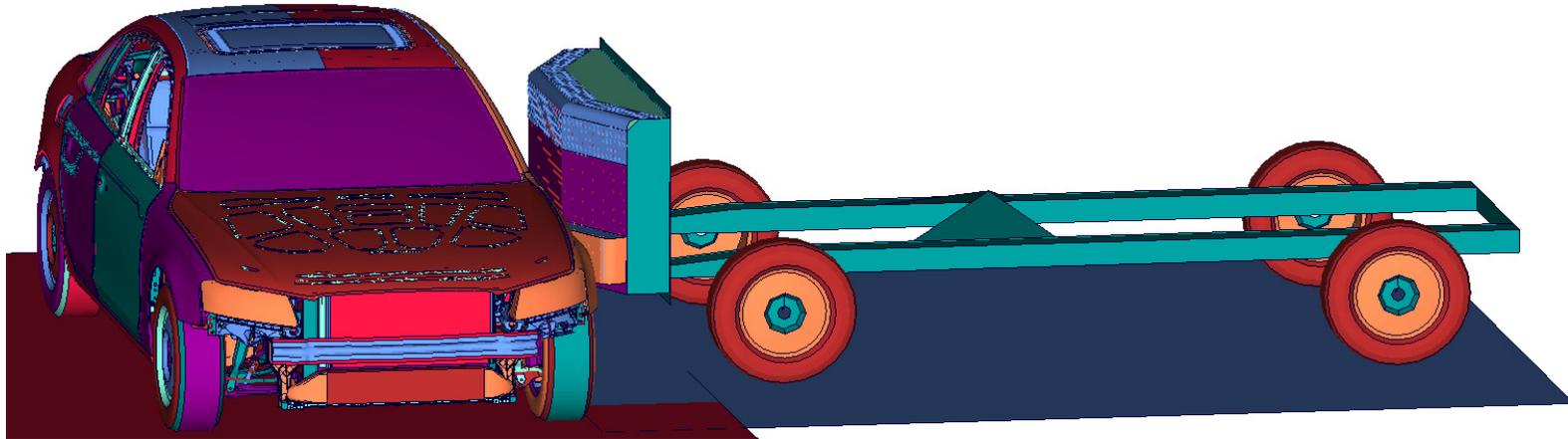
G. Geißler (DYNAmore), C. Dornberg (AUDI), A. Teibinger (ViF)

Gliederung

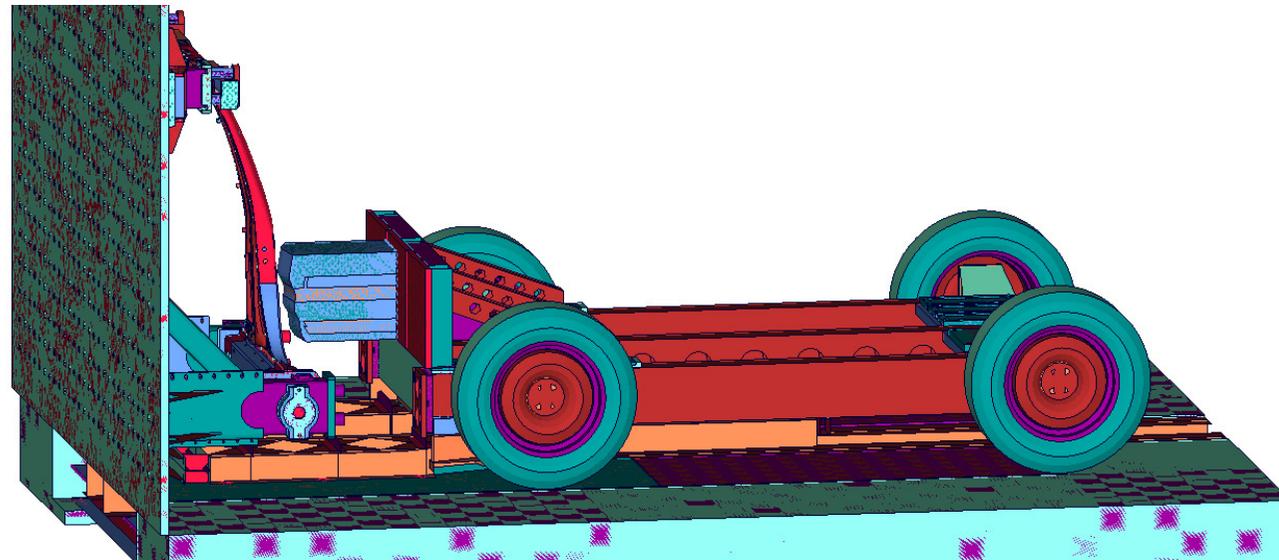
- Aufgabenstellung und Optimierungsziel
- Parametrisierung und Modellaufbau
- Optimierung und Auswertung
- Ergebnisse



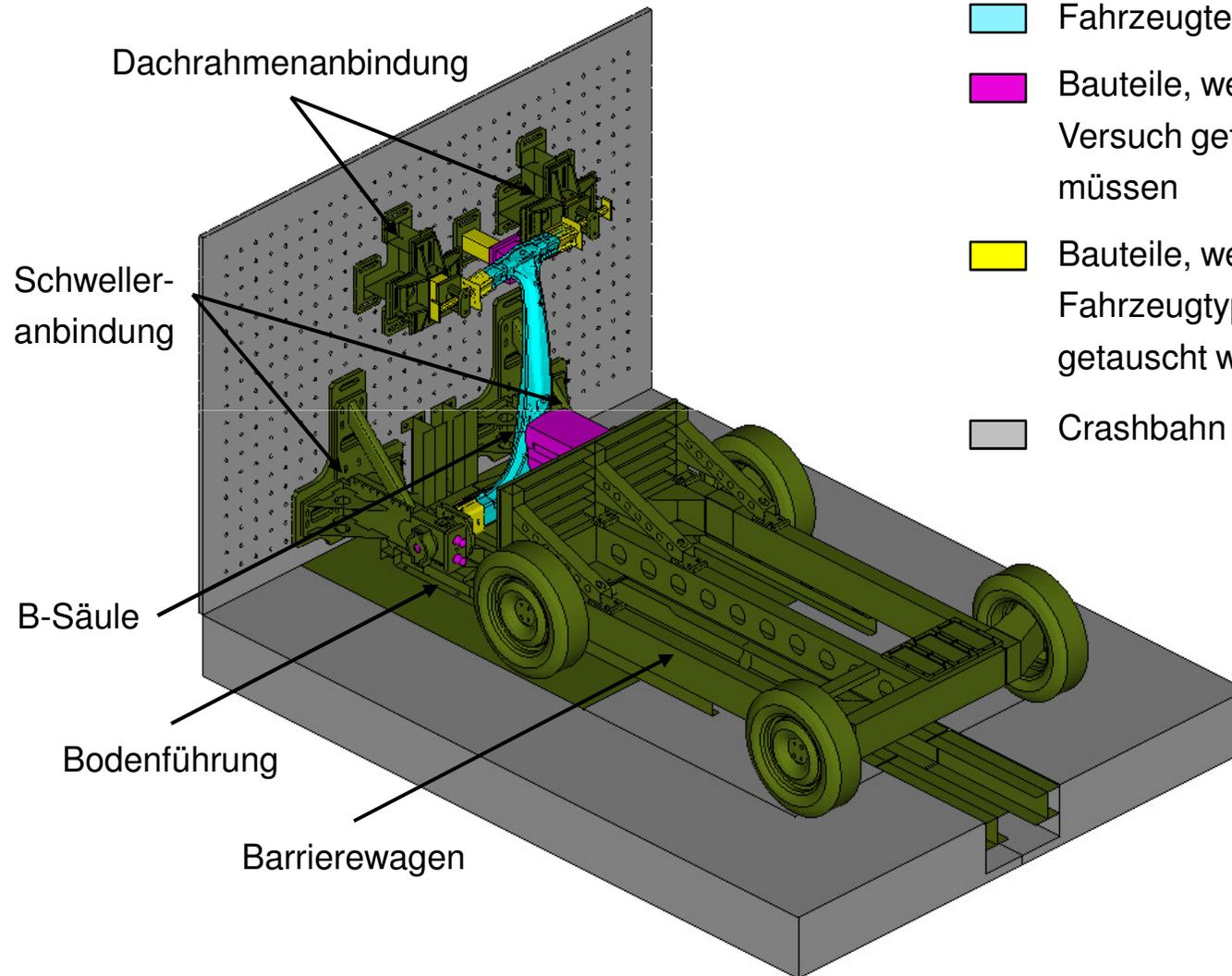
Gesamtfahrzeug



Prüfstand



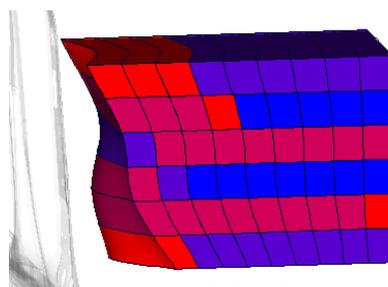
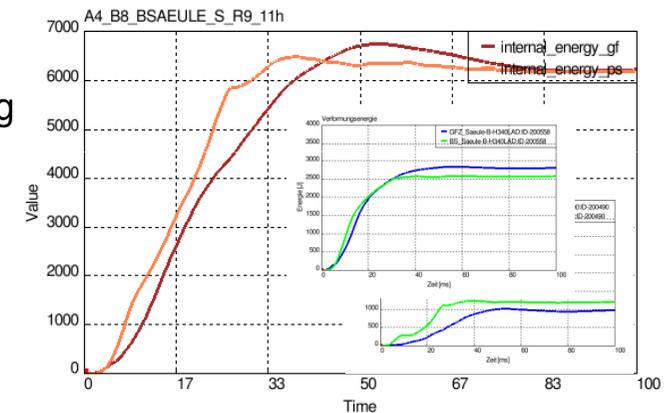
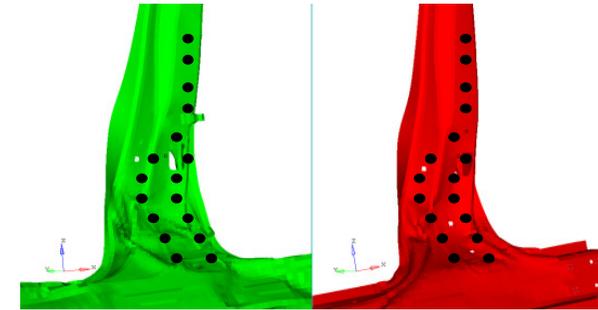
Aufbau Prüfstand



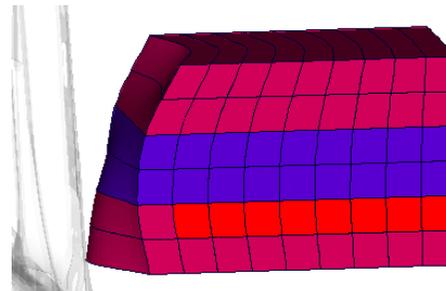
-  Bauteile des Prüfstandes
-  Fahrzeugteile
-  Bauteile, welche bei jedem Versuch getauscht werden müssen
-  Bauteile, welche bei jedem Fahrzeugtypwechsel getauscht werden müssen
-  Crashbahn

Optimierungsziele

- Verformungskriterium
 - Differenz der Knotenverformungen über die Zeit
 - Auswertung: Animator-Session file, shell-Skript
 - user-defined response: perl-Skript
- Energiekriterium
 - Differenz der Verformungsenergie über die Zeit
 - Auswertung: Animator-Session file
 - MeanSqErr response: TARGET_energy → Gesamtfahrzeug
COMPUTED_energy → Prüfstand
- Minimierung der Komplexität des Impaktors
 - Anzahl zusammenhängender Blöcke gleichen Materials
 - Auswertung: python-Skript beim Zusammenbau
 - user-defined response: perl-Skript



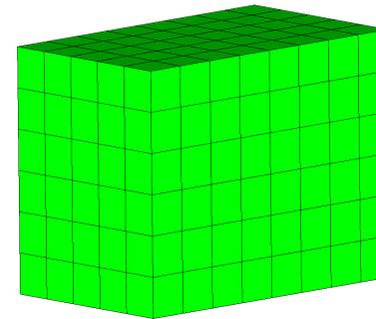
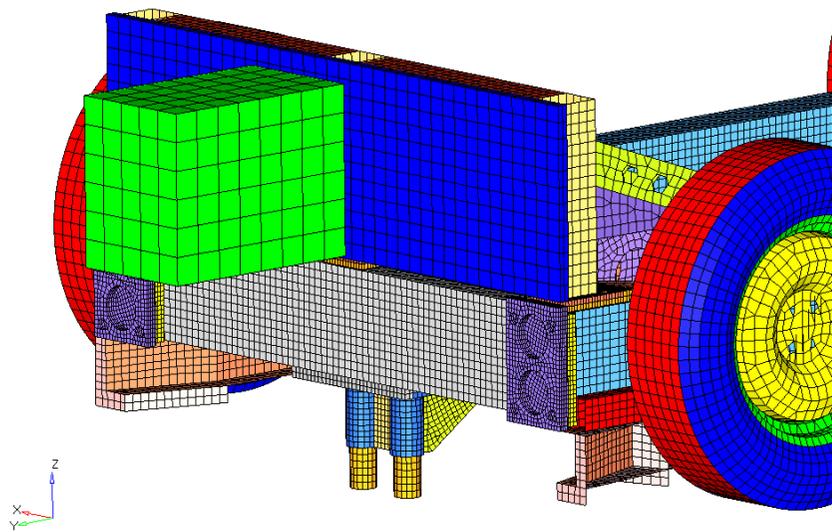
schlecht



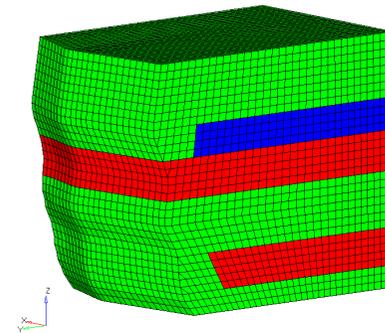
gut

Impaktroptimierung

- Impaktor kann aus max. 4 unterschiedlichen Materialien bestehen
 - Stahl (quasistarr, S235)
 - EPP 140 (Rohdichte 140 kg/m³)
 - EPP 50 (Rohdichte 50 kg/m³)
 - EPP 220 (Rohdichte 220 kg/m³)
- Aufteilung des Impaktors in Blöcke gleichen Materials (Abmessungen: 50x50x50mm)
- Einschränkungen für die Kombination zwischen den unterschiedlichen Materialien
 - Stahl kann nur vom Barrierewagen weg platziert werden
 - max. 2 Materialwechsel pro Ebene in y-Richtung
 - kein Materialwechsel entlang X-Achse
- Impaktorhöhe ist begrenzt, ansonsten Größe und Form frei



Ausgangszustand



optimierter Impaktor

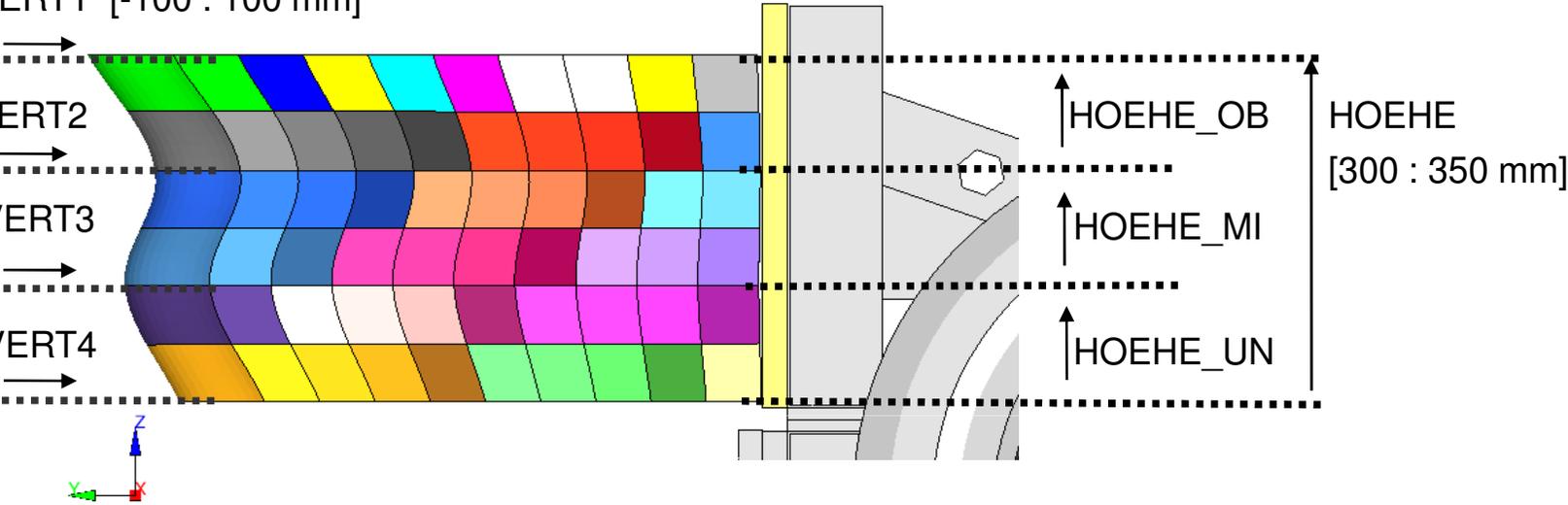
Morphingparameter

KONVERT1 [-100 : 100 mm]

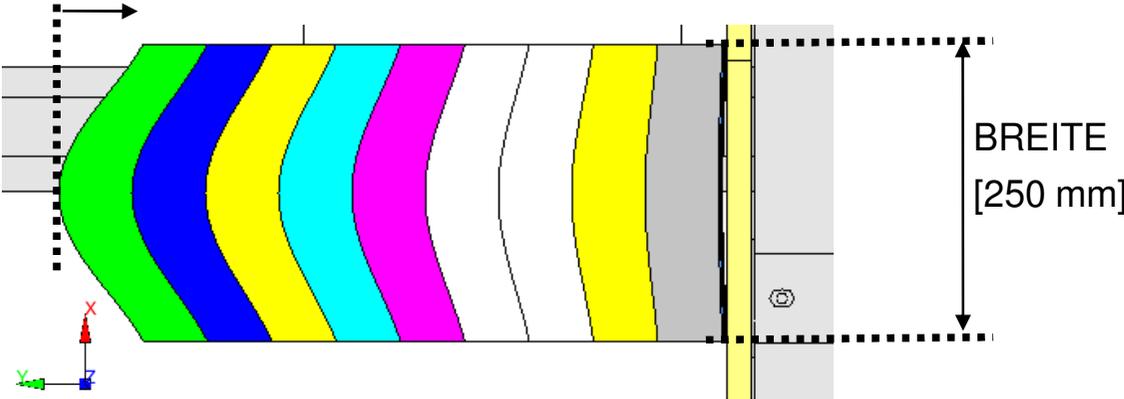
KONVERT2

KONVERT3

KONVERT4



KONTHOR1 (oben), KONTHOR4 (unten) [-100 : 100 mm]



ANSA morphing

The screenshot displays the ANSA v12.1.6 64bit (PAM-CRASH) interface. The main window shows a 3D model of a B-column test stand with a green wireframe overlay. The terminal window at the bottom right contains the following text:

```
#!/bin/bash
# Shell skript zur Erzeugung eines PAMCRASH includes fuer die Optimierung eines B-Saehlen Pruefstandes
# Verwendung innerhalb der Optimierung des Prallkoerpers fuer die Barriere
# Definition der Geometrie und des Morphing in SANSa_FILE

# Programmversionen
# ANSA default executable
ANSA=ansa

cat << EOF >>tmpPfad/$INDV_FILE
#
# ANSA_VERSION: 12.1.6
#
# file created by A N S A Tue Aug 11 09:06:50 2009
#
# Output from:
# /home/weg49ft/PROJEKTE/OPTIMIERUNG_VIF/gg/MORPHING/impaktor_____AU481_BSP_Optimierung_____K0_A_0001_weg49ft_.ansa
#
# DESIGN VARIABLES
#-----
# ID | DESIGN VARIABLE NAME | TYPE | RANGE | CURRENT VALUE | MIN VALUE --> MAX VALUE | STEP
#-----
1, Hoehe_oben, REAL, BOUNDS, HOEHE_OB , 0., 50.
2, Hoehe_mitte, REAL, BOUNDS, HOEHE_MI , 0., 33.333332
3, Hoehe_unten, REAL, BOUNDS, HOEHE_UN , 0., 16.666666
4, Kont_Vert_1, REAL, BOUNDS, KONVERT1 , -60., 0.
5, Kont_Vert_2, REAL, BOUNDS, KONVERT2 , -60., 0.
6, Kont_Vert_3, REAL, BOUNDS, KONVERT3 , -60., 0.
7, Kont_Vert_4, REAL, BOUNDS, KONVERT4 , -60., 0.
8, Kont_Hor_1, REAL, BOUNDS, KONTHORI , -100., 100.
9, Kont_Hor_2, REAL, BOUNDS, KONTHOR2 , -100., 100.
10, Kont_Hor_3, REAL, BOUNDS, KONTHOR3 , -100., 100.
11, Kont_Hor_4, REAL, BOUNDS, KONTHOR4 , -100., 100.
```

Variablen für die Materialzuweisung

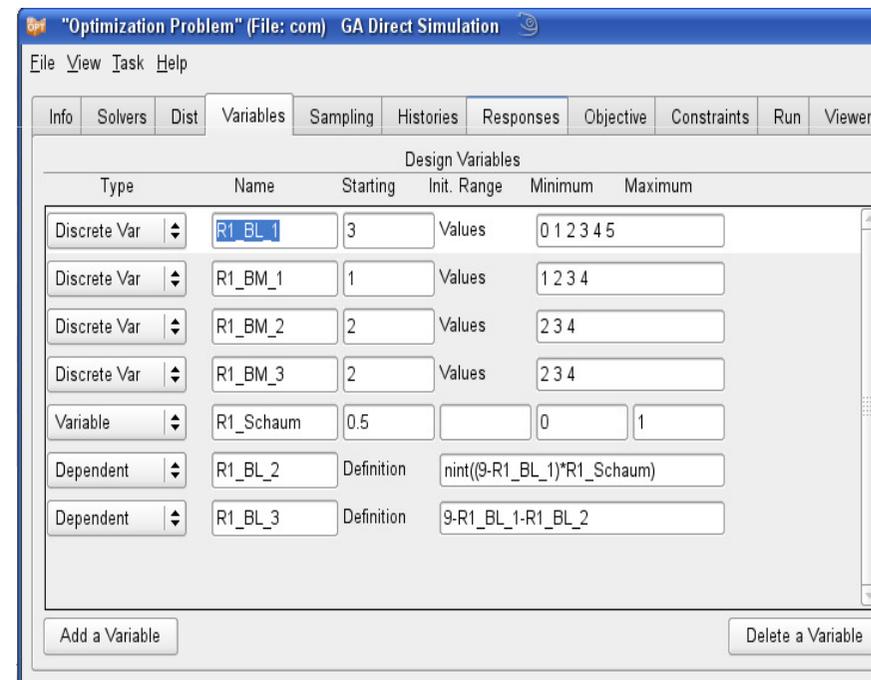
- Blocklänge
 - diskrete Variable $\rightarrow Ri_BL_j$
 - Blocklänge 1 im Intervall [0:9]
 - Aufteilung Blocklänge 2, 3 im Verhältnis Ri_Schaum [0:1]



- Materialzuweisung
 - diskrete Variable $\rightarrow Ri_BM_j$
 - 1 – Stahl 3 – EEP 140
 - 2 – EPP 50 4 – EEP 220

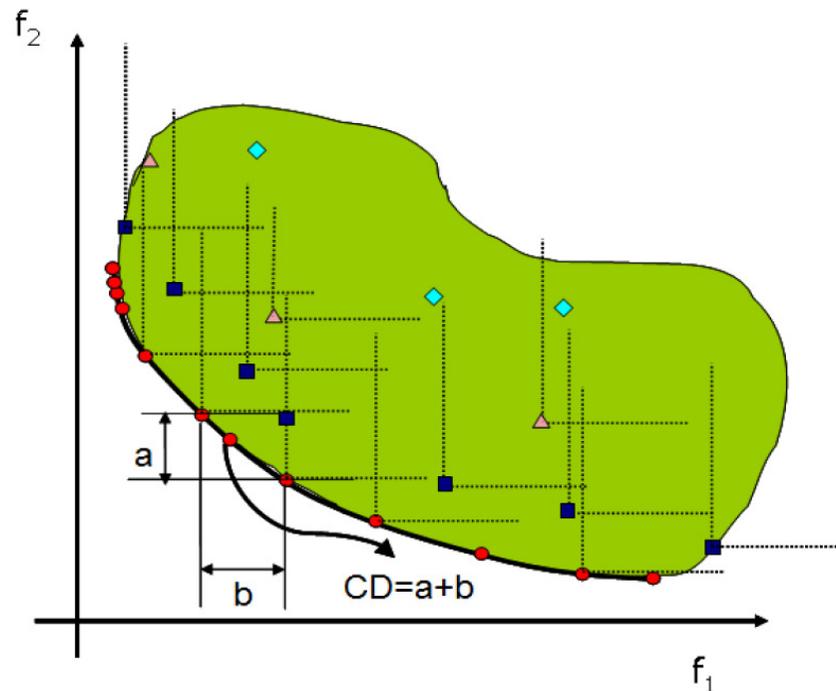
Optimierungsvariablen

- Morphing Parameter 7
 - Blocklänge 12
 - Materialzuweisung 18
- SUMME: 37



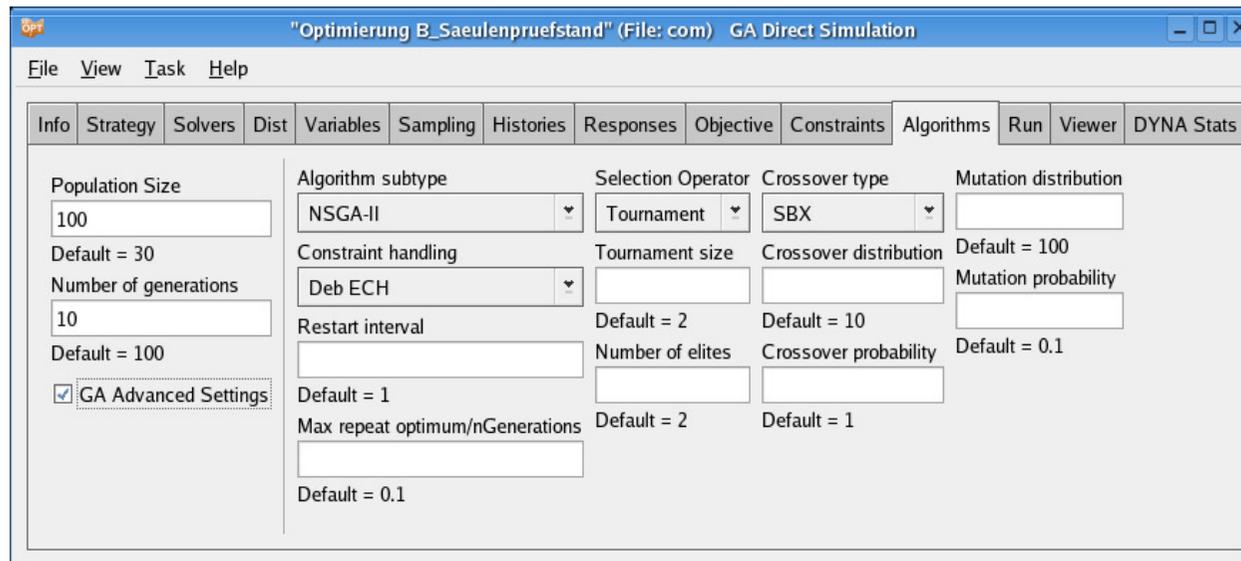
Optimierungsalgorithmus

- viele diskrete Optimierungsvariablen → genetischer Algorithmus
 - Blocklänge, Materialzuweisung → diskret
 - Morphing → kontinuierlich
- drei Optimierungsziele → „multi-objective optimization“ (MOO)
 - Verschiebungskriterium
 - Energiekriterium
 - Komplexität des Impaktors
- konkurrierende Optimierungsziele → „pareto optimal solutions“



Genetischer Algorithmus → „genetic algorithm“ (GA)

- antwortflächenfreies Verfahren, kein Metamodell erforderlich
- globales Optimierungsverfahren ohne Konvergenzkriterium
- basierend auf Selektion, Kombination und Mutation des Vektors der Designvariablen
- „nature inspired“, „survival of the fittest“
- Notation:
 - Individuum → jeder Vektor der Designvariablen, Designpunkt
 - Population → Gruppe von Individuen, Populationsgröße
 - Generation → Individuen einer Iteration, Elterngeneration, Kindgeneration



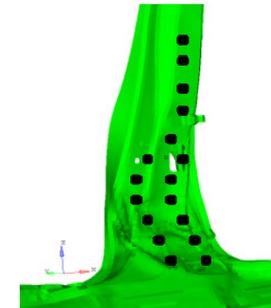
Auswertung – Deformationsbild (DNO_MEAN_ERROR_D_DISP_TIME)

Quadratischer Mittelwert

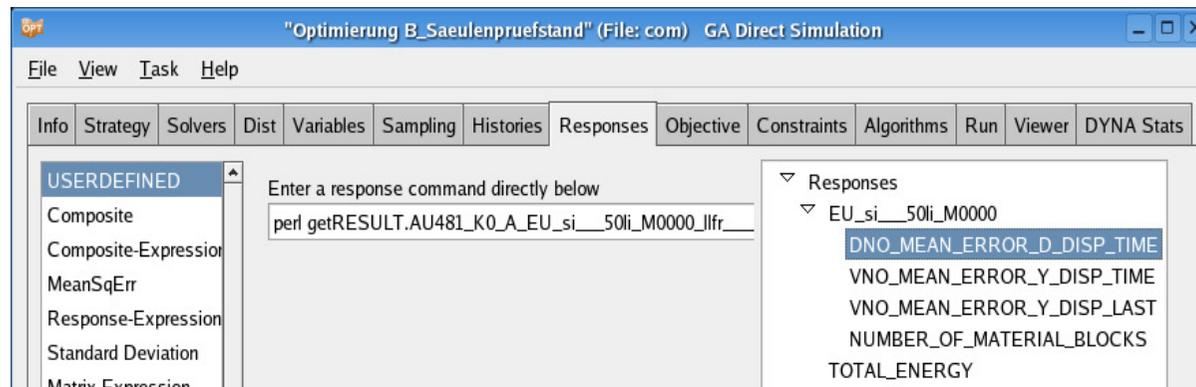
$$QMW = \sqrt{\frac{1}{|t_2 - t_1|} \int_{t_1}^{t_2} f(t)^2 dt}$$

Erzeugung Animator Sessionfile

```
# Schleife ueber alle Knoten der B-Saeule
# Berechnung des quadratischen Mittelwertes (QMW) fuer kontinuierliche Verschiebungsdifferenz
# QMW = sqrt((int_t0^t100(u(t))/(abs(t0-t100)))
for I in `cat $NODES_FILE`; do
  echo "s[0]: !ide his dst nod 0:$I nod 1:$I" >>$SESSION_FILE
  echo "s[0]: !c2d cal error_uno = {VNerror_uno} + sqrt(int(([0:1]^2),0,99)/100)" >>$SESSION_FILE
  echo "s[0]: !c2d cal error_vno = {VNerror_vno} + sqrt(int(([0:2]^2),0,99)/100)" >>$SESSION_FILE
  echo "s[0]: !c2d cal error_wno = {VNerror_wno} + sqrt(int(([0:3]^2),0,99)/100)" >>$SESSION_FILE
  echo "s[0]: !c2d cal error_dno = {VNerror_dno} + sqrt(int(([0:4]^2),0,99)/100)" >>$SESSION_FILE
  echo 's[0]: !c2d cal error_uno_last = {VNerror_uno_last} + sqrt(int(([0:1]^2),99.8,99.9)*10)' >>$SESSION_FILE
  echo 's[0]: !c2d cal error_vno_last = {VNerror_vno_last} + sqrt(int(([0:2]^2),99.8,99.9)*10)' >>$SESSION_FILE
  echo 's[0]: !c2d cal error_wno_last = {VNerror_wno_last} + sqrt(int(([0:3]^2),99.8,99.9)*10)' >>$SESSION_FILE
  echo 's[0]: !c2d cal error_dno_last = {VNerror_dno_last} + sqrt(int(([0:4]^2),99.8,99.9)*10)' >>$SESSION_FILE
  echo "s[0]: !c2d del all" >>$SESSION_FILE
  echo "!xcm vie clo" >>$SESSION_FILE
done
```



LS-OPT



LS-OPT: User-Defined Response

The image shows two overlapping windows from the LS-OPT software. The top window is a terminal window displaying simulation results for various mean error metrics. The bottom window is the 'User-Defined Response' dialog, where a response command is being defined.

```
??? ISOCODE ??? ; UNO_MEAN_ERROR_X_DISP_TIME; 10.45464 ; 0
??? ISOCODE ??? ; VNO_MEAN_ERROR_Y_DISP_TIME; 28.53966 ; 0
??? ISOCODE ??? ; WNO_MEAN_ERROR_Z_DISP_TIME; 52.23695 ; 0
??? ISOCODE ??? ; DNO_MEAN_ERROR_D_DISP_TIME; 63.20021 ; 0
??? ISOCODE ??? ; UNO_MEAN_ERROR_X_DISP_LAST; 9.26952 ; 0
??? ISOCODE ??? ; VNO_MEAN_ERROR_Y_DISP_LAST; 41.26244 ; 0
??? ISOCODE ??? ; WNO_MEAN_ERROR_Z_DISP_LAST; 66.47468 ; 0
??? ISOCODE ??? ; DNO_MEAN_ERROR_D_DISP_LAST; 83.88326 ; 0
```

The 'User-Defined Response' dialog shows the following configuration:

- Case: EU_si__50li_M0000
- Multiplier: 1
- Offset: 0
- Not metamodel-linked:
- Response Name: VNO_MEAN_ERROR_Y_DISP_TIME
- Response Command: `peri getRESULT.AU481_K0_A_EU_si__50li_M0000_lifr_____weg49ft__BSP_Optimierung.pl VNO_`
- Responses list: EU_si__50li_M0000
 - DNO_MEAN_ERROR_D_DISP_TIME
 - VNO_MEAN_ERROR_Y_DISP_TIME (highlighted)
 - VNO_MEAN_ERROR_Y_DISP_LAST
 - TOTAL_ENERGY

LS-OPT v4.1: GENeric EXtractor

The screenshot displays the LS-OPT v4.1 interface with the GeSEx window open. The GeSEx window shows a tree view on the left with 'ANCHOR_DNO' selected, and a data table on the right. The data table contains the following rows:

Entity Name	Value
NUMBER_OF_MATERIAL_BLOCKS	13 ; 0
UNO_MEAN_ERROR_X_DISP_TIME	7.41645 ; 0
VNO_MEAN_ERROR_Y_DISP_TIME	27.62345 ; 0
WNO_MEAN_ERROR_Z_DISP_TIME	34.31007 ; 0
DNO_MEAN_ERROR_D_DISP_TIME	45.88310 ; 0
UNO_MEAN_ERROR_X_DISP_LAST	5.61357 ; 0
VNO_MEAN_ERROR_Y_DISP_LAST	33.90089 ; 0
WNO_MEAN_ERROR_Z_DISP_LAST	34.76110 ; 0
DNO_MEAN_ERROR_D_DISP_LAST	51.11710 ; 0

The LS-OPT main window shows the 'Responses' tab selected. The 'Responses' list contains 'DNO_MEAN_EROR_D_DISP_'. The 'Entities' list contains 'DNO_MEAN_ERROR_D_DISP_TIME'. The 'Input GeSEx file' is set to '/home/weg49ft/PROJEKTE'. The 'Input data file' is set to 'AU481_K0_A_EU_si_50l'. The 'Entities' list is empty. The 'Reread entities' button is visible.

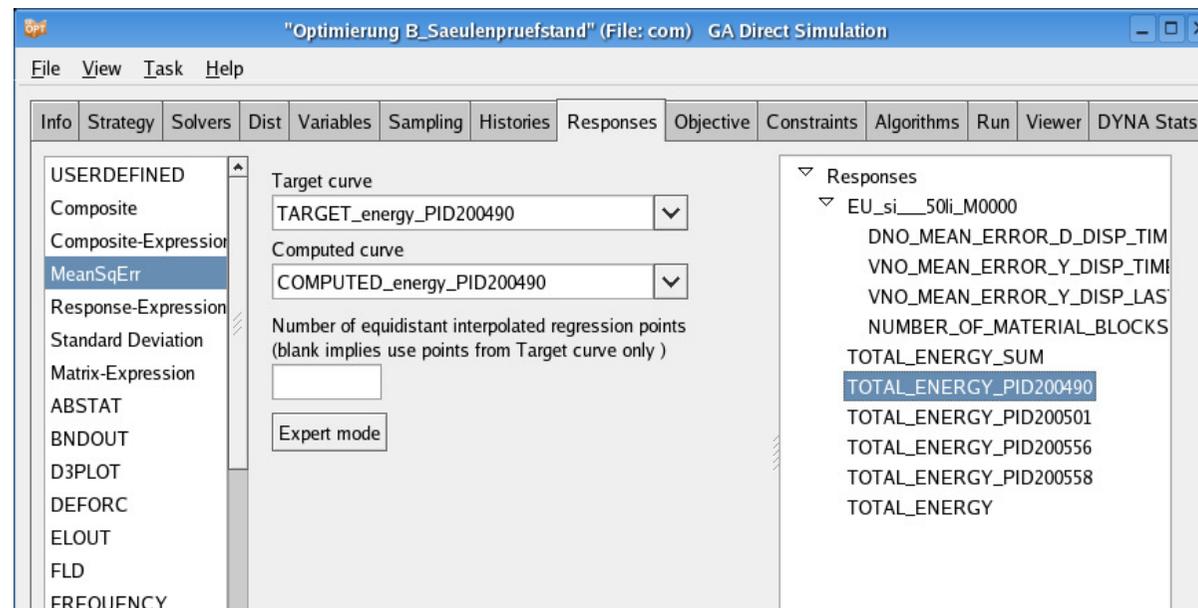
The right-hand panel shows the configuration for the selected response 'DNO_MEAN_ERROR_D_DISP_TIME'. The 'Entity name' is 'DNO_MEAN_ERROR_D_DISP_TIME'. The 'Origin' is 'ANCHOR_DNO'. The 'Number format' is set to 'Decimal separator(s): .' and 'Exponent character(s): Ee'. The 'Thousands separators' are 'Space'. The 'Relative location' is '0 lines, 11 columns'. The 'Column separators' are 'Tab', 'Space', and 'Whitespace'. The 'Maximum length' is '0 character(s)'.

Auswertung – Verformungsenergie (TOTAL_ENERGY)

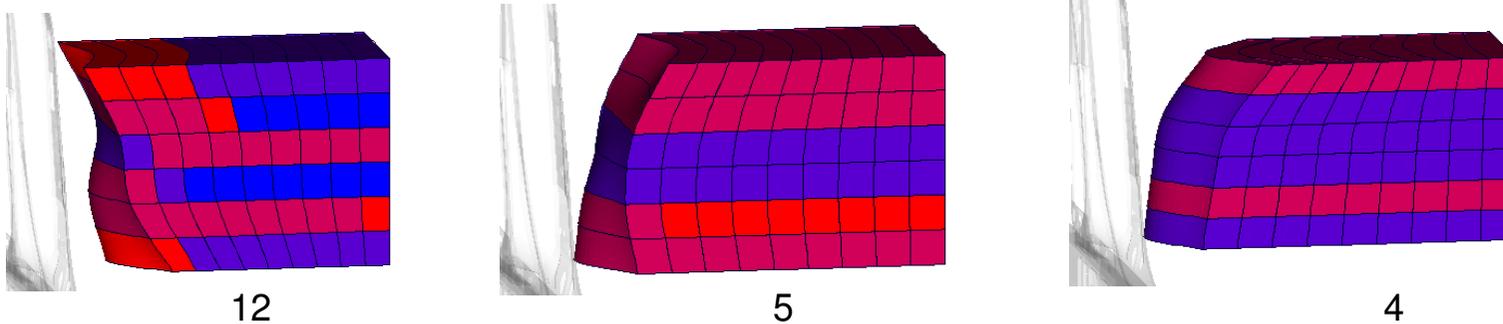
Quadratischer Mittelwert (LS-OPT - MeanSqErr)

$$\varepsilon = \frac{1}{P} \sum_{p=1}^P W_p \left(\frac{f_p(\mathbf{x}) - G_p}{s_p} \right)^2 = \frac{1}{P} \sum_{p=1}^P W_p \left(\frac{e_p(\mathbf{x})}{s_p} \right)^2$$

LS-OPT



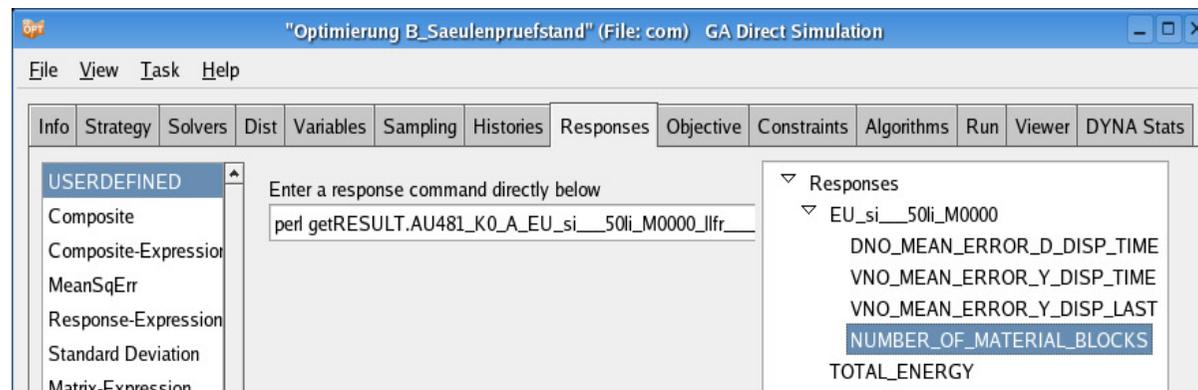
Auswertung – Impaktorkomplexität (NUMBER_OF_MATERIAL_BLOCKS)



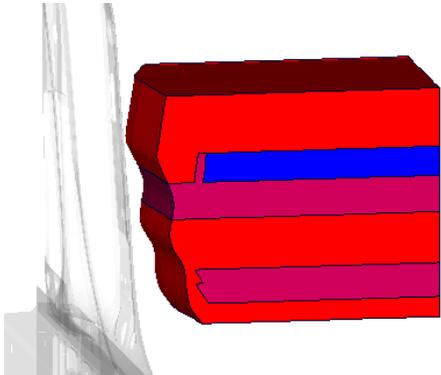
Python Skript

```
# Anzahl der zusammenhaengenden Bloecke mit gleichem Material (nr_of_blocks)
nr_of_blocks=0
for i in range(6):
    BL = 0
    # Anzahl der Bloecke maximal pro Reihe
    nr_of_blocks = nr_of_blocks + 3
    for j in range(3):
        # gleiche Blockmaterialien nebeneinander
        if (j<2) and (RX_BM[i][j] == RX_BM[i][j+1]) and (RX_BL[i][j] != 0) and (RX_BL[i][j+1] != 0):
            nr_of_blocks = nr_of_blocks - 1
        # Blocklaenge 0
        if (RX_BL[i][j] == 0):
            nr_of_blocks = nr_of_blocks - 1
    ...
```

LS-OPT



Ausgangsbasis



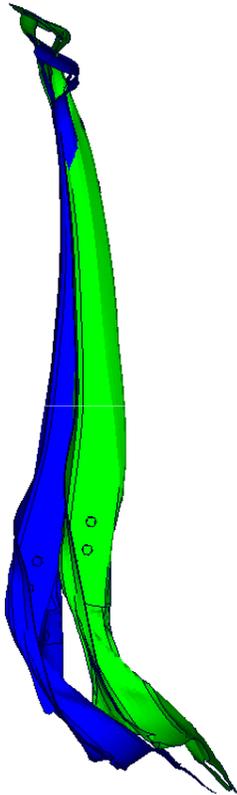
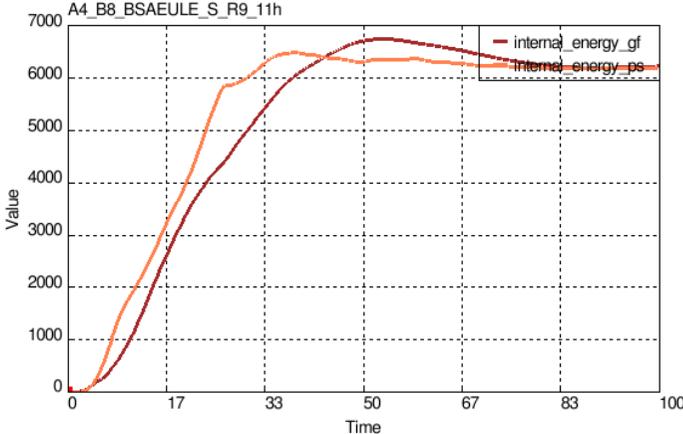
- Stahl St355
- EPP 250
- EPP130

Deformationsbild

DNO_MEAN_ERROR_D_DISP_TIME = 68.18

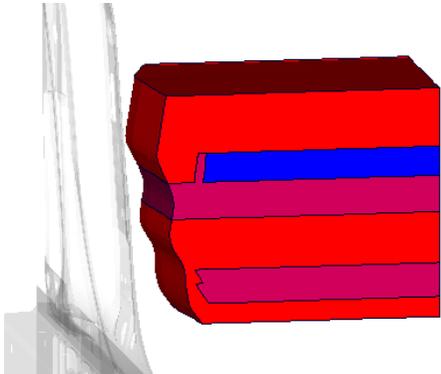
Verformungsenergie

TOTAL_ENERGY = 0.0987



- Prüfstand
- Gesamtfahrzeug

Ausgangsbasis



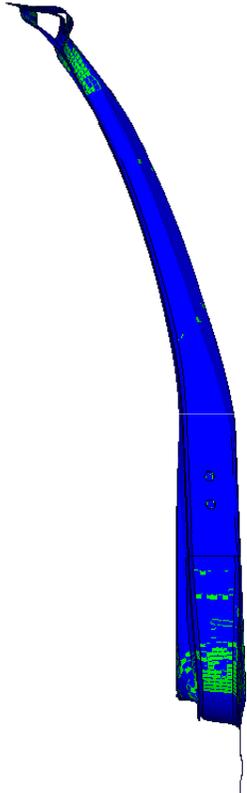
- Stahl St355
- EPP 250
- EPP130

Deformationsbild

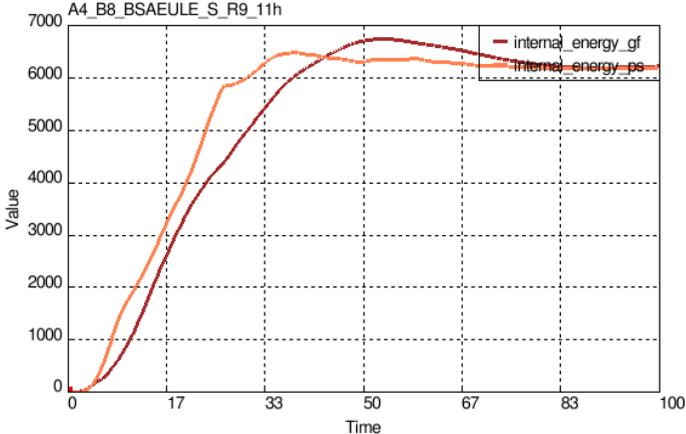
DNO_MEAN_ERROR_D_DISP_TIME = 68.18

Verformungsenergie

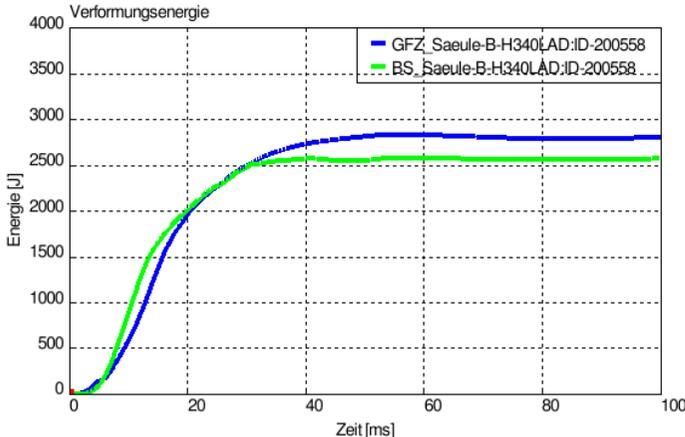
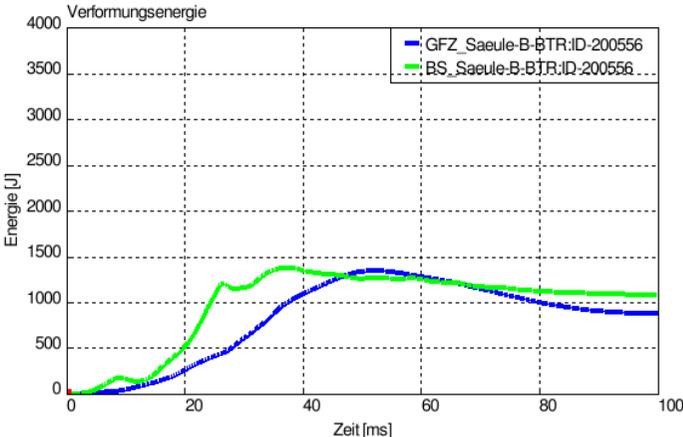
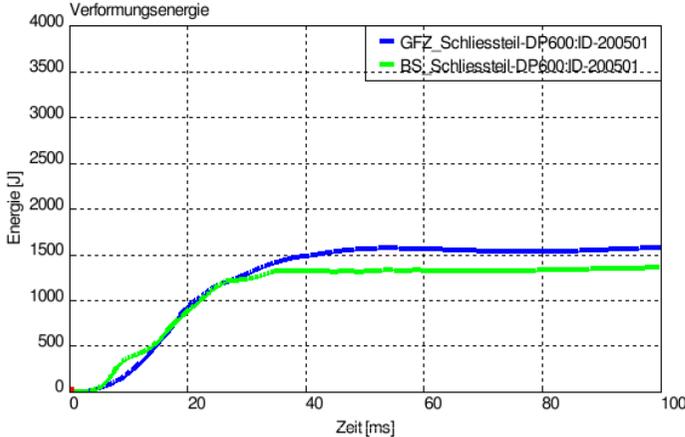
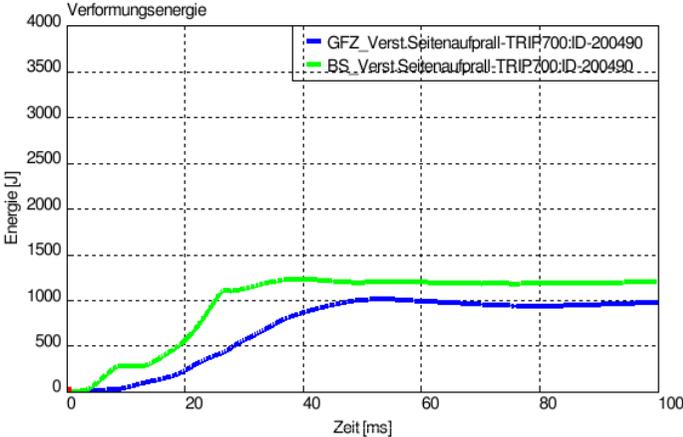
TOTAL_ENERGY = 0.0987



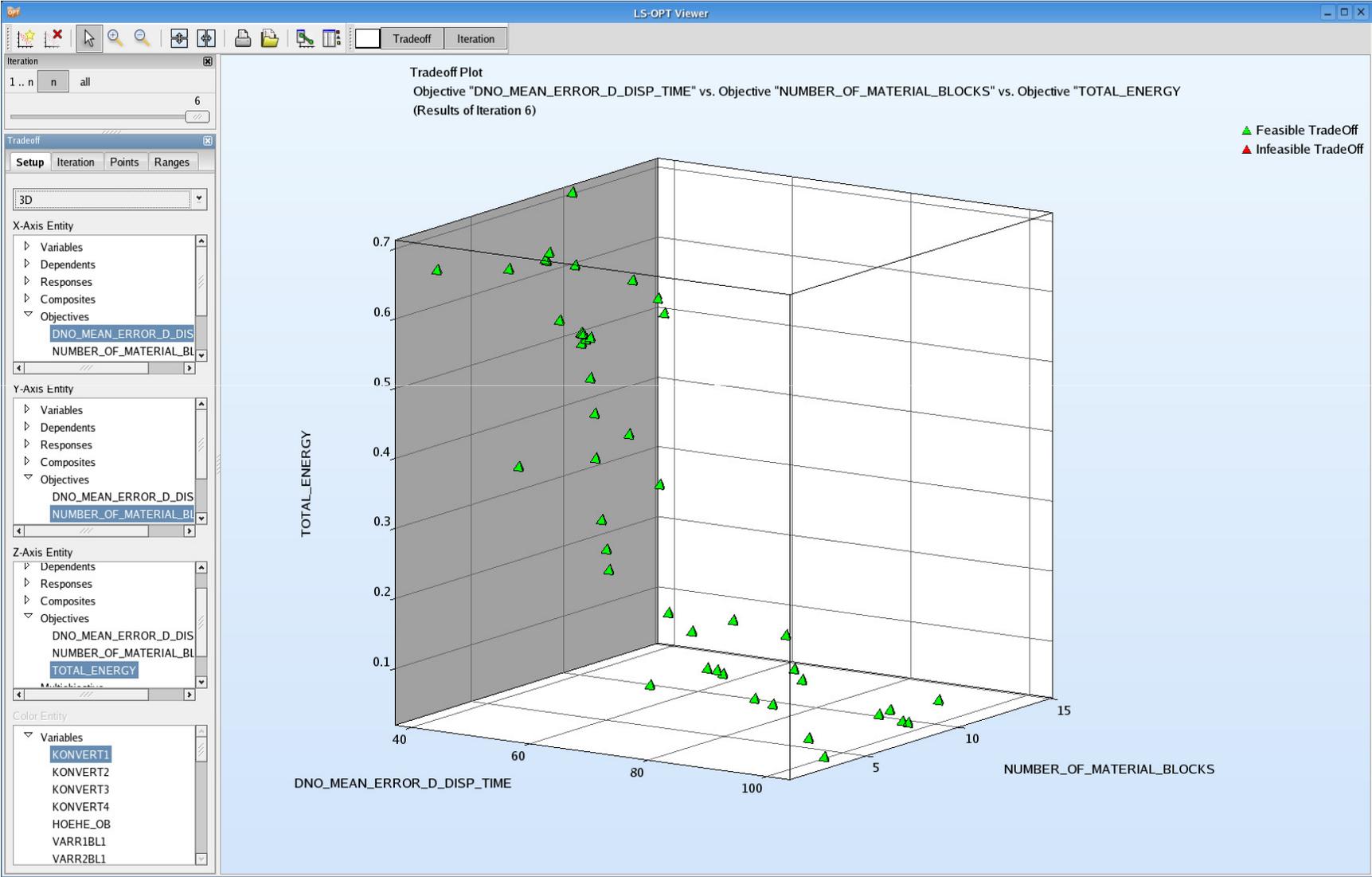
- Prüfstand
- Gesamtfahrzeug



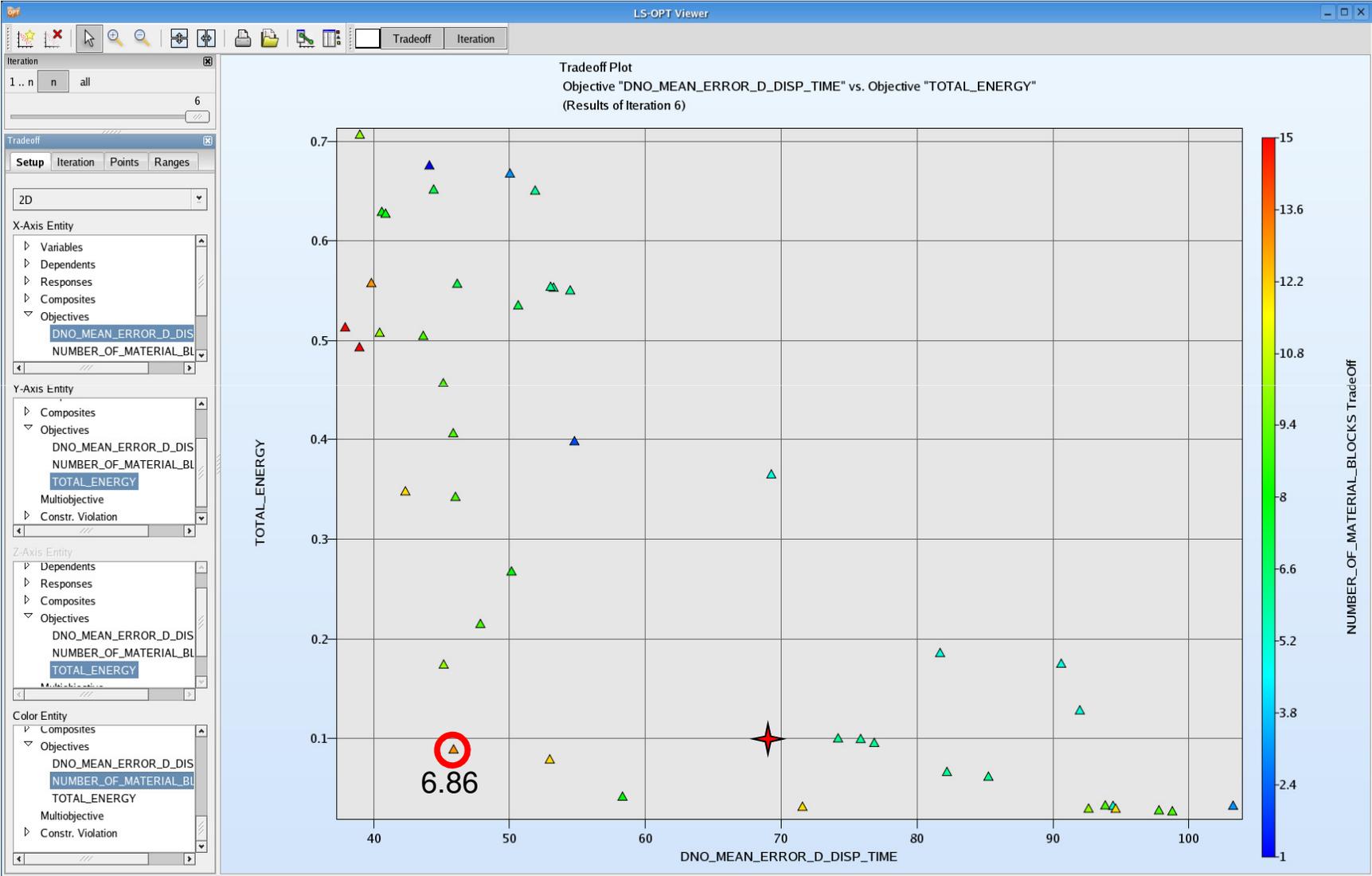
Ausgangsbasis



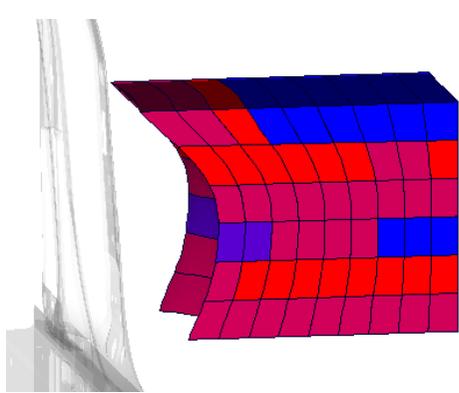
Tradeoff Plott (6. Generation)



Tradeoff Plott (6. Generation)



Variante 6.86



- Stahl St355
- EPP 220
- EPP 140
- EPP 70

Impaktorkomplexität

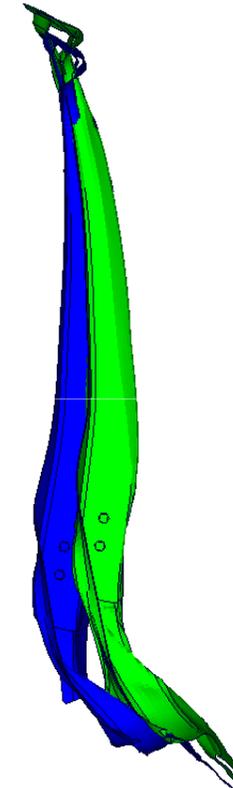
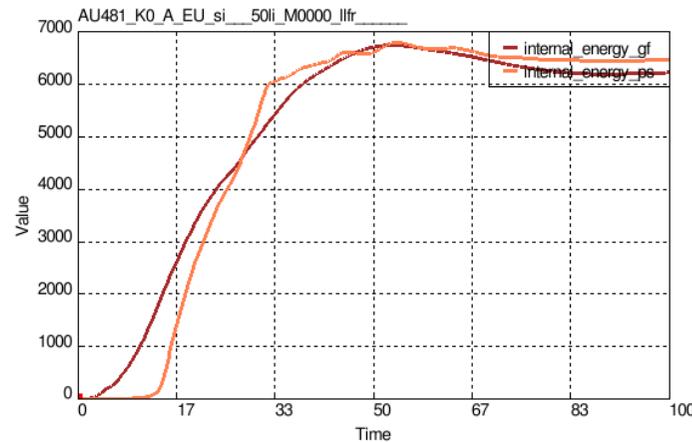
NUMBER_OF_MATERIAL_BLOCKS = 13

Deformationsbild

DNO_MEAN_ERROR_D_DISP_TIME = 45.88

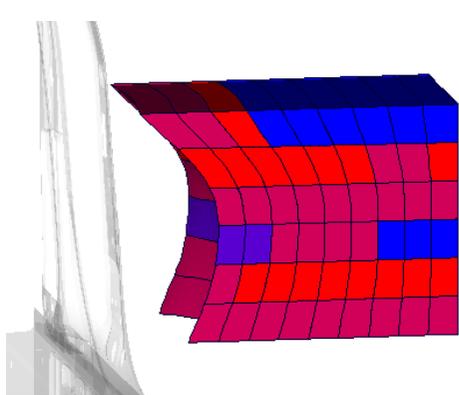
Verformungsenergie

0.0882

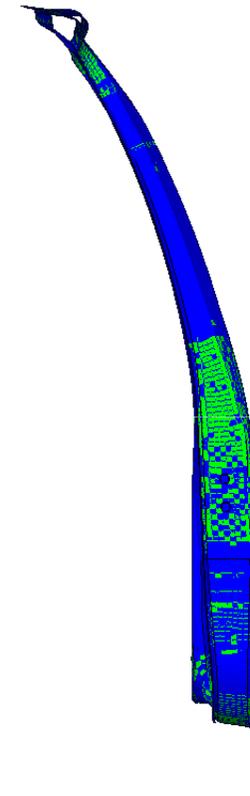


- Prüfstand
- Gesamtfahrzeug

Variante 6.86



- Stahl St355
- EPP 220
- EPP 140
- EPP 70



- Prüfstand
- Gesamtfahrzeug

Impaktorkomplexität

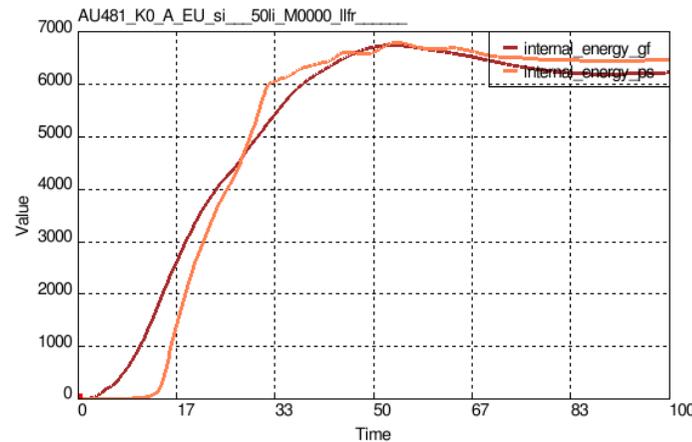
NUMBER_OF_MATERIAL_BLOCKS = 13

Deformationsbild

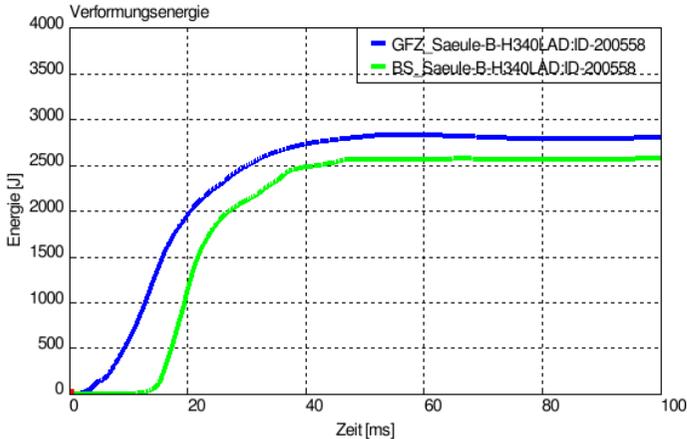
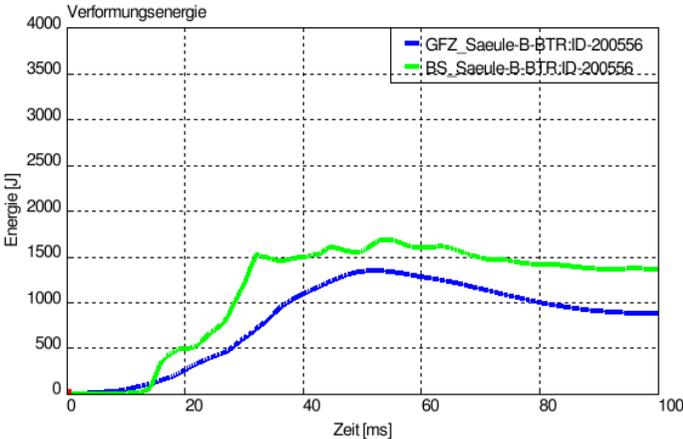
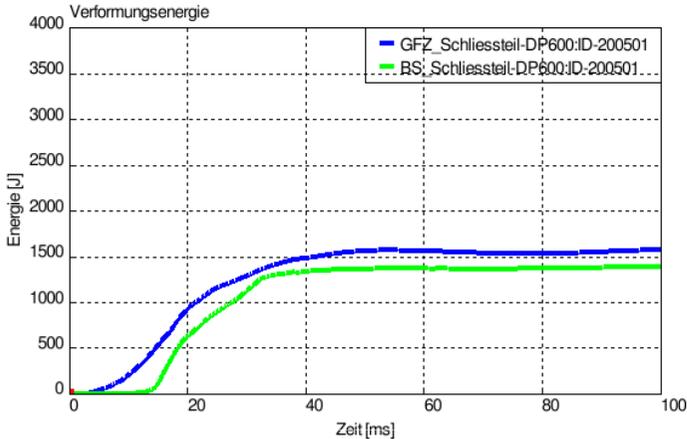
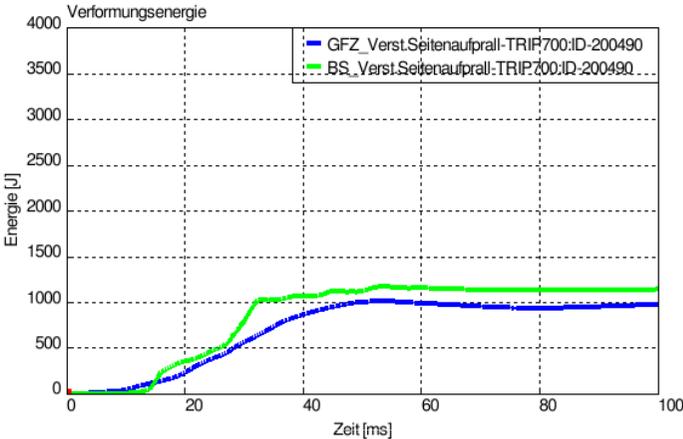
DNO_MEAN_ERROR_D_DISP_TIME = 45.88

Verformungsenergie

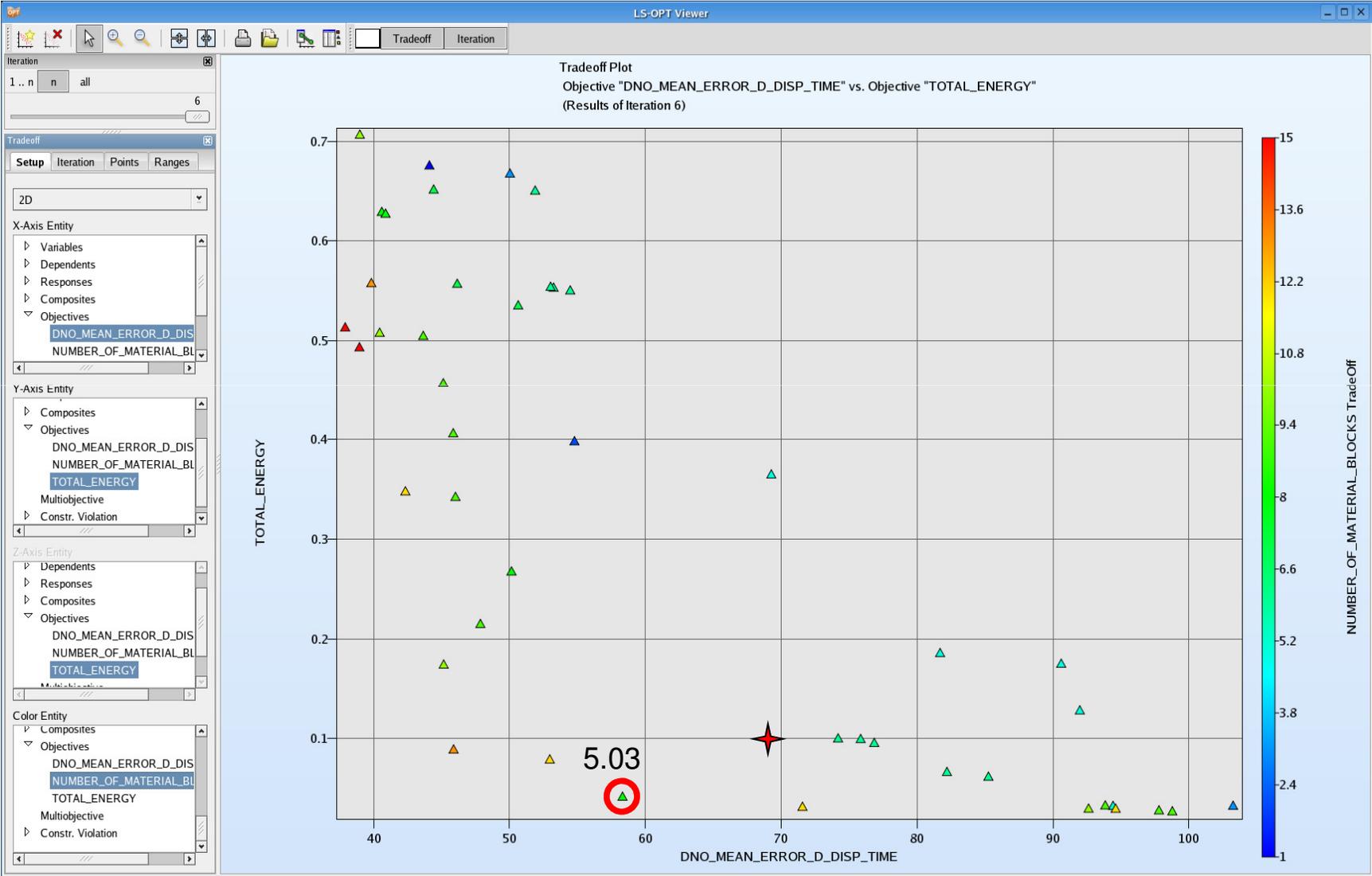
0.0882



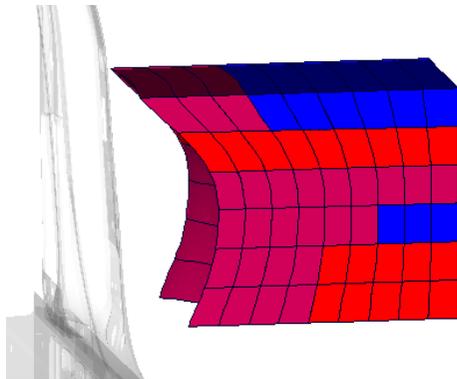
Variante 6.86



Tradeoff Plott (6. Generation)



Variante 5.03



- Stahl St355
- EPP 220
- EPP 140
- EPP 70

Impaktorkomplexität

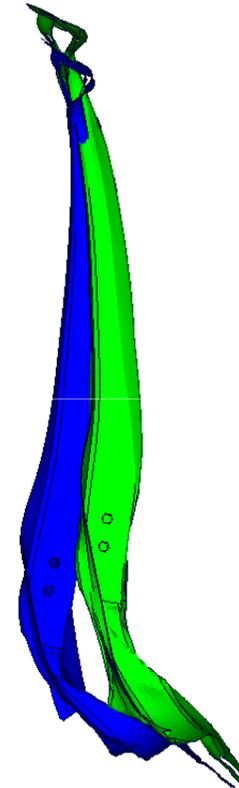
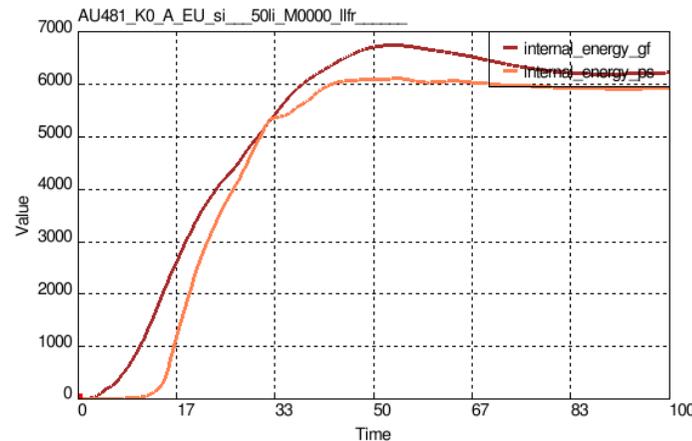
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Deformationsbild

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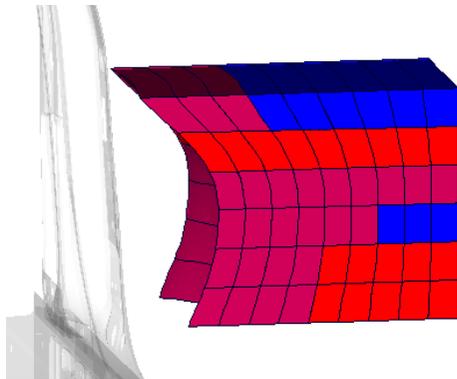
Verformungsenergie

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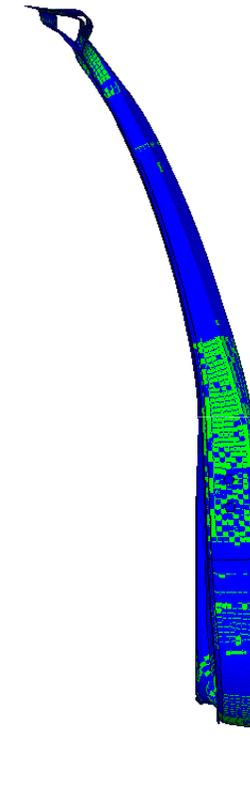


- Prüfstand
- Gesamtfahrzeug

Variante 5.03



- Stahl St355
- EPP 220
- EPP 140
- EPP 70



Impaktorkomplexität

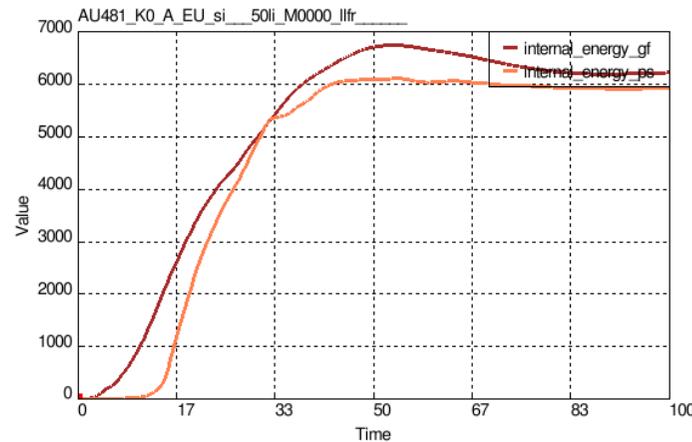
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Deformationsbild

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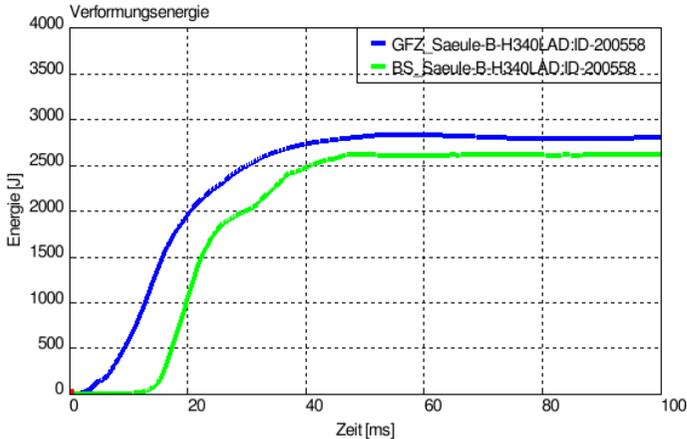
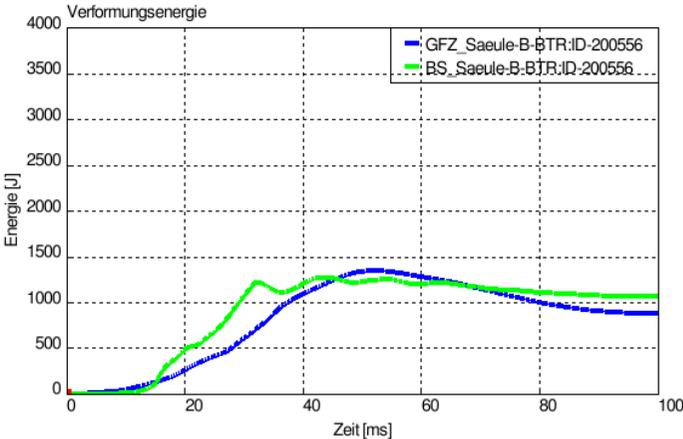
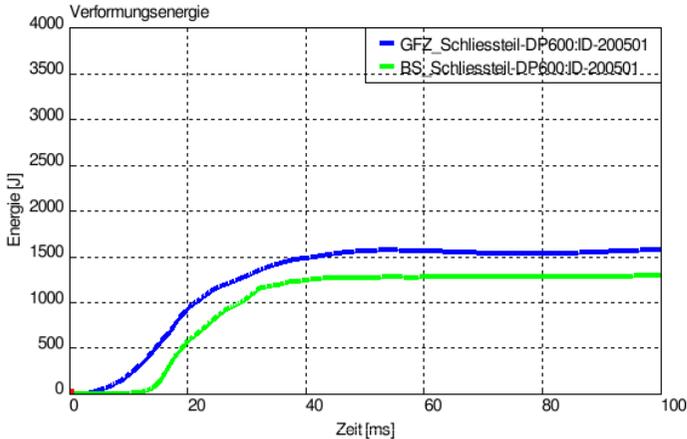
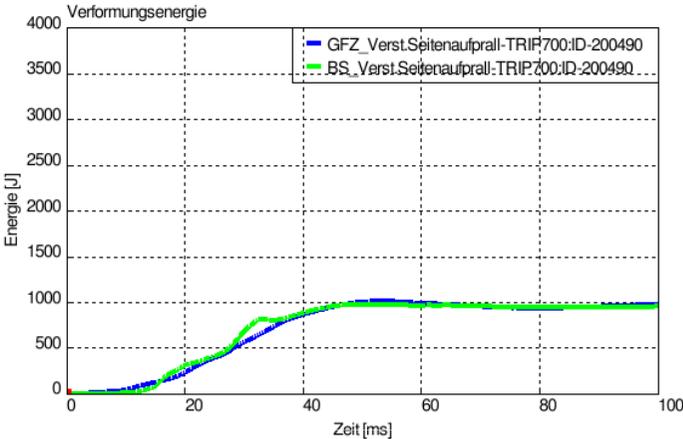
Verformungsenergie

0.0407



- Prüfstand
- Gesamtfahrzeug

Variante 5.03



Zusammenfassung

- Optimierungsaufgabe mit einer Vielzahl diskreter Variablen
 - genetischer Algorithmus (NSGA-II)
- mehrere, konkurrierende Optimierungsziele
 - „multi-objective optimization“ (MOO)
 - „pareto optimal solutions“

Ergebnisse

- im Vergleich mit der handoptimierten Ausgangsbasis
 - geringere Abweichungen im Verformungsbild
 - bessere Übereinstimmung im Energieverlauf
- Berücksichtigung der Impaktorkomplexität (Fertigungsbedingung)
- bessere Ergebnisse bereits nach wenigen Generationen

