Hochschule Aalen

NUMISHEET 2005
Benchmark 2 | Cross Member

Strategies to improve the Efficiency of Sheet Metal Forming Simulations with LS-DYNA

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Hochschule Aalen

- 5.700 Studierende
- Über 50 Bachelor- und Master-Studienangebote
- Ranking deutschlandweit (von insgesamt 102 Hochschulen)
  - Wirtschaftswissenschaften Platz 1
  - Maschinenbau 3. Platz
- Weiterbildungsakademie (berufsbegleitend)
  - 4 Bachelorstudiengänge
  - 6 Masterstudiengänge

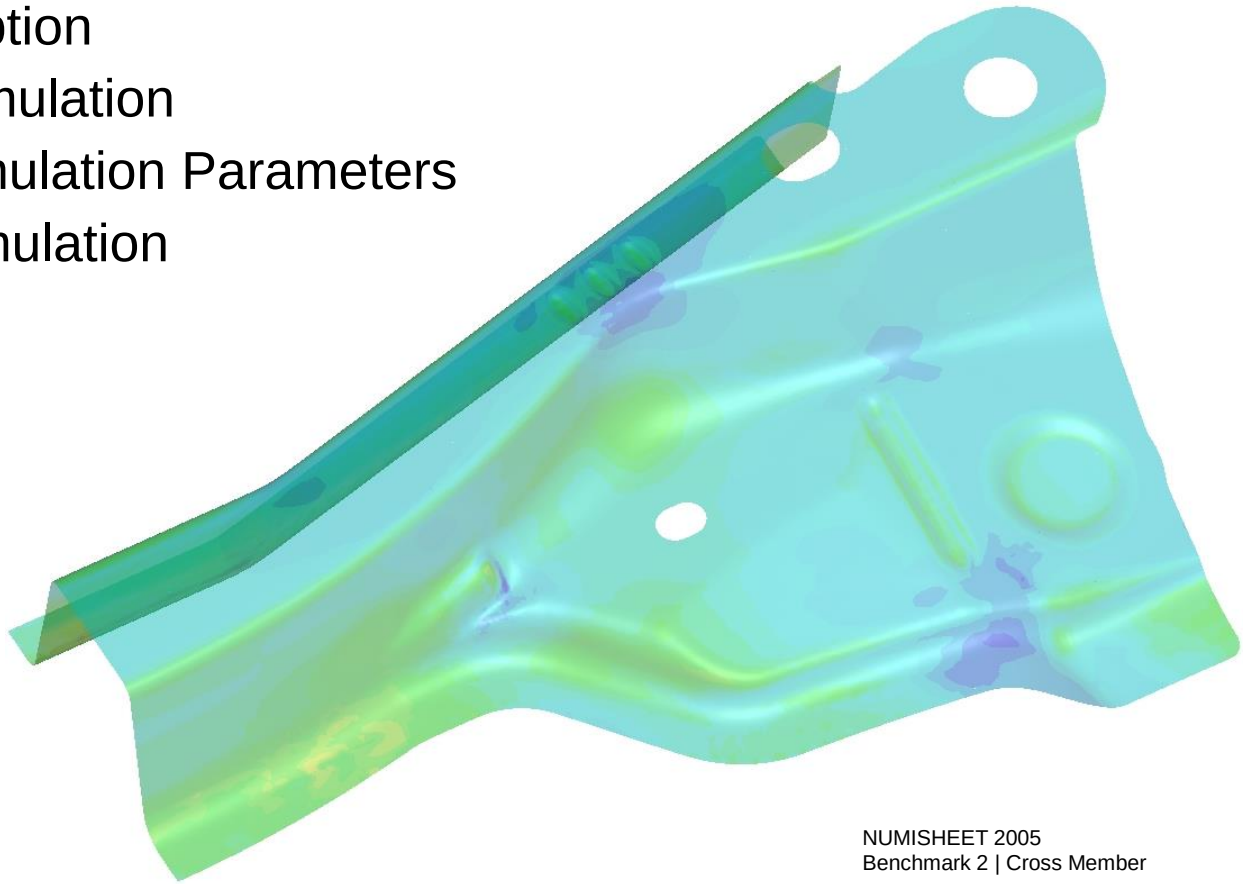
Hochschule Aalen

- Forschungsstärkste Hochschule in Baden-Württemberg
- FH-Impuls : „Smarte Materialien und intelligente Produktionstechnologien für energieeffiziente Produkte der Zukunft“ (SmartPro)
- Schwerpunkte
  - Advanced Materials and Manufacturing
  - Photonics
  - Analytische und organische Chemie
  - Intelligente mechatronische Systeme
  - Ökonomische und soziale Innovationne im gesellschaftlichen Wandel

- Zwei neue Forschungszentren bis 2019
  - Zentrum innovativer Materialien und Technologien für effiziente elektrische Energiewandler-Maschinen (ZiMATE)
  - Zentrum Technik für Nachhaltigkeit - Ressourcenschonung, Umwelt, CO2-Reduzierung (ZTN)

Overview

- Challenge
- Model Description
- Reference Simulation
- Examined Simulation Parameters
- Optimized Simulation
- Conclusions



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Challenge

LS-DYNA is an accepted FE-Solver in the Sheet Metal Forming Area …

+ Cost-Efficient
+ High Accuracy
+ High Flexibility

… but there are still some concerns in the customer's mind:

- "Tool for Experts and academic applications"
- **Simulation Time**

➔ We need optimized simulation settings with an acceptable loss of accuracy

Model Description

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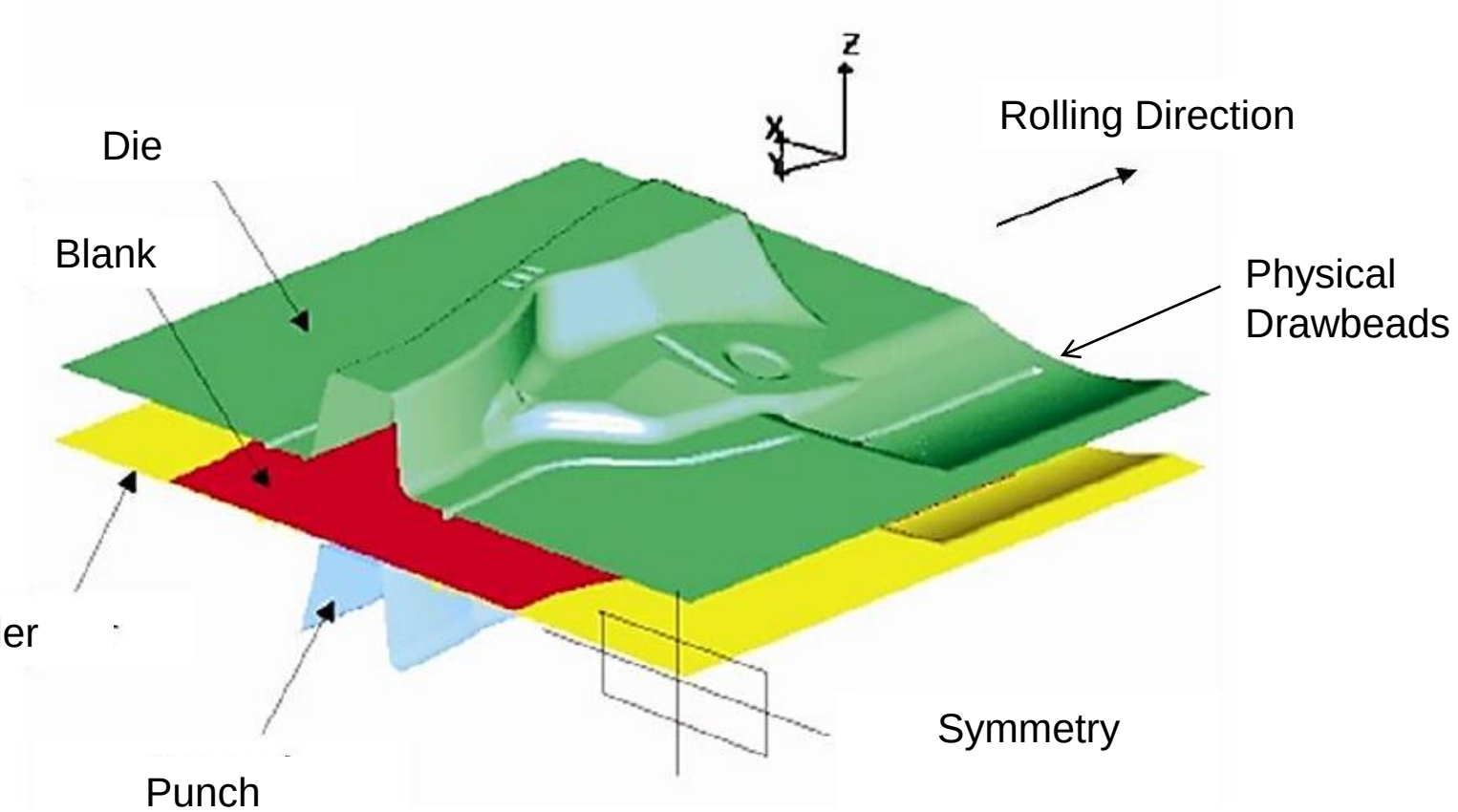
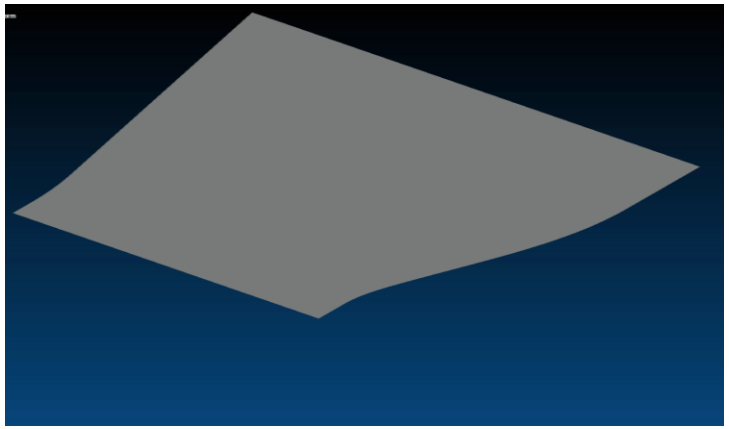


t = 1.6 mm, Aluminum Al5182-0, MAT036, F_{binder} = 200 KN

Model Description

- Process Chain

OP10 Forming



OP15 Trimming

OP25 Springback

Highest potential to reduce simulation time in the forming operation

Model Description

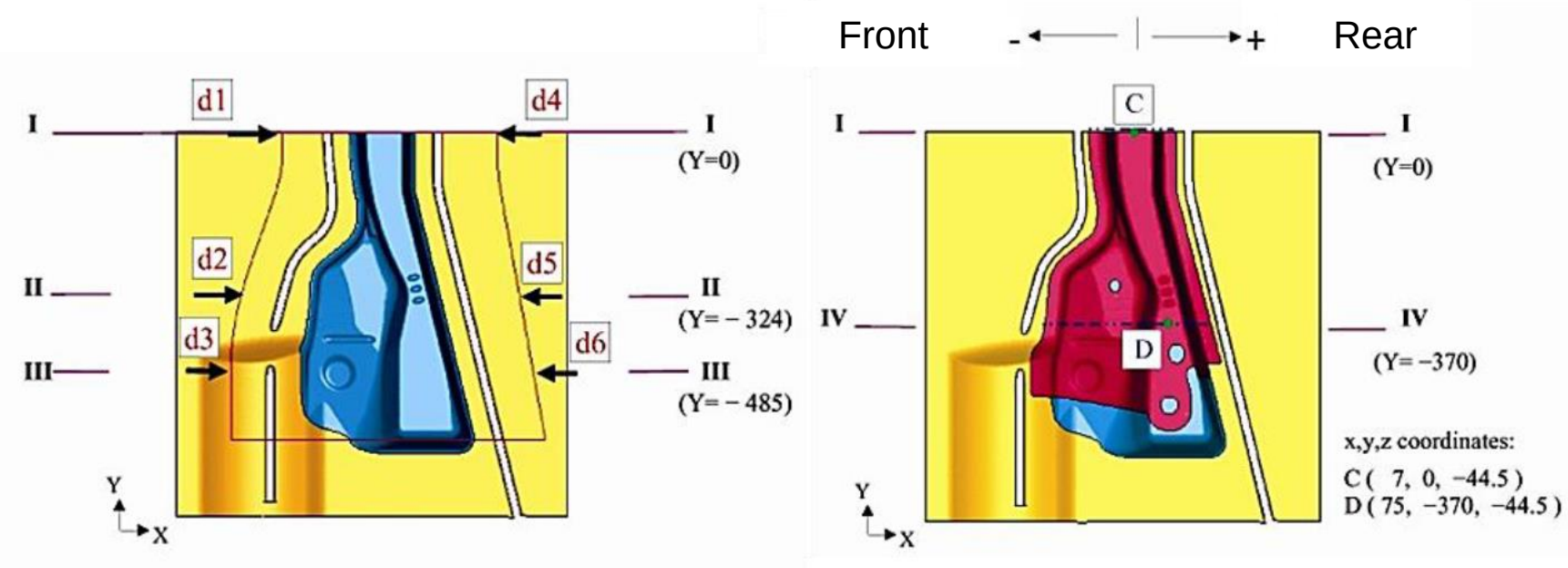
Procedure

- Setup and validation of a reference model
- Determination of the reference simulation time t_{ref}
- Variation of simulation parameters
- Comparison of forming and springback results
- Comparison of time

➔ **Setup recommendations for the early development phase**

Model Description

- Postprocessing (requested by the Benchmark)



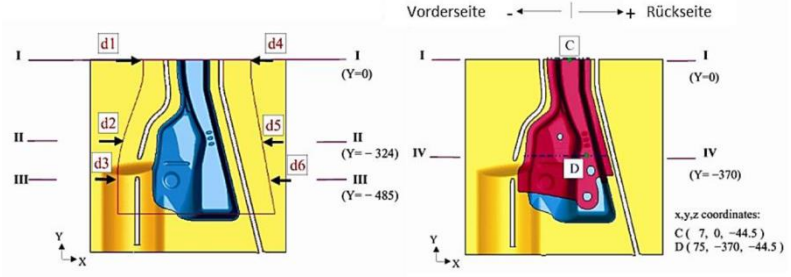
- Tonnage Prediction in KN of the whole model
- Blank draw-in in Δx (mm) at the sections I, II and III (d1 to d6)
- Major/Minor true strain distribution at the upper surface and true thickness strain distribution after forming at the sections I and IV (C an D are zero points; strain over arc length distance from C and D)
- Section cuts of the part before and after springback at sections I and IV
- Evaluation of the simulation time

Reference Simulation

- Model:
  - Elform 16
  - NIP 7
  - Element size 0.8 mm
  - No adaptive mesh refinement
  - Conventional mass scaling DT2MS=-1,46 e-7, mass increase 0.3 %
  - Tool velocity 2000 mm/sec (closing) and 5000 mm/sec (drawing)

Reference Simulation

- Results
  - Blank draw-in



Blecheinzug (Δx)	d1(mm)	d2(mm)	d3(mm)	d4(mm)	d5(mm)	d6(mm)
Experiment	62,2	51,8	56,0	73,7	57,6	47,8
Referenzsimulation	56,7	50,4	54,8	70,2	54,4	47,9

  - Springback

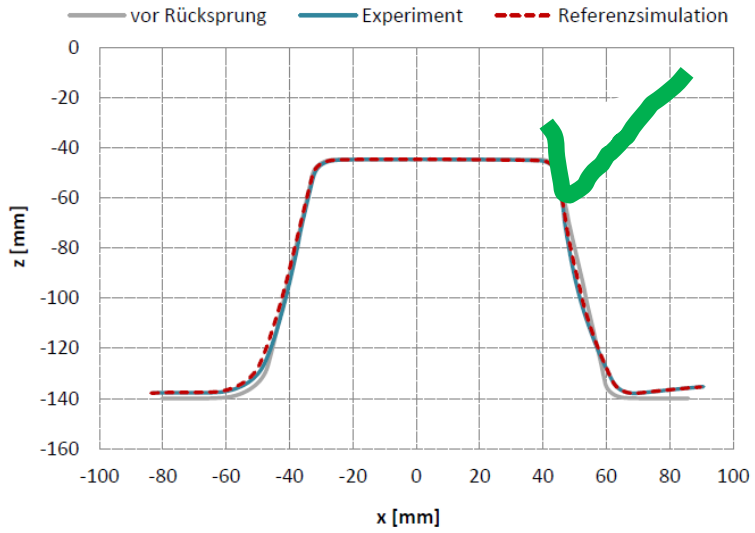


Abbildung 5.6: Rücksprung – Referenzmodell (Schnitt I)

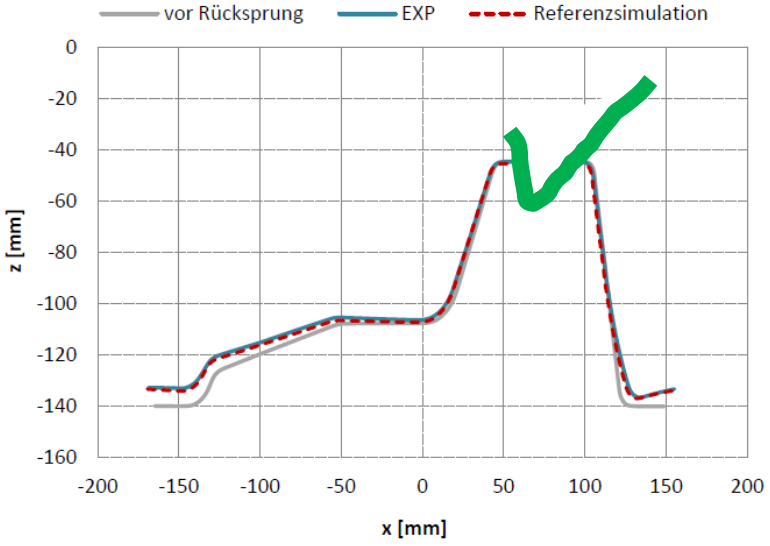
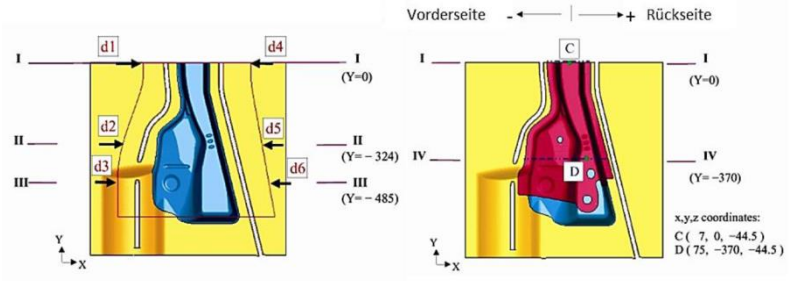


Abbildung 5.7: Rücksprung – Referenzmodell (Schnitt IV)

Reference Simulation



Simulation time (4 Cores):

67 hours 34 min. 2 sec.

☹

Examined Parameters to reduce Simulation Time

- Symmetry
- Analytical / physical drawbeads
- Number of CPUs/cores
- Conventional mass scaling
- Adaptive mesh refinement
- Element type (2, 16)
- Number of integration points
- Selective mass scaling
- Tool velocity

Examined Parameters to reduce Simulation Time

- Adaptive mesh refinement

Reference

MAXLVL	Ausgangselementkantenlänge l [mm]
1	0,8
2	1,6
3	3,2
4	6,4
5	12,8

Tabelle 5.1: Ausgangselementlänge

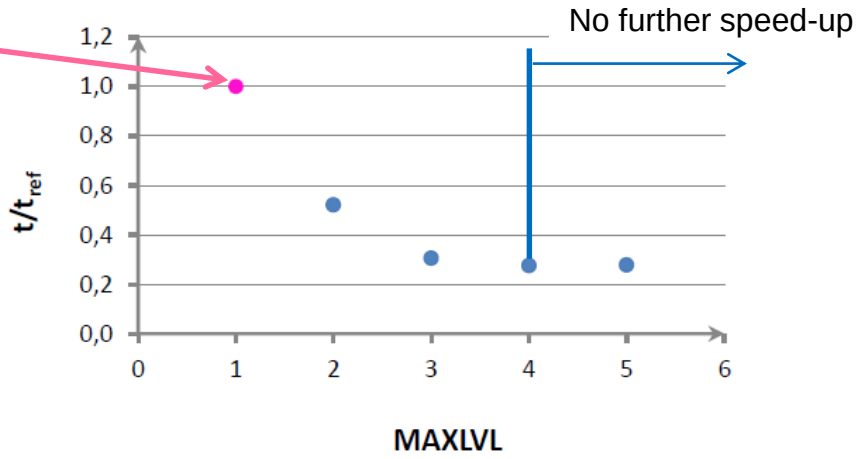
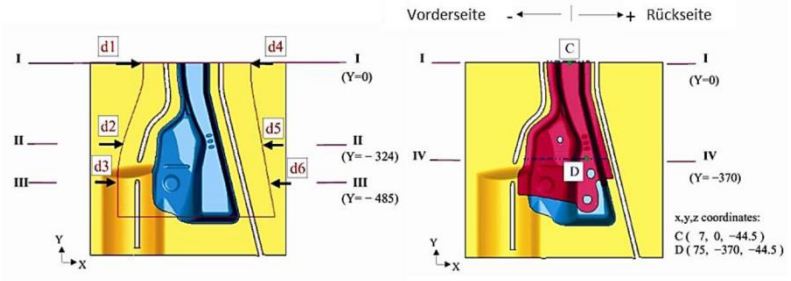


Abbildung 5.8: relative Rechenzeit – Adaptive Netzverfeinerung

- MAXLVL 4: Time reduction 72 %

Results MAXLVL 4



Blecheinzug (Δx)	d1(mm)	d2(mm)	d3(mm)	d4(mm)	d5(mm)	d6(mm)
Referenzsimulation	56,7	50,4	54,8	70,2	54,4	47,9
maxlvl4	57,1	50,2	54,6	71,7	55,6	49,3

Tabelle 5.3: Blecheinzüge – erung

Different mesh leads to different node positions

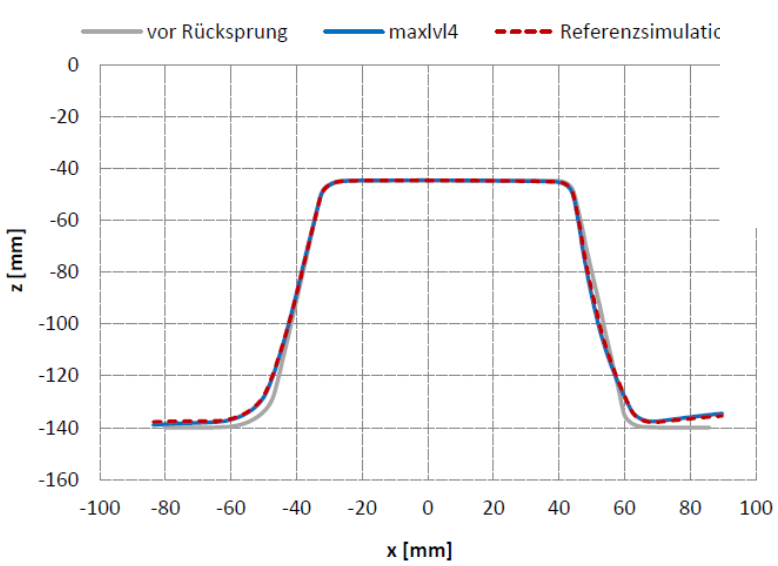


Abbildung 5.9: Rücksprung – Adaptive Netzverfeinerung (Schnitt I)

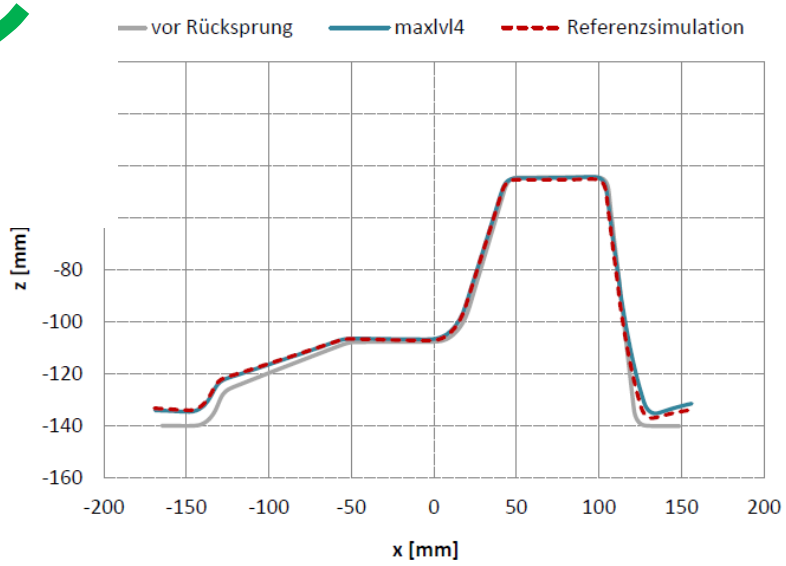


Abbildung 5.10: Rücksprung – Adaptive Netzverfeinerung (Schnitt IV)

Examined Parameters to reduce Simulation Time

- Element Type (16, 2)

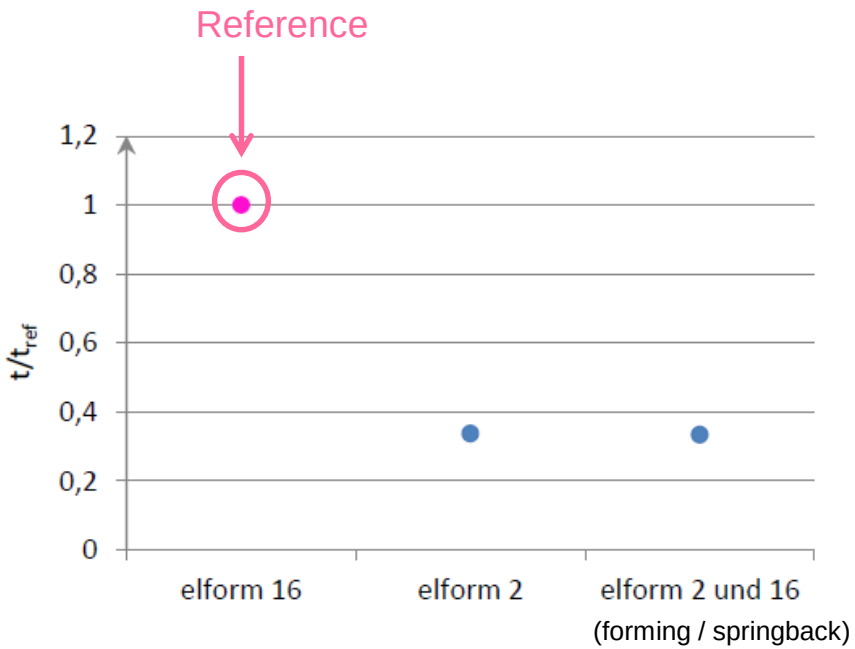
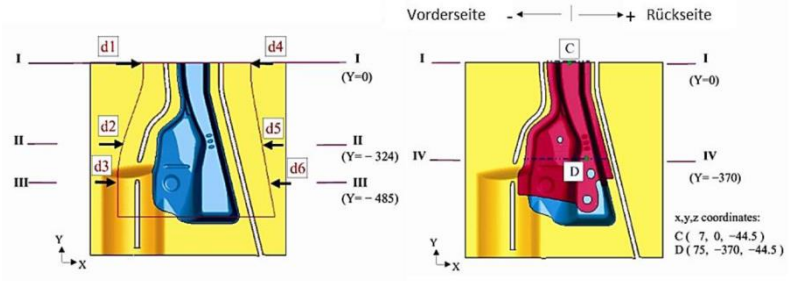


Abbildung 5.11: relative Rechenzeit – Elementtyp

- ELFORM 2: Time reduction 66 %

Results Element Type (16, 2)



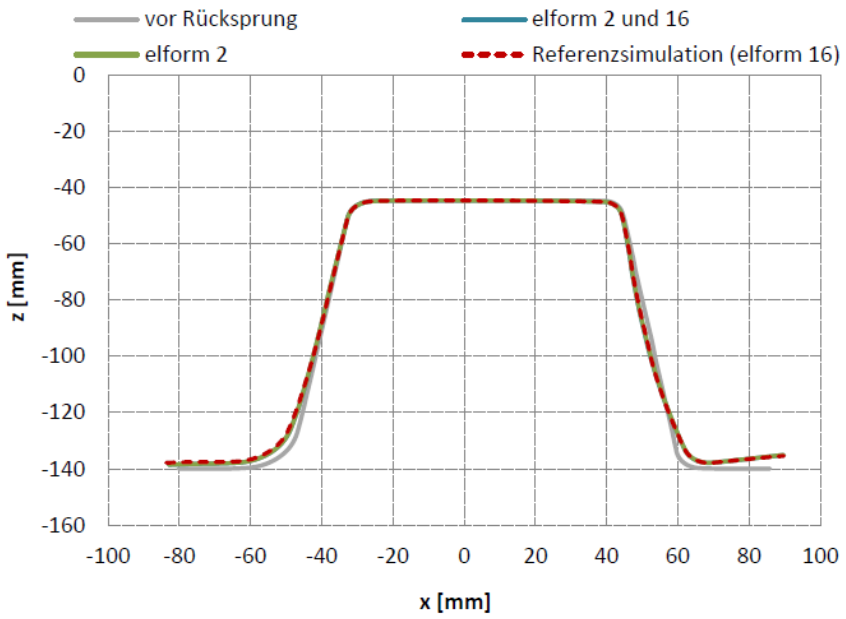


Abbildung 5.12: Rücksprung – Elementtyp (Schnitt I)

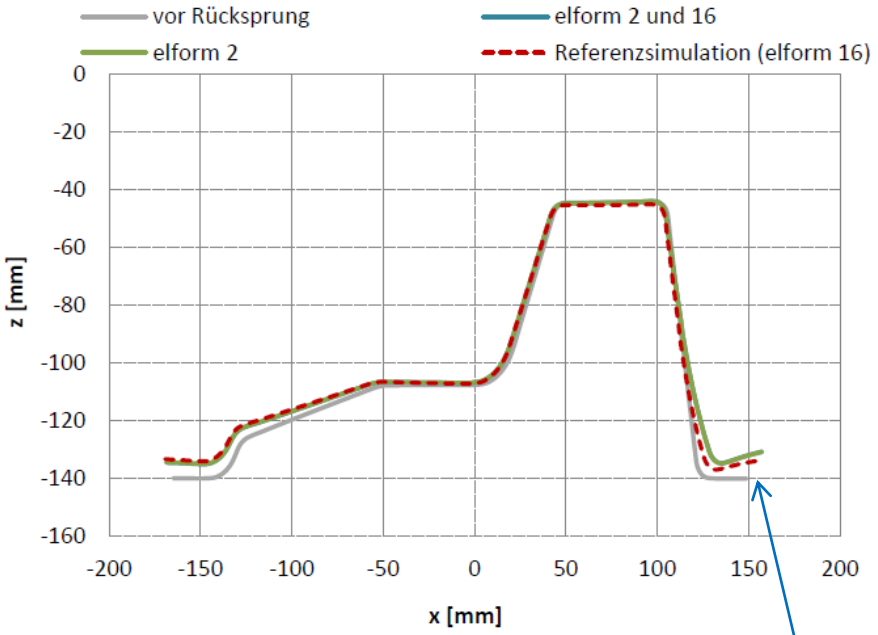


Abbildung 5.13: Rücksprung – Elementtyp (Schnitt IV)

Deviation

Results Element Type (16, 2)

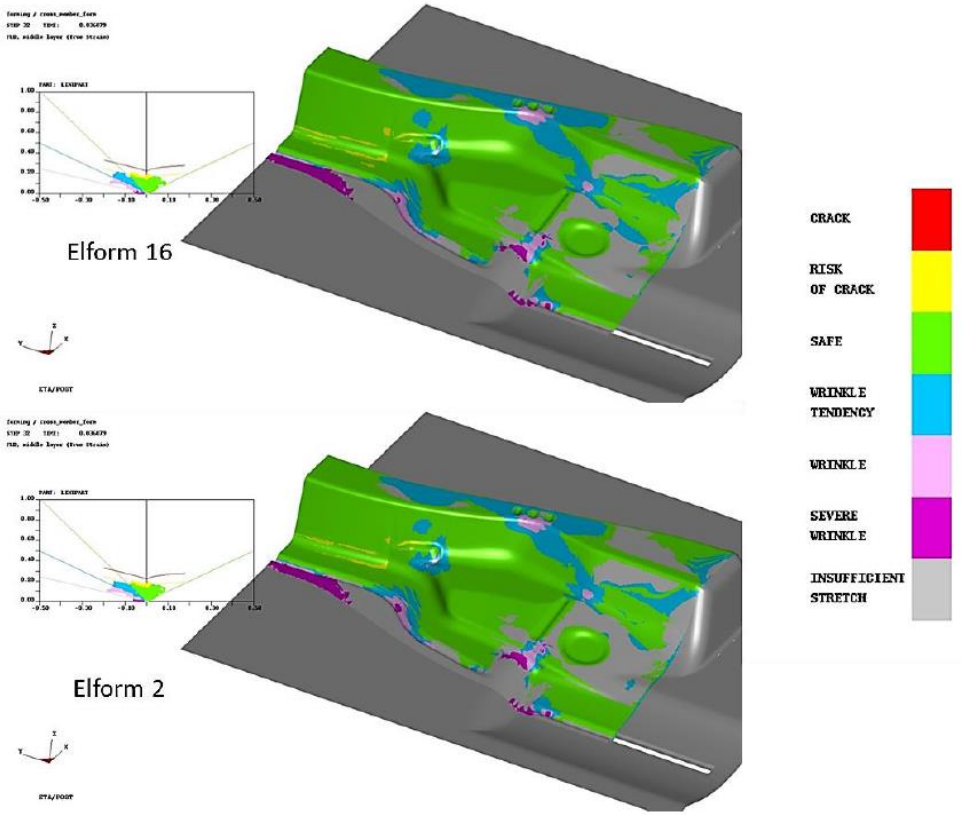


Abbildung 5.14: FLD-Diagramm – Elementtyp

- ELFORM 2:
  - Time reduction 66 %
  - Forming results ok
  - Deviations in springback

Examined Parameters to reduce Simulation Time

- Number of Integration Points (ELFORM 16)

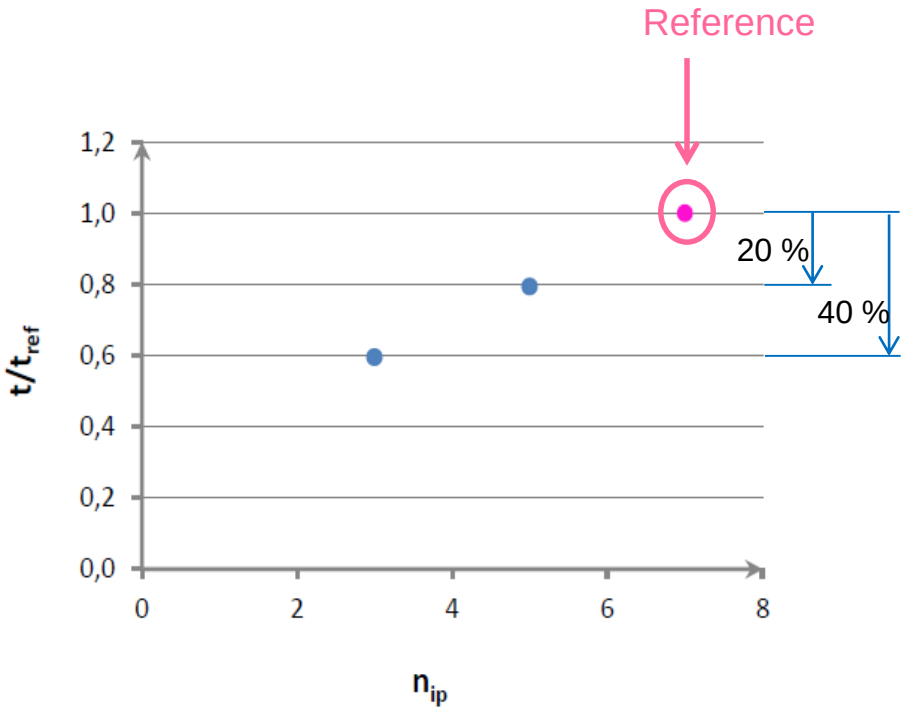
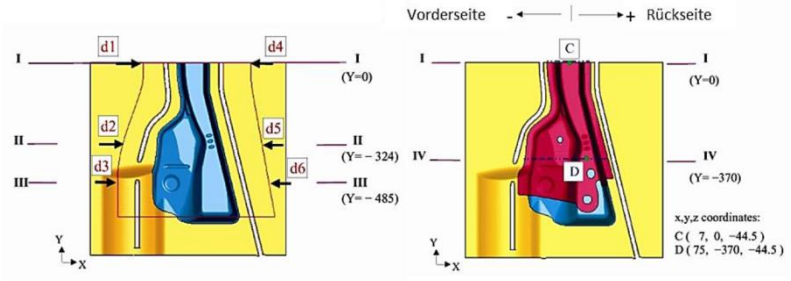
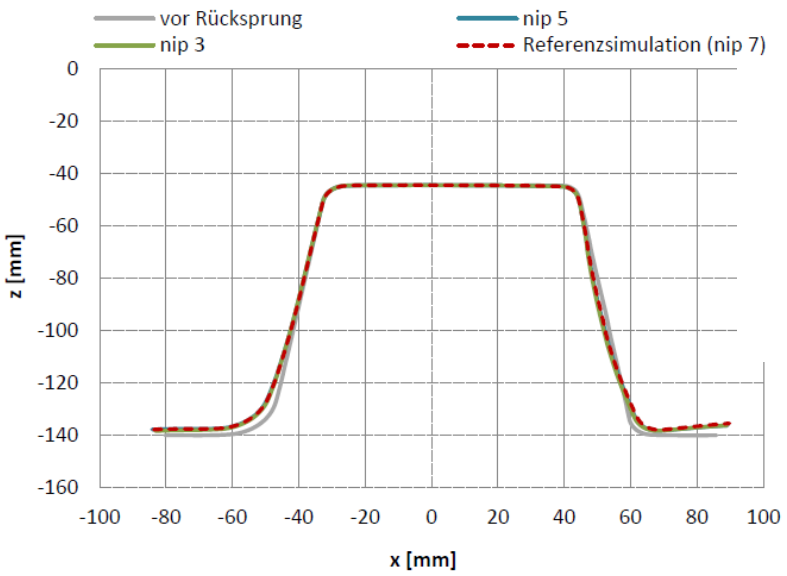


Abbildung 5.15: relative Rechenzeit – Anzahl der Integrationspunkte (ELFFORM16)

- Number of Integration Points (ELFORM 16)





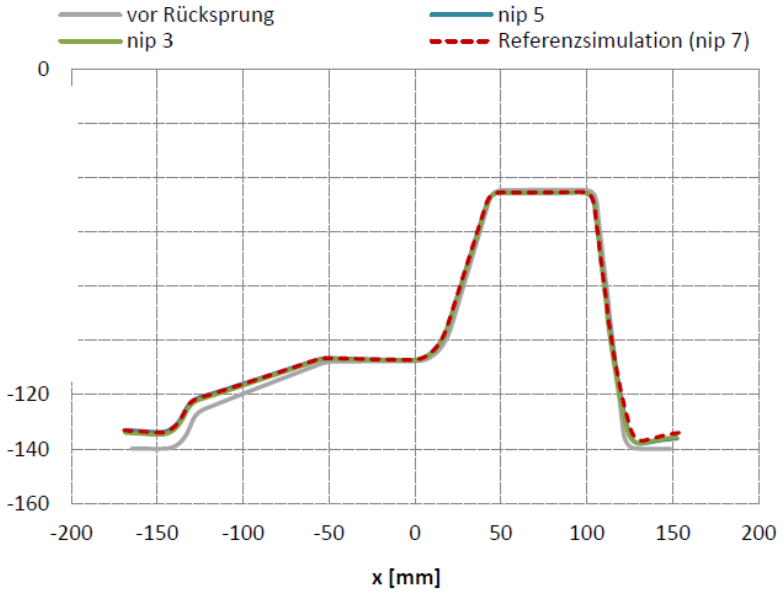


Abbildung 5.16: Rücksprung – Anzahl der Integrationspunkte ELFORM16 (Schnitt I)

Abbildung 5.17: Rücksprung – Anzahl der Integrationspunkten ELFORM16 (Schnitt IV)

Examined Parameters to reduce Simulation Time

- Selective Mass Scaling (ELFORM 16)

C: Scaling factor of the time Step size related to the reference simulation

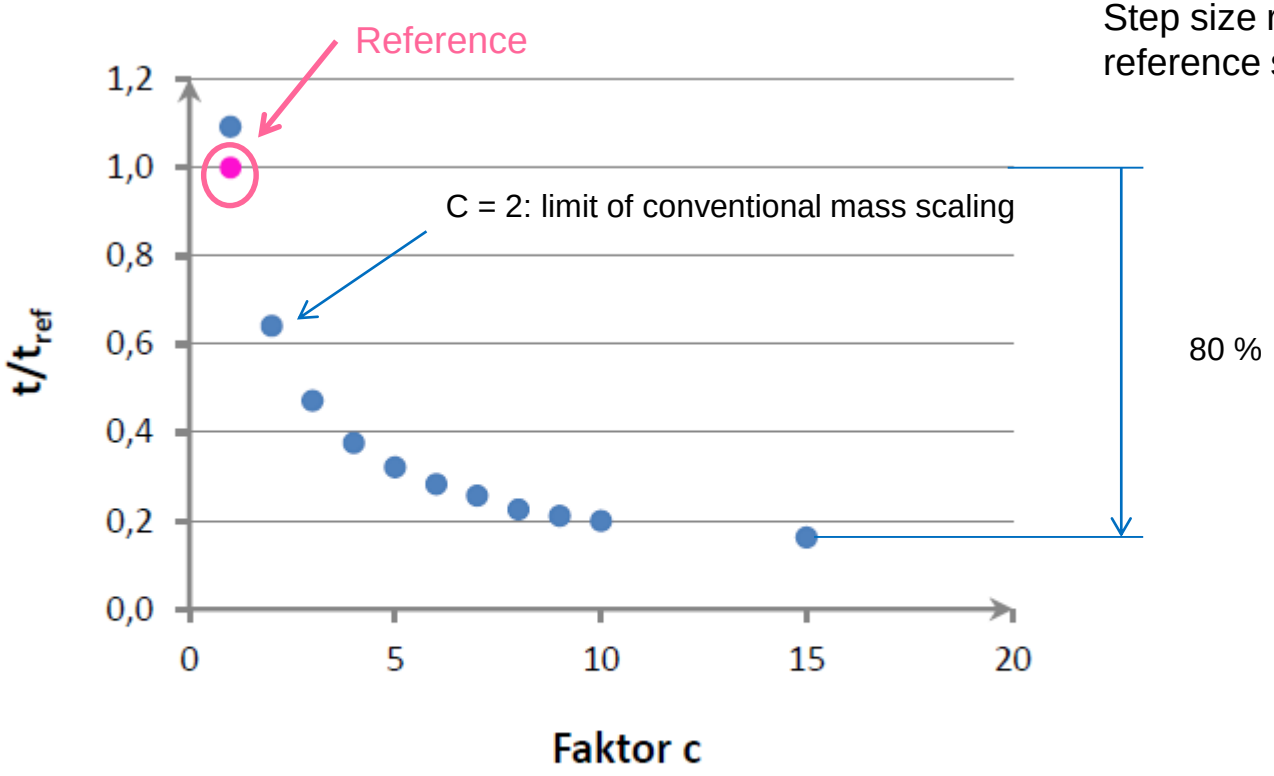


Abbildung 5.27: relative Rechenzeit – selektive Massenskalierung

Selective Mass Scaling (c = 15)

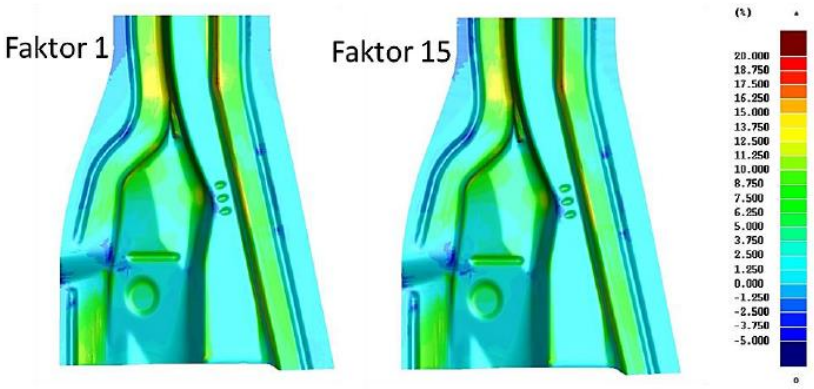
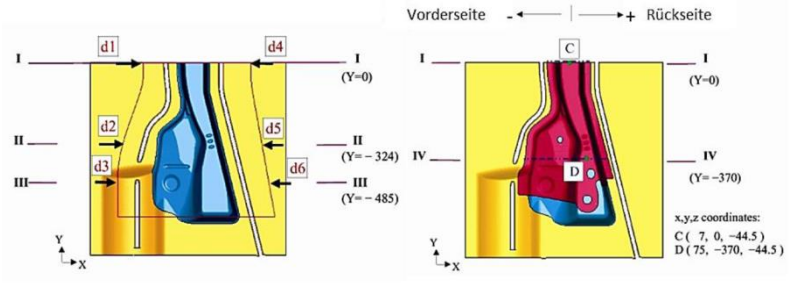


Abbildung 5.31: Ausdünnung in Prozent



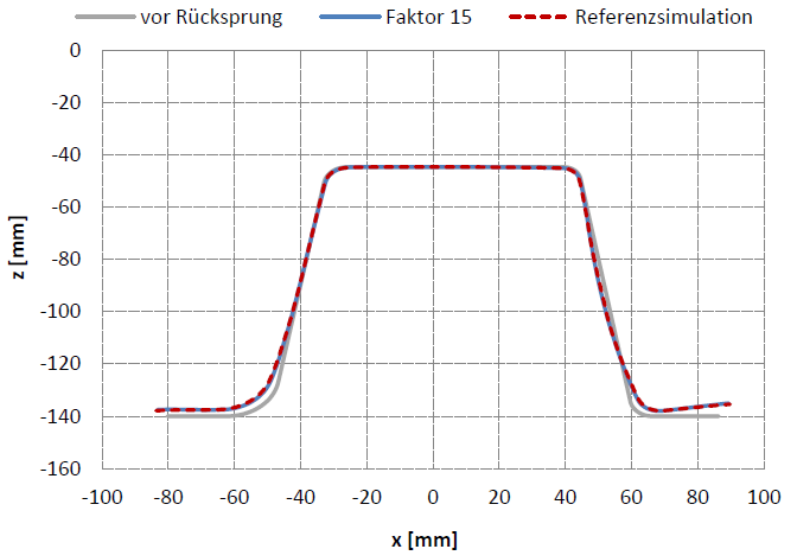


Abbildung 5.29: Rücksprung – selektive Massenskalierung (Schnitt I)

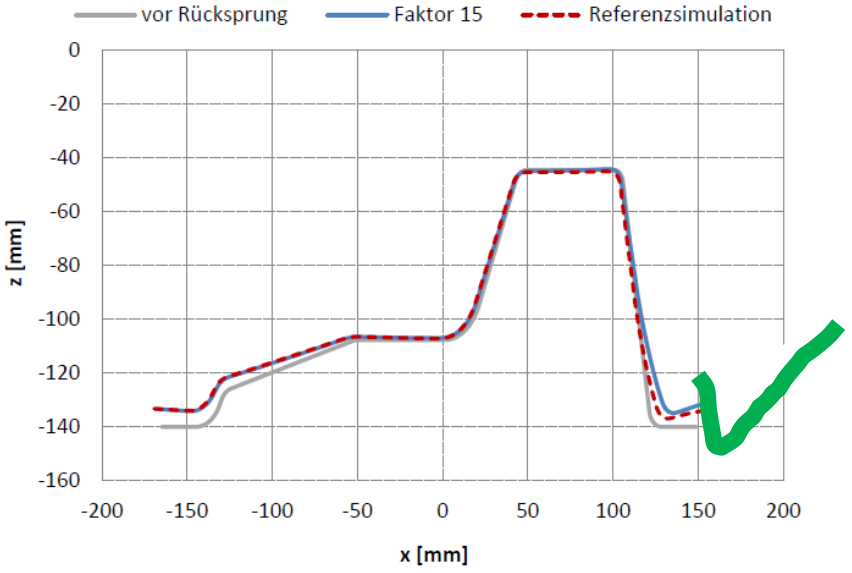


Abbildung 5.30: Rücksprung – selektive Massenskalierung (Schnitt IV)

Summary

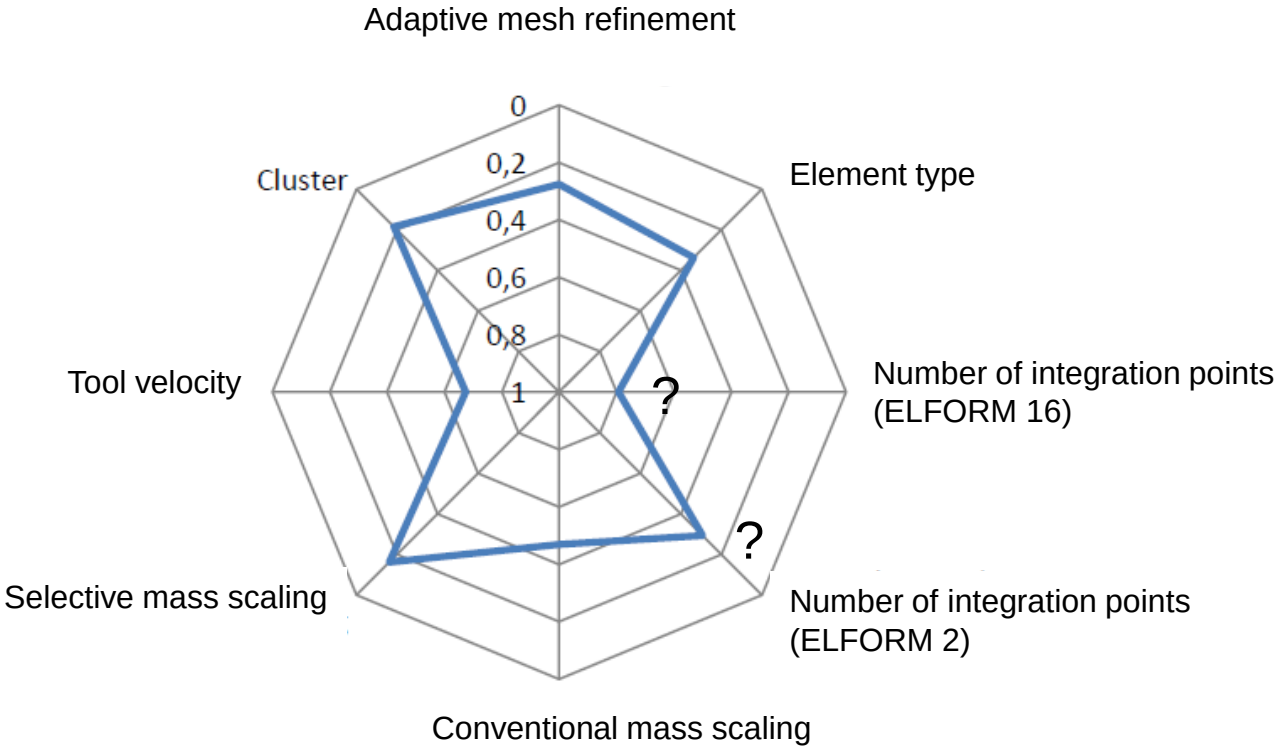
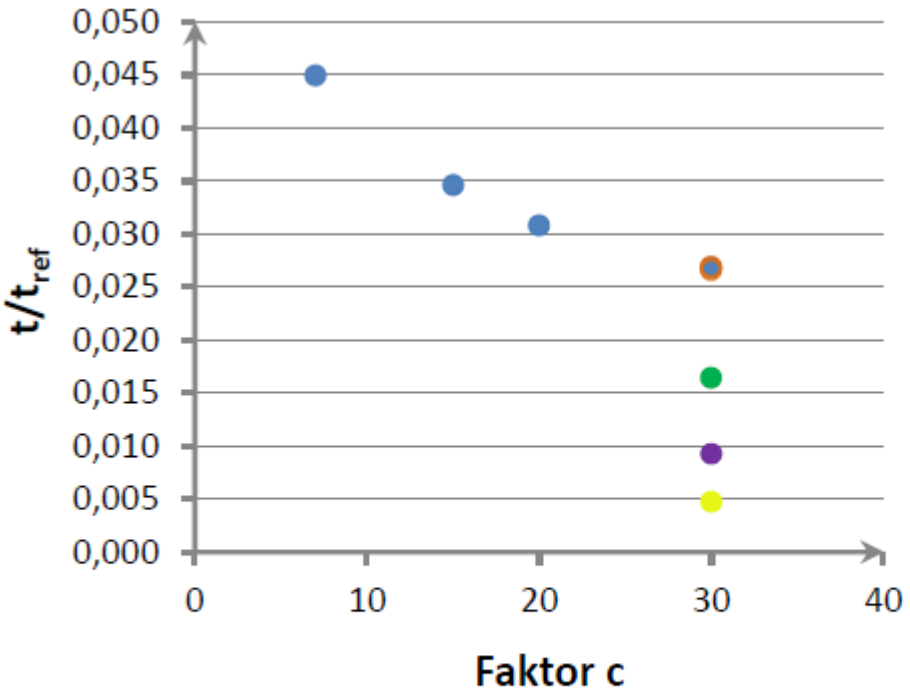


Abbildung 5.36: Vergleich der Parameterstudien

Optimized Parameters

- Selective mass scaling, MAXLVL 4, ELFORM 2



(c= 7, 15, 30)

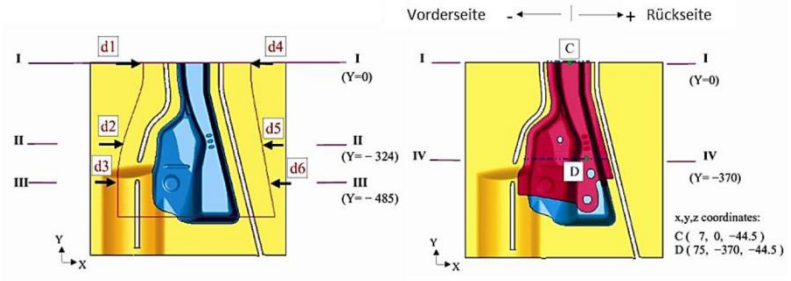
(NIP 7 → 3)

(v = 5000 → 10.000 mm/sec)

(20 Cores, no fusion)

Abbildung 5.37: relative Rechenzeit – Variation der Parameter

- Selective mass scaling, MAXLVL 4, ELFORM 2



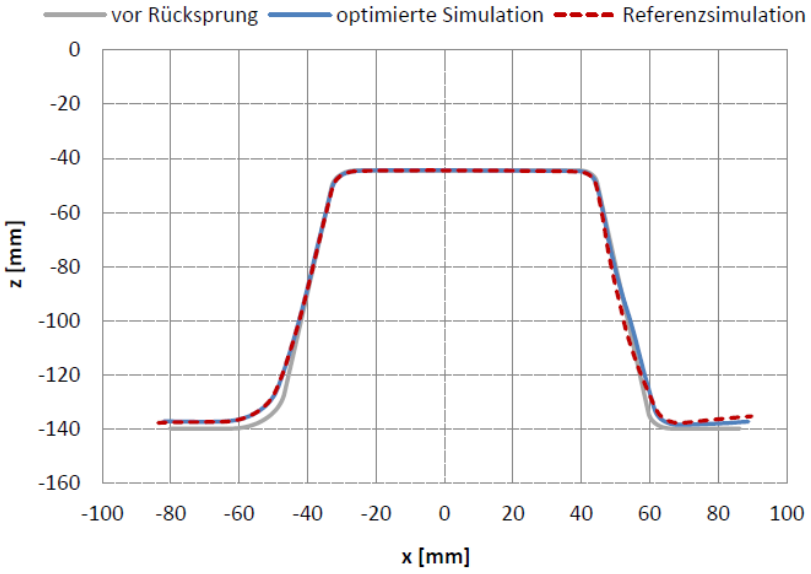


Abbildung 5.39: Rücksprung – Variation der Parameter (Schnitt I)

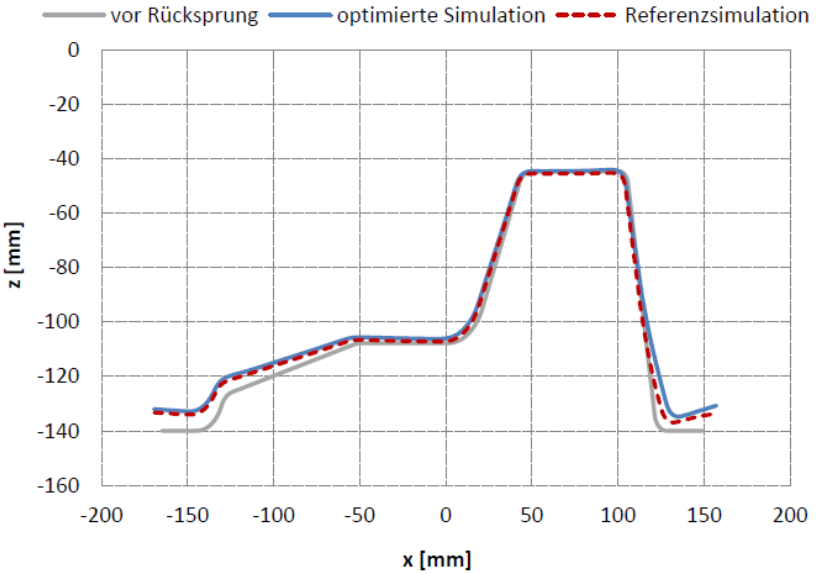
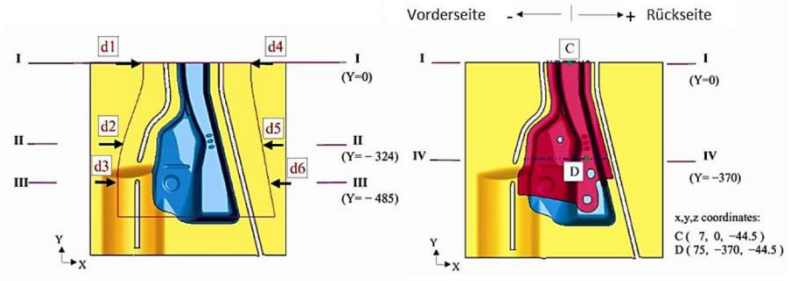


Abbildung 5.40: Rücksprung – optimierte Simulation

- Selective mass scaling, MAXLVL 4, ELFORM 2



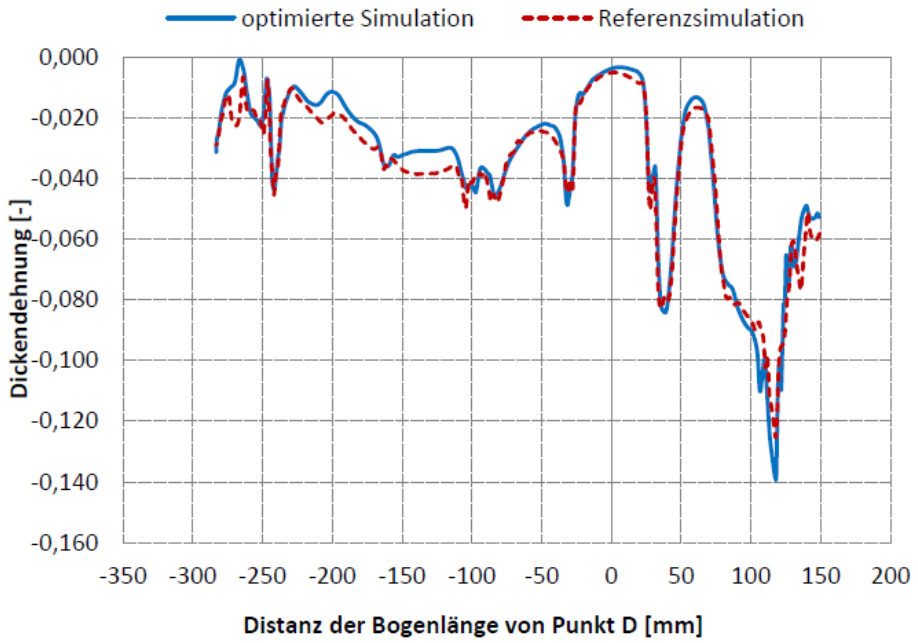


Abbildung 5.41: Dickendehnung

Simulation time: 38 minutes

Conclusions

- Parameter studies have been performed to reduce the simulation time of the forming process of a cross member
- The studies confirm the expectations:
  - Reasonable settings for adaptivity/fusion, element type and NIP can reduce simulation time considerably at an acceptable loss of accuracy
  - Forming results are robust
  - Springback results are sensitive
- Selective Mass Scaling is very effective
- The simulation time has been reduced from 67 hours to 38 minutes
- Suitable values of the parameters have been developed
- The optimized parameters have been transferred to a customer`s forming process (not shown) with promising results
- The parameters have to be adapted to each part design