Use of Forming Simulation in Modelling and Process Development of Sheet Metal Forming Processes

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LS-Dyna Forum 2016

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Agenda

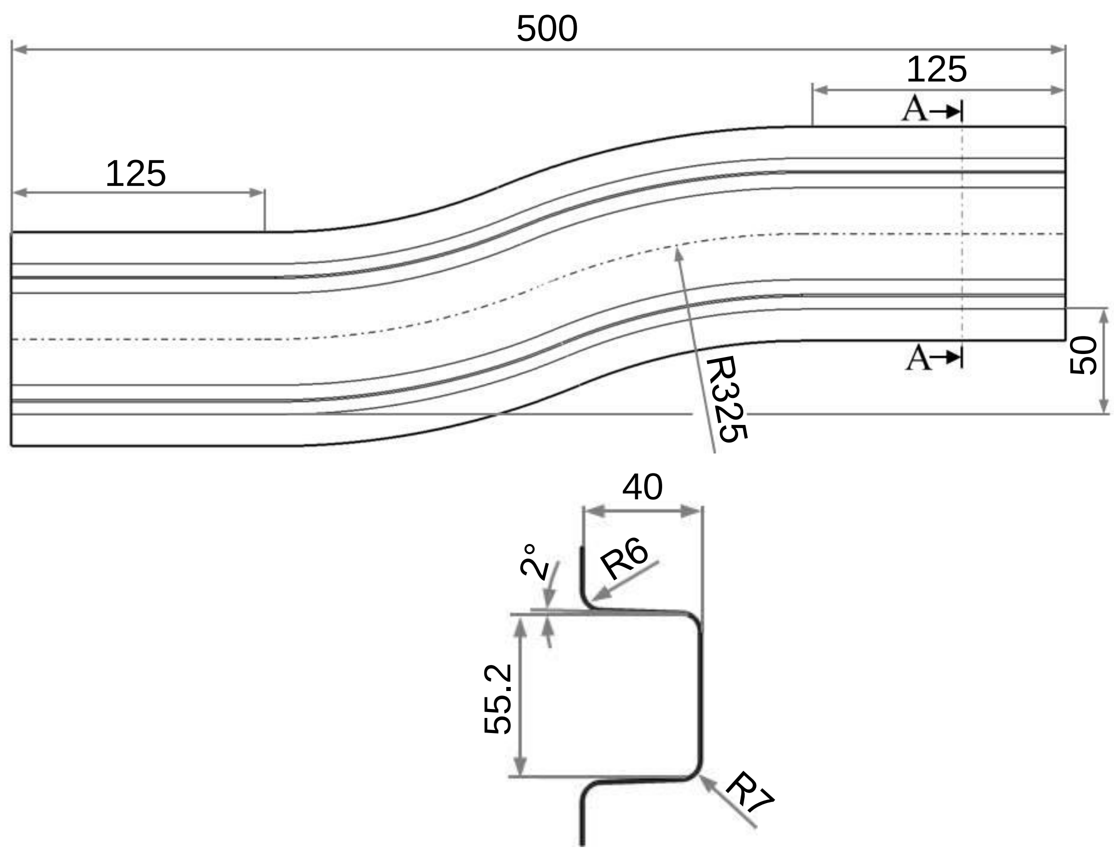
- Investigation of springback behaviour of high-strength sheet materials
- Process control using LS-Dyna
- Wrinkling prediction in sheet metal forming
- Prediction of localised necking for non-linear strain paths
- Offers to the industry
- Summary and outlook

Simulation of springback

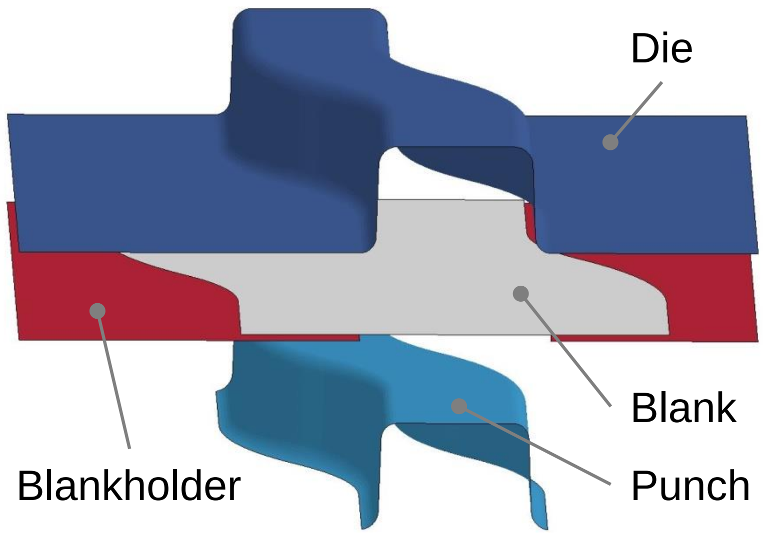
Material parameters

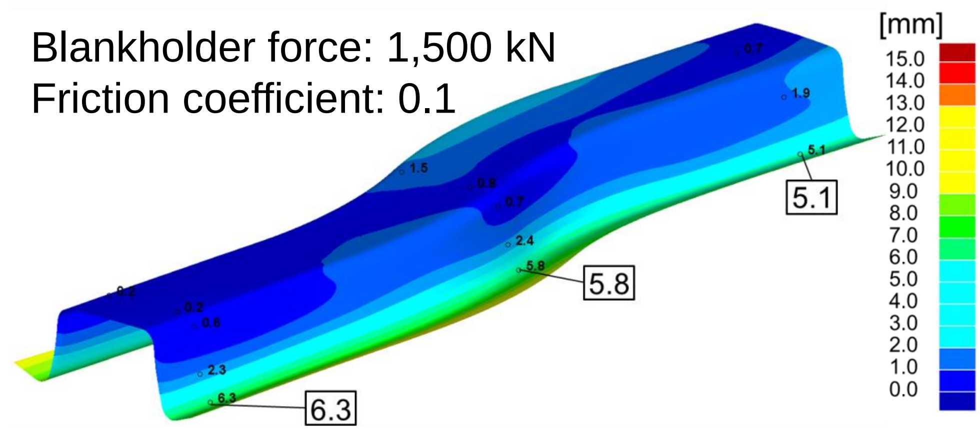
Material		HCT 980 X
Sheet thickness [mm]		1.15
Poisson ratio		0.28
Yield modulus [GPa]		210
Lankford coefficients	r_0	0.735
	r_{45}	0.989
	r_{90}	0.64
Yield stress [MPa]		745
Ultimate stress [MPa]		1,070

Part geometry



Simulation of springback





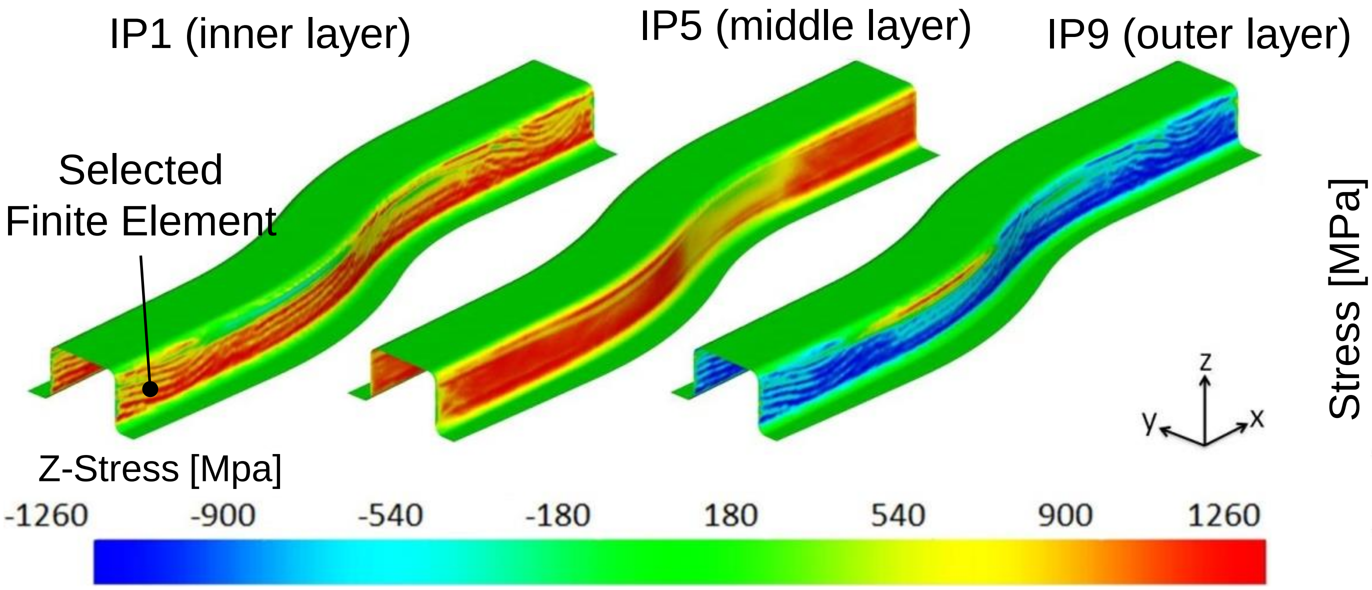
Simulation results

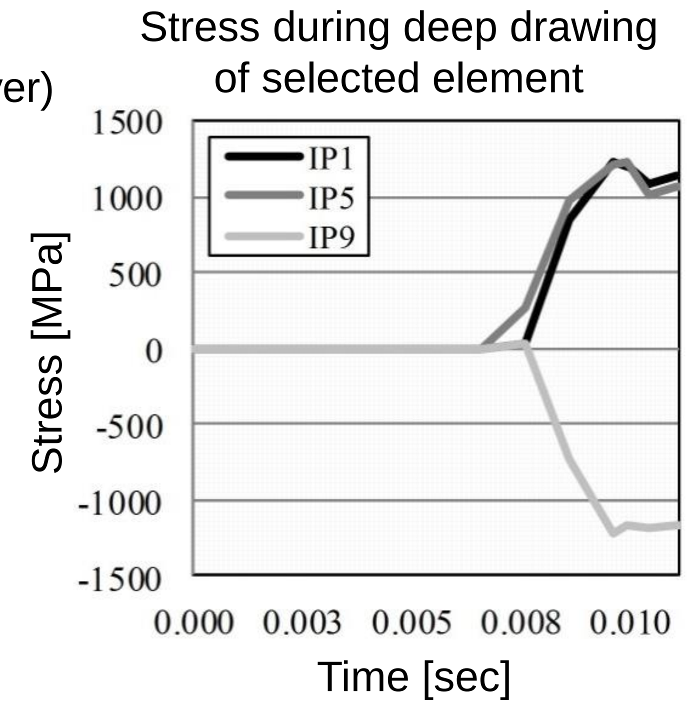
- Tool surfaces were meshed using shell elements (Belytscko-Tsay-Schell)
- Blank was meshed through sheet thickness using shell element type 16 with nine integration points
- Material model *MAT_125 was used

- Simulation results show significant diffe-rences in part shape, especially in lower part of the part wall (more than 6 mm)
- Strong curvature in part side wall

Simulation of springback

Analysis of stress distribution

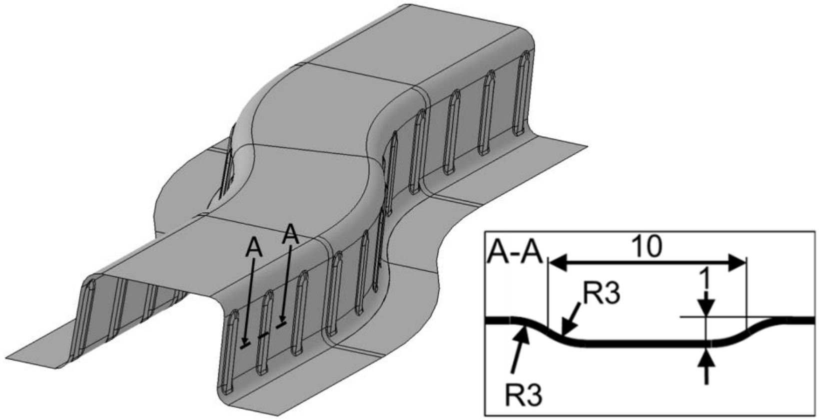




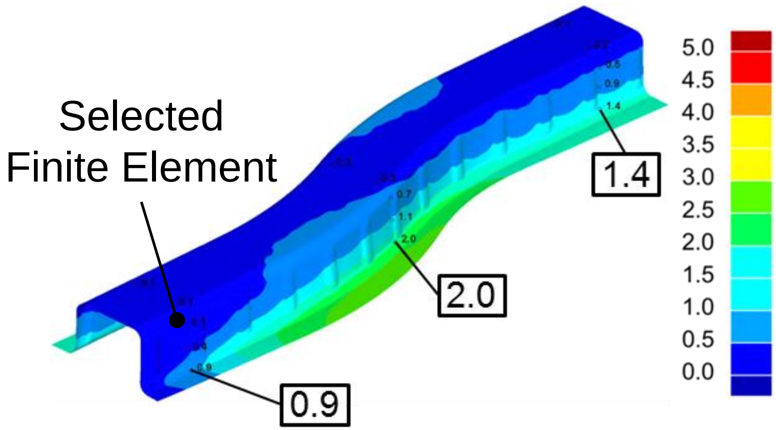
- High tensile stresses dominate the inner fibre of part side wall
- Due to tensile stress superposition and shift of neutral fibre towards part inside, tensile stresses occur in the initial neutral fibre (IP5)
- In IP9 (outer layer) stresses emerge as high compression stresses

Simulation of springback

Reduction of springback by restriking



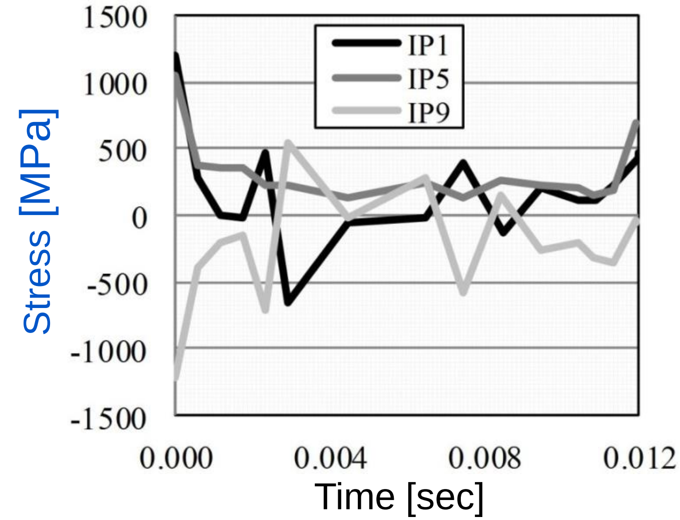
Tool geometry for restriking operation



Part shape deviation

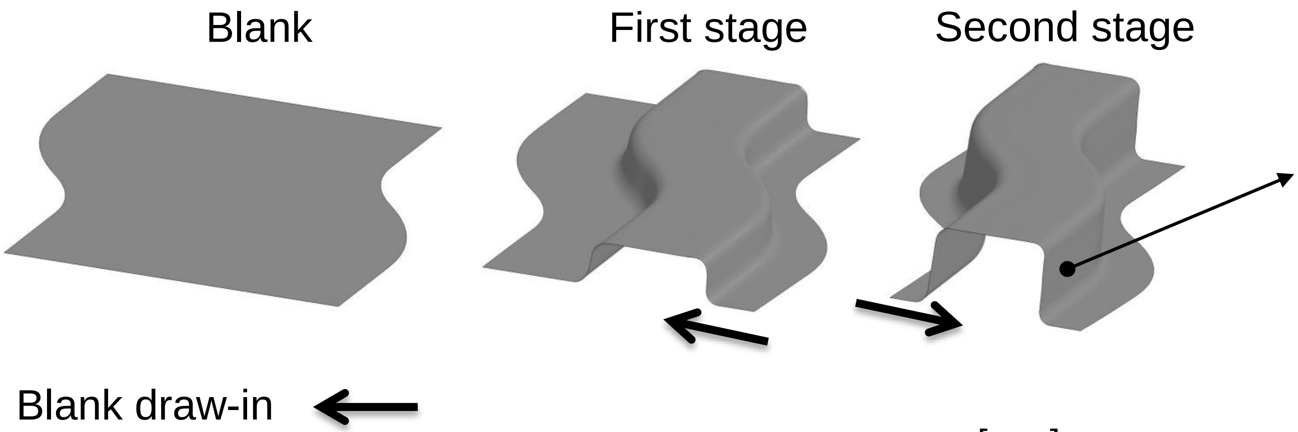
- Embossing part geometry with selected stiffening beads results in changes of current stress state
- After embossing part side wall, stress difference between outer and inner fibre is reduced significantly
- This results in a significant reduction of part side wall curvature and springback in general

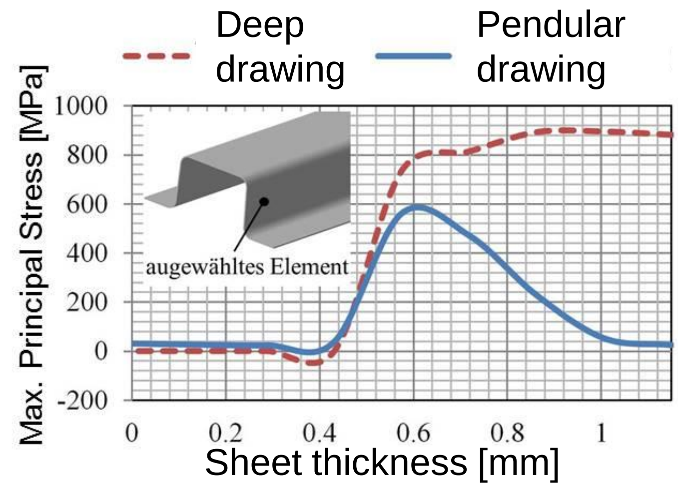
Stress development during restriking in selected element



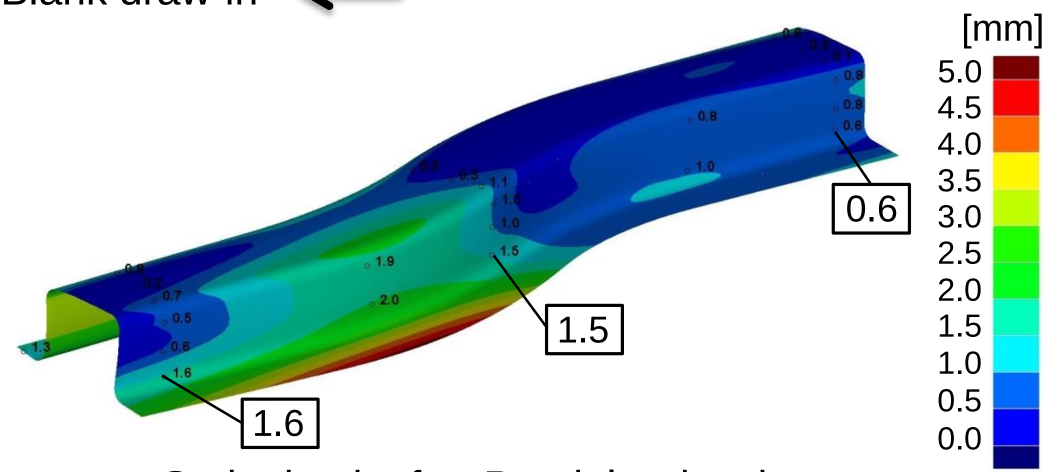
Simulation of springback

Reduction of springback using Pendular drawing





Stress distribution in sheet thickness by deep drawing and Pendular drawing for a selected finite element



Springback after Pendular drawing

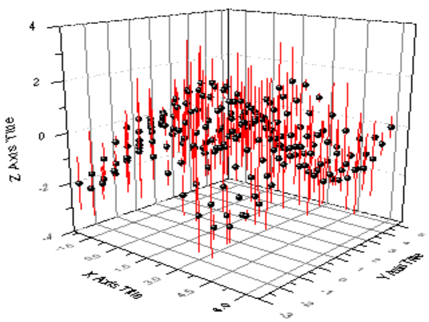
- Using Pendular drawing, the stress difference between outer and inner fibre is reduced significantly
- Because of this effect springback is significantly lower compared to deep drawing

Deep Drawing Process control using LS-Dyna

Motivation

- Load and process deviations in critical forming processes can result in high number of scrap parts
- Using advanced control methods during sheet metal forming can improve production performance
- Established methods allows for varying process parameters between two press strokes
- IFU developed a method to change process parameters in real time during press stroke

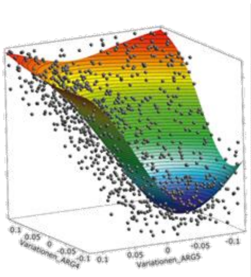
Improved production performance



Deep Drawing Process control using LS-Dyna

Concept

Improved production performance



optiSLang

MATLAB

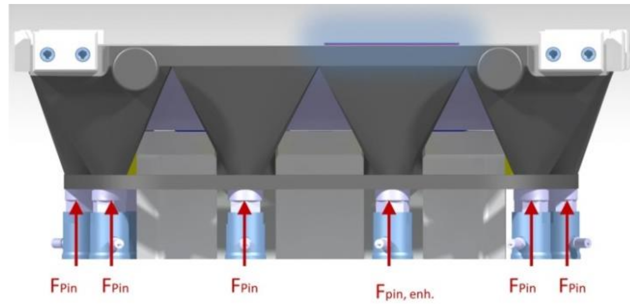
- Calculation of ideal trajecotries of part wall stresses
- Ideal trajectories are used as reference input during forming process to influence blankholder force
- Calculation of ideal trajectories using LS-Dyna and OptiSlang for setup of closed loop control via Matlab and Dspace

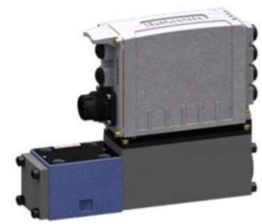
Deep Drawing Process control using LS-Dyna

Hardware setup

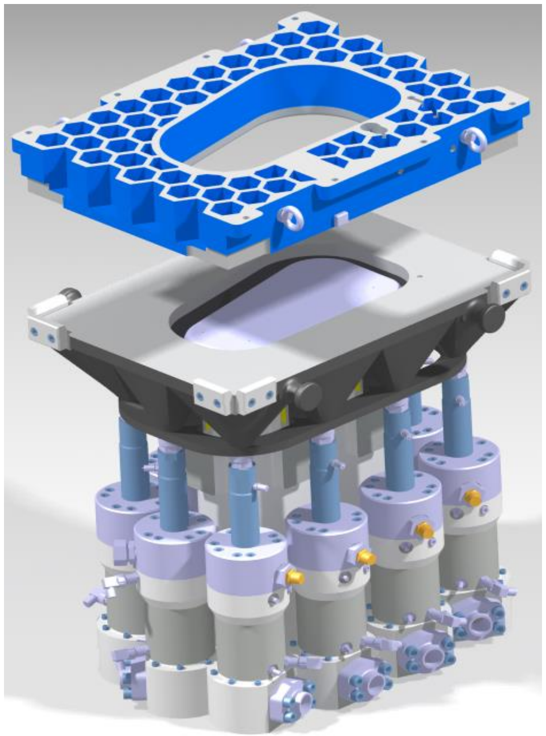
Forming tool with controlled blankholder force and sensors for measurement of part wall stresses and draw-in

Actuator:

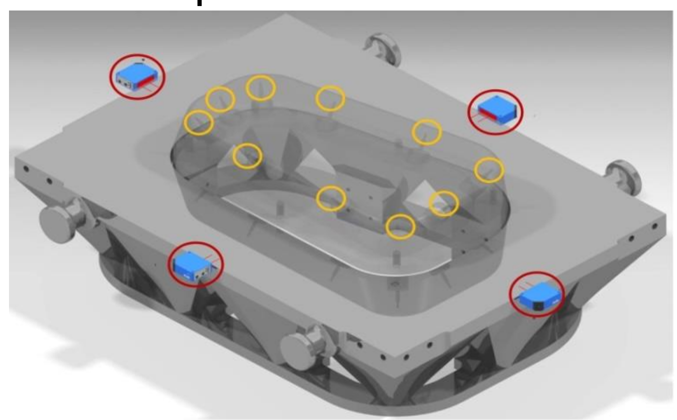




Tool

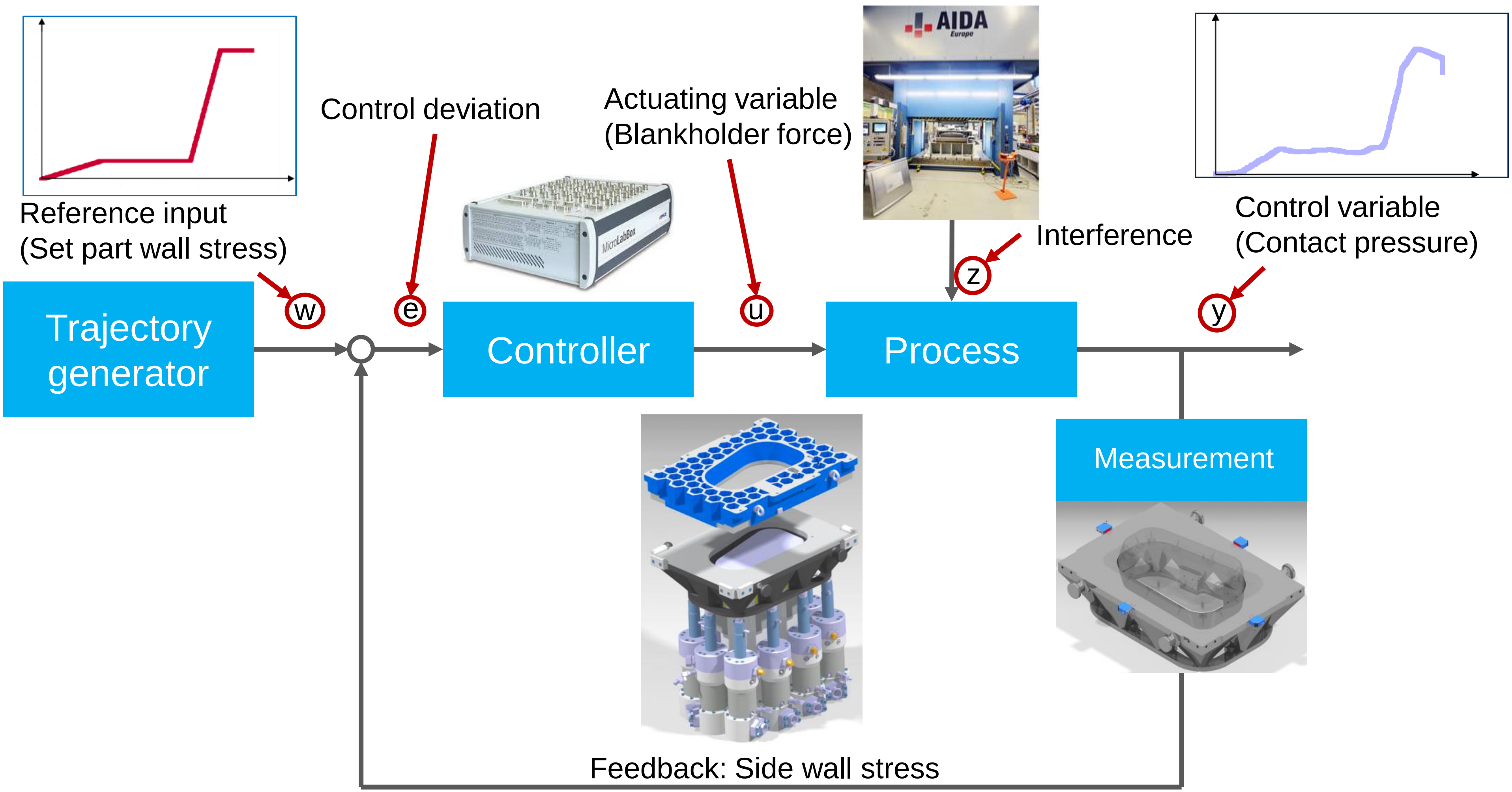


Sensor positions

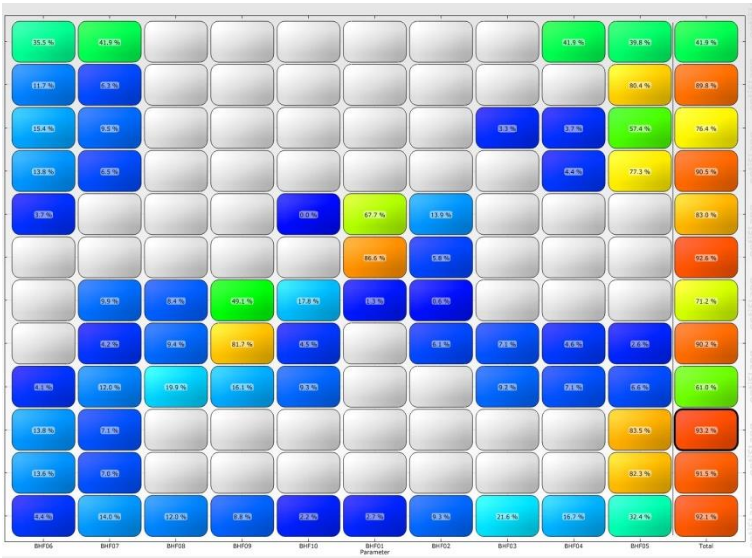


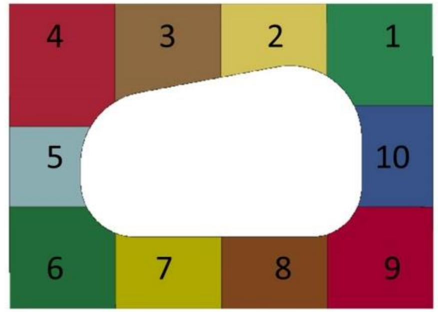
Deep Drawing Process control using LS-Dyna

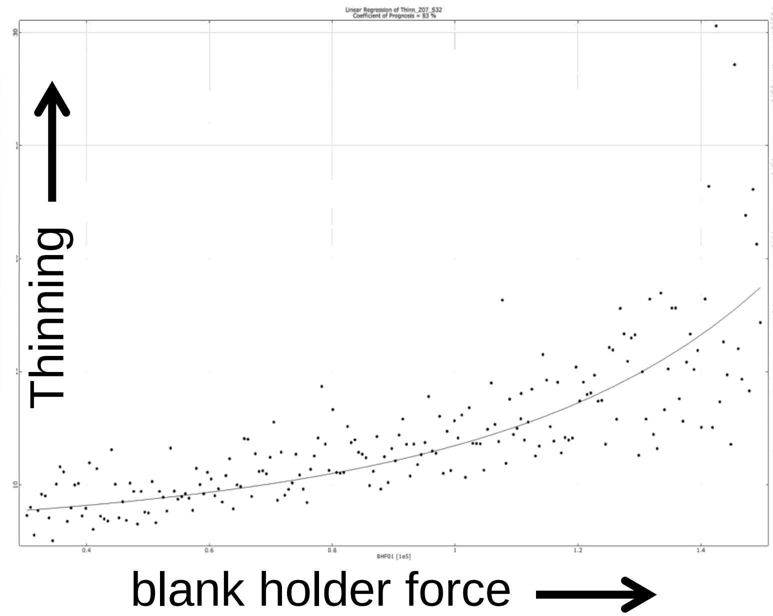
Closed loop control using trajectory tracking



Deep Drawing Process control using LS-Dyna

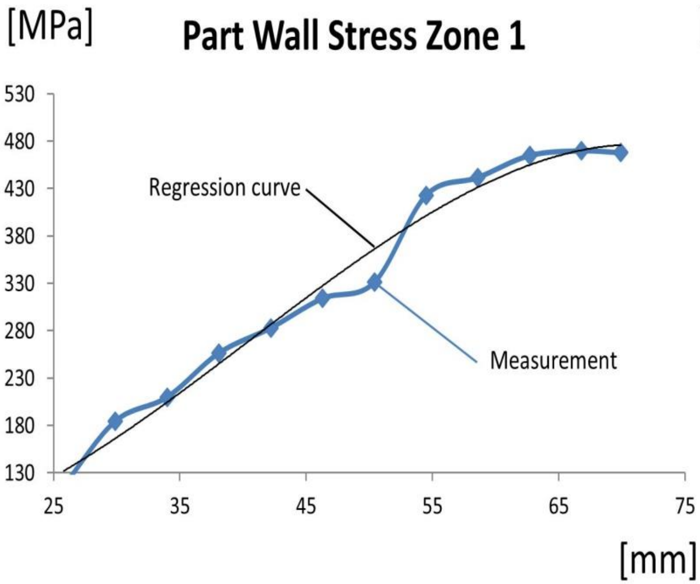


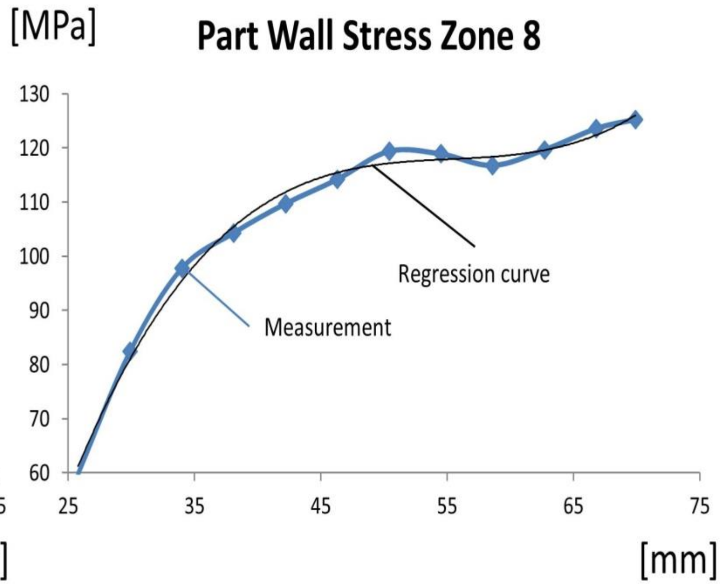


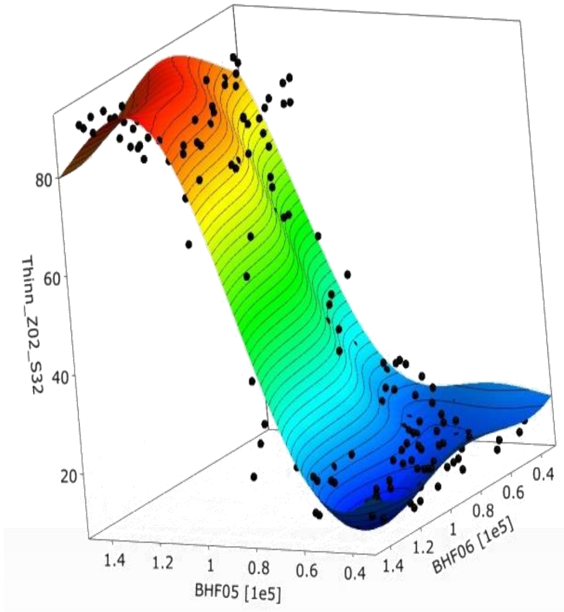


- Using FEM simulation, a Model of Prognosis was calculated
- Results are used to determine influence of different part segments on forming process for improved closed loop control

Deep Drawing Process control using LS-Dyna
Simulation







- Using stochastic simulation in LS-Dyna and OptiSlang; ideal trajectories for different segments of part side wall were calculated

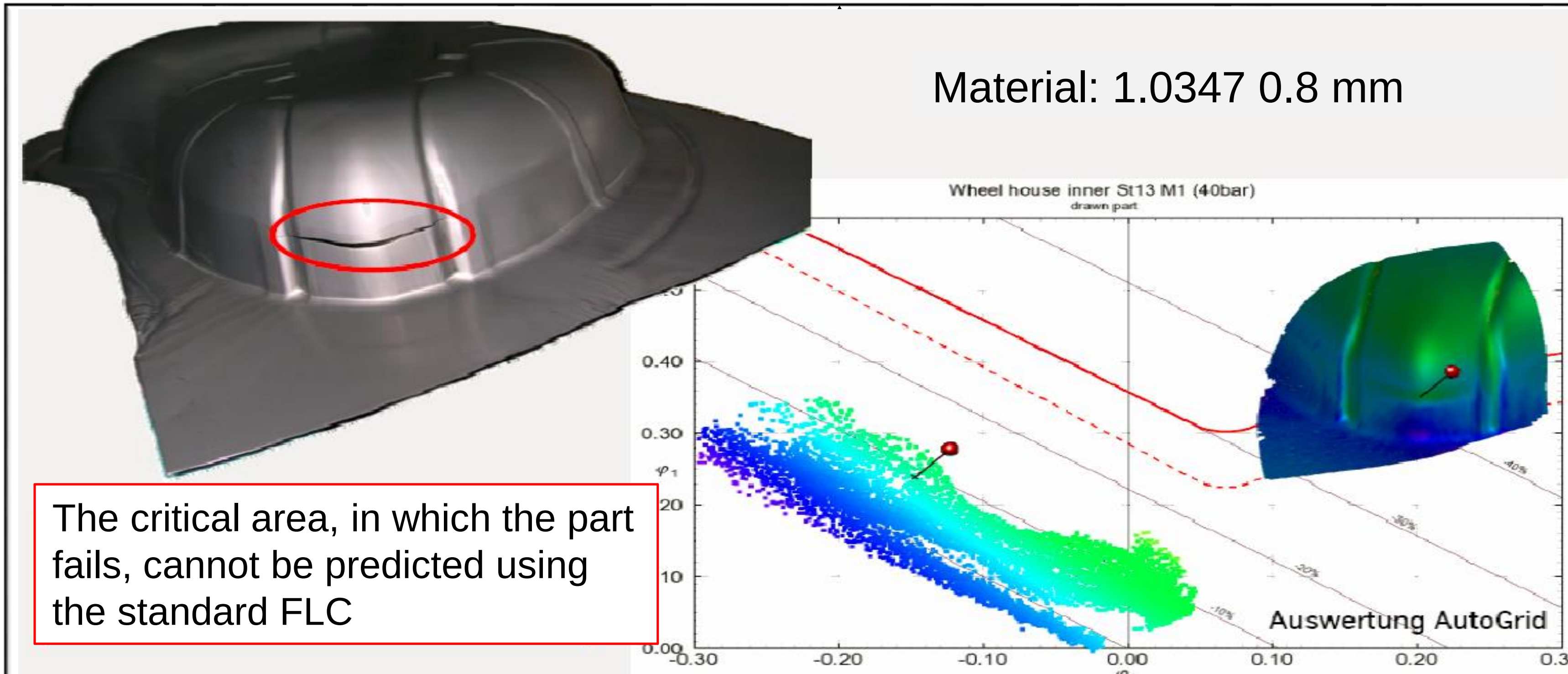
→ Trajectories are used for closed loop control when forming real parts

Strain path dependency of FLC

Non-proportional loading influences of material formability

When forming complex part geometries, and especially in multi-step processes, failure can occur although strain level in the part is below the Forming Limit Curve

Material: 1.0347 0.8 mm

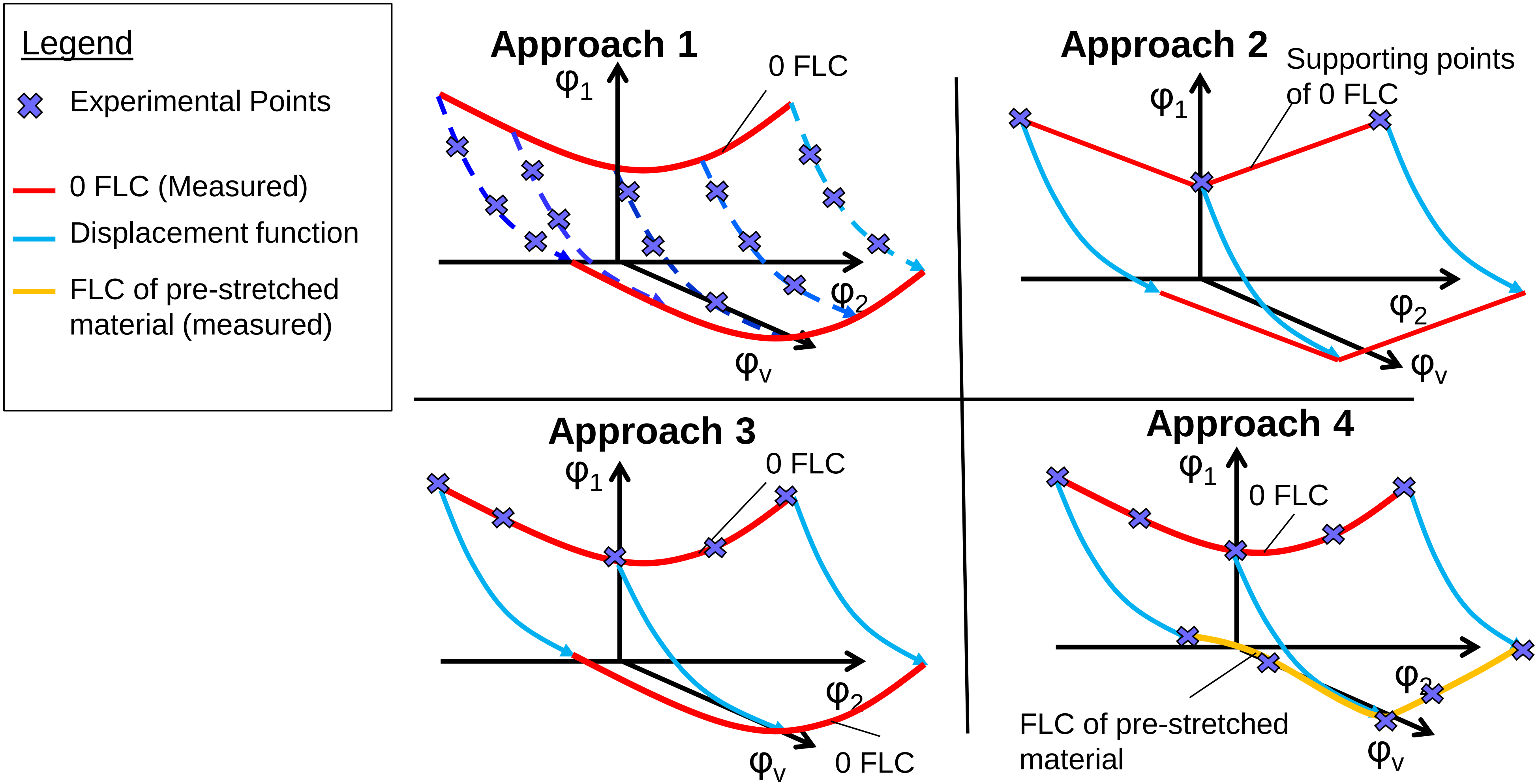


The critical area, in which the part fails, cannot be predicted using the standard FLC

Source: ThyssenKrupp Steel

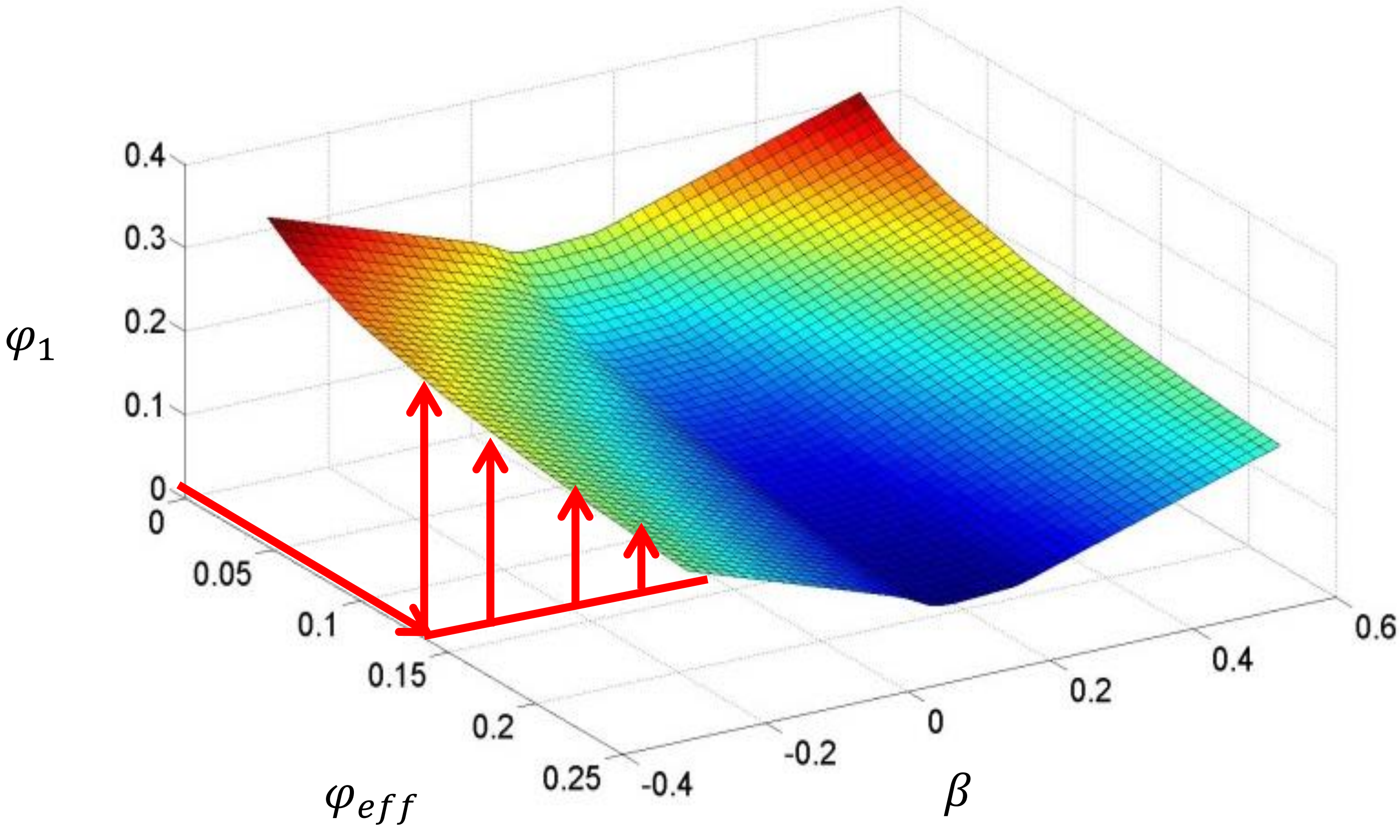
Advanced failure criteria for deep drawing processes

IFU-FLC-Criterion for non-linear strain paths



Advanced failure criteria for deep drawing processes

IFU-FLC-Criterion for non-linear strain paths



Forming operation 1:

- $\beta = \frac{\varphi_2}{\varphi_1}$
- φ_{eff}

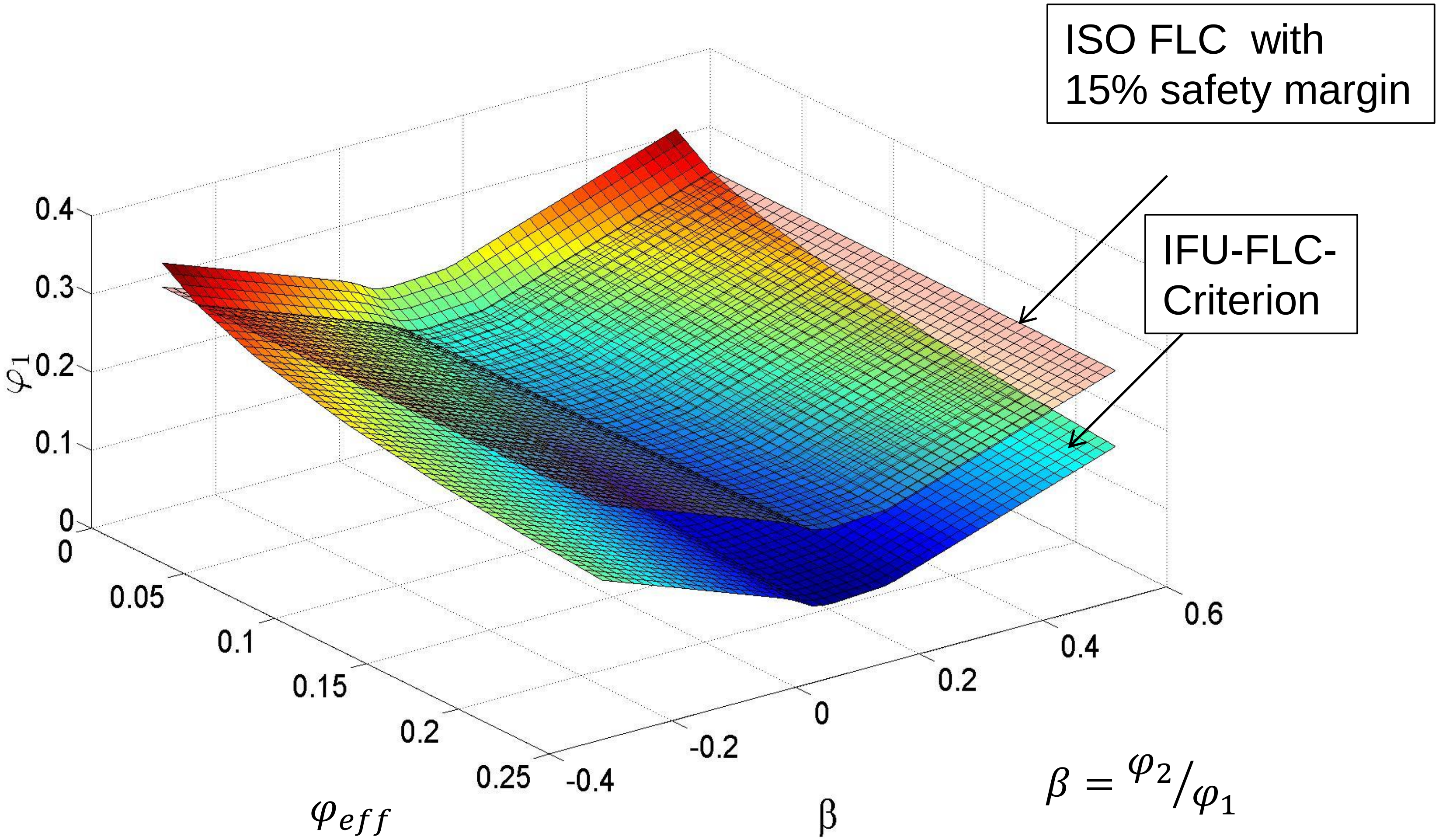
Forming operation 2:

- φ_1

New testing methods for validation of advanced failure criteria are required

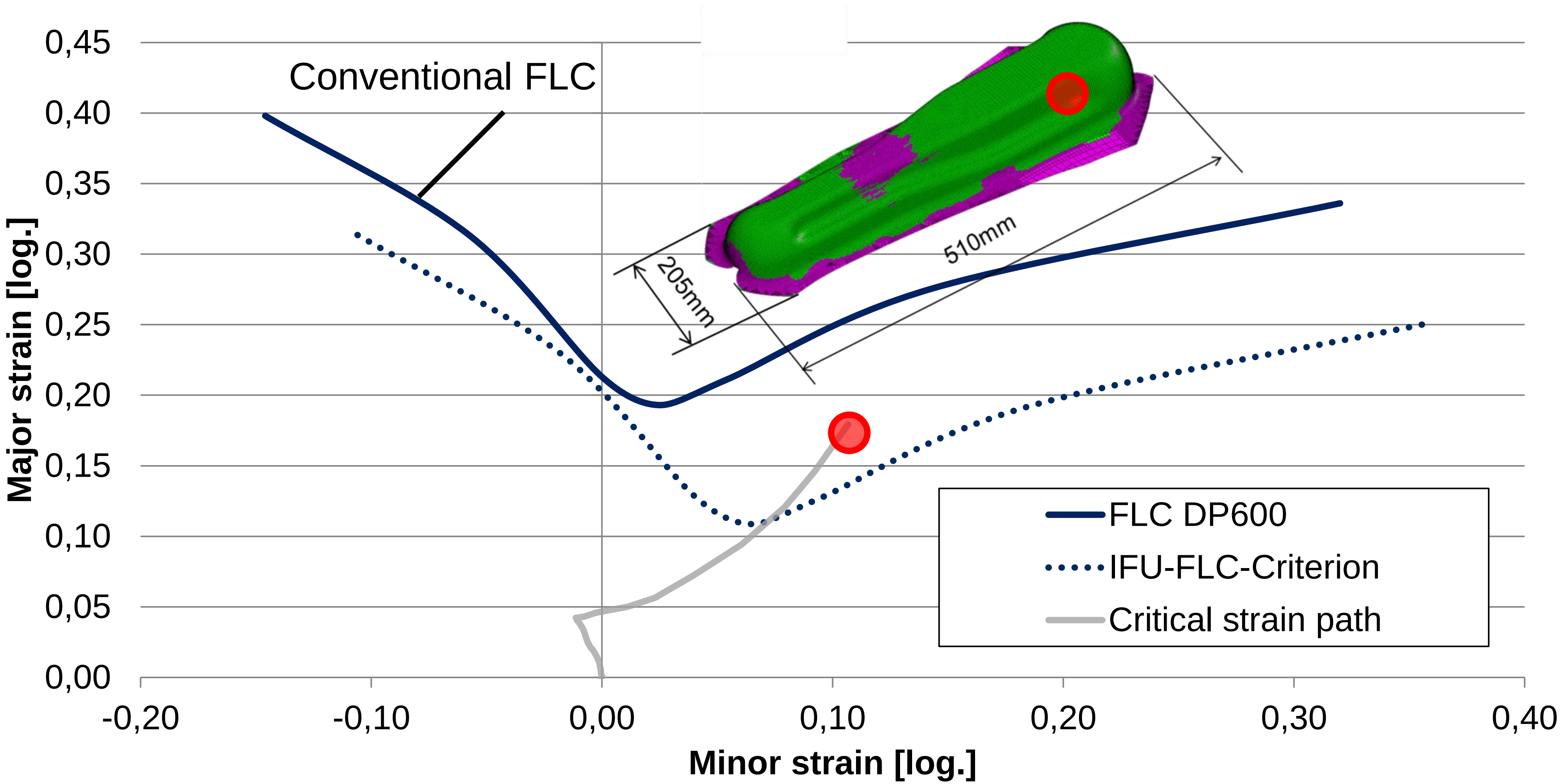
IFU-FLC-Criterion

Three-dimensional failure surface



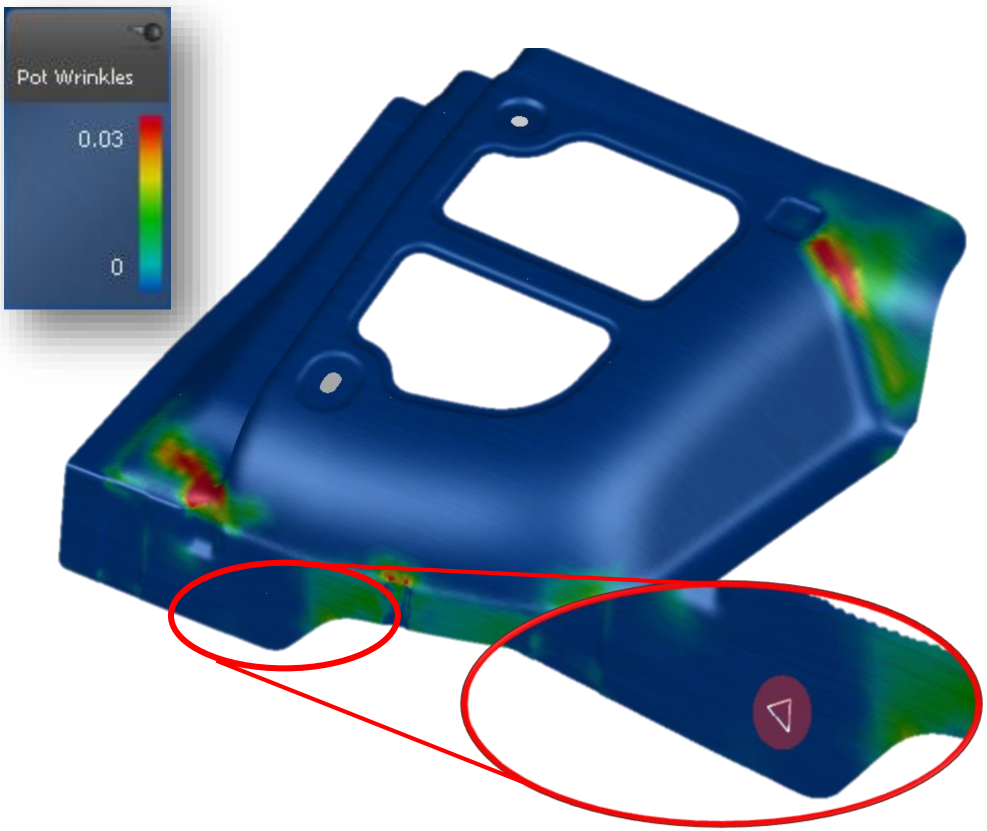
Prediction of localised necking using advanced failure criteria

IFU-FLC-Criterion for non-linear strain paths



Development of IFU-Wrinkle criterion

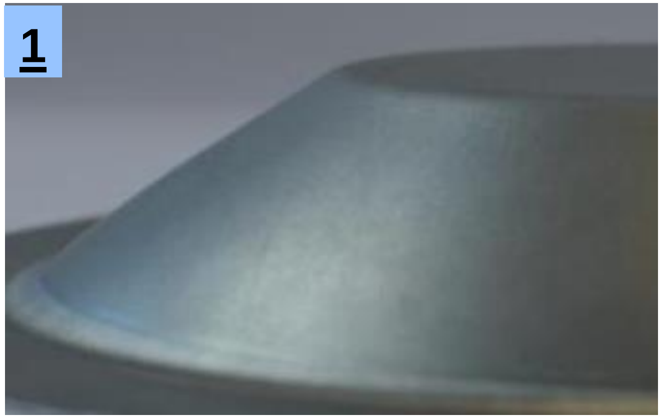
Conventional forming simulation



Real part

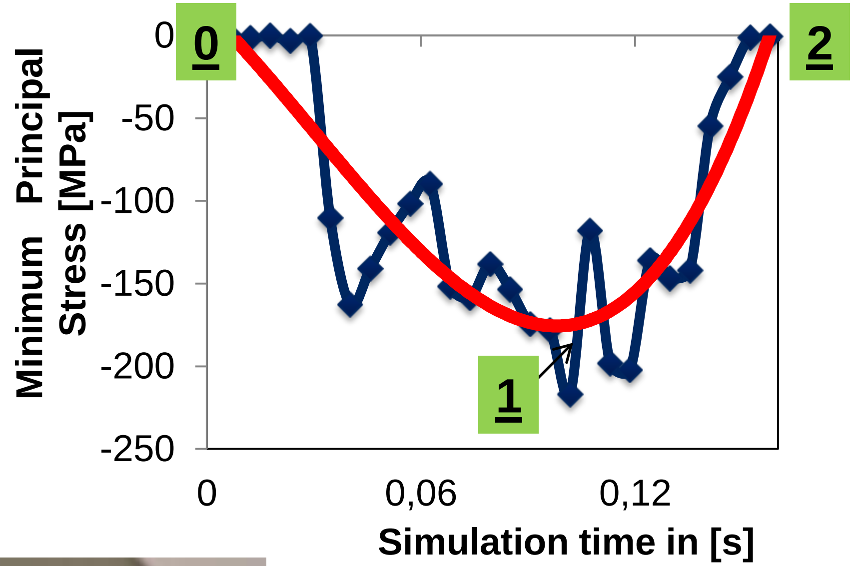
Application of a new phenomenological criterion to define the onset of part wall wrinkling in deep drawing processes

Results:



0 - 1:
– Good surface quality

1:
surface defect of buckling

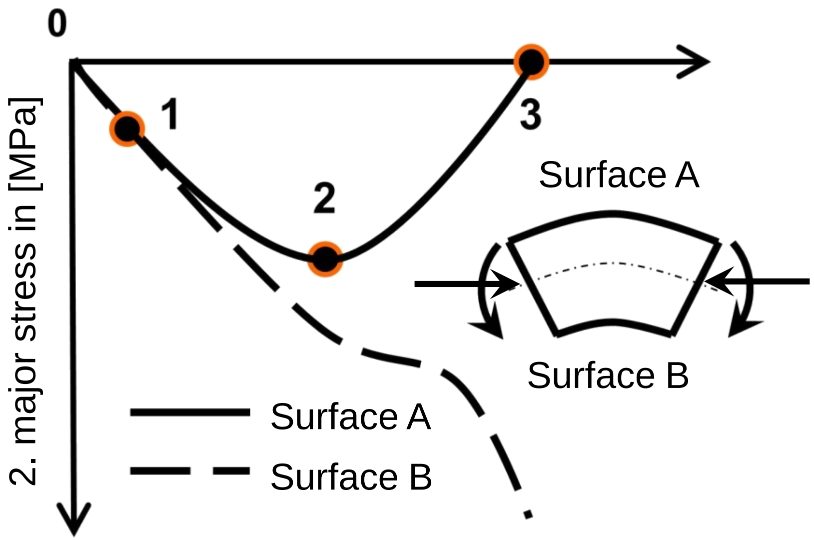


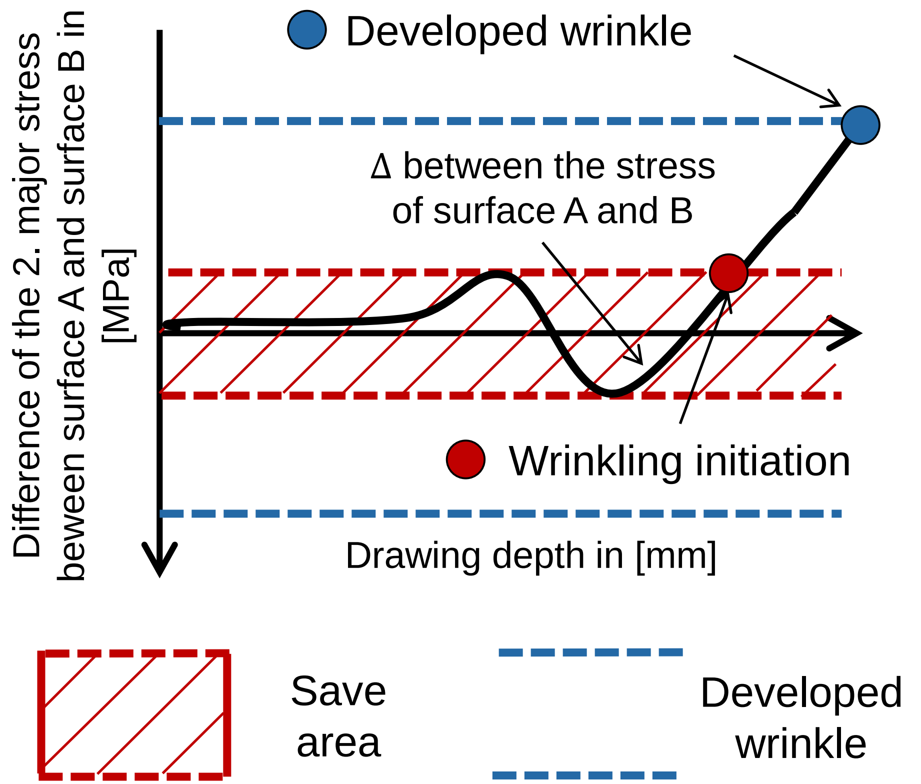
1 - 2:
surface defect of buckling + initiated wrinkling

2:
surface defect of wrinkling

Time and stress dependent wrinkling criterion

Approach to predict wrinkling of the second order





Wrinkles of 2nd order do appear when:

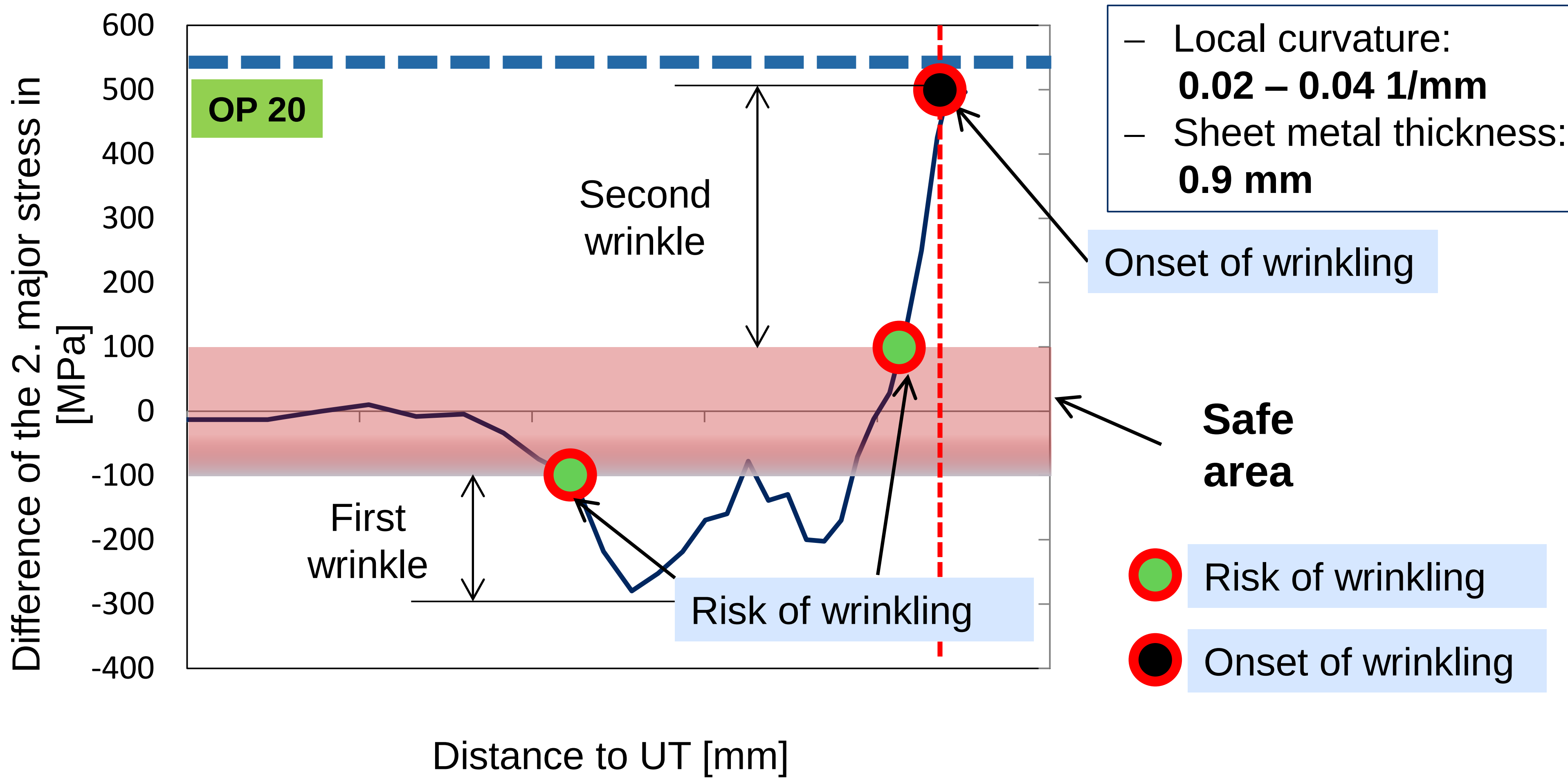
- A deviation of the 2. major stress between top and bottom layer of a finite element is calculated
- The start of the wrinkling initiation was defined by maximum value of $\boldsymbol{\sigma}_{\textbf{surface A}}$ during development of 2. major stress

Outside of the defined save area:

- Surface defect
- Appearance of Wrinkling

Validation of time and stress dependent wrinkling criterion

Case study: Adapter doorframe – Position 2: Evaluation with safe area



- Local curvature: **0.02 – 0.04 1/mm**
- Sheet metal thickness: **0.9 mm**

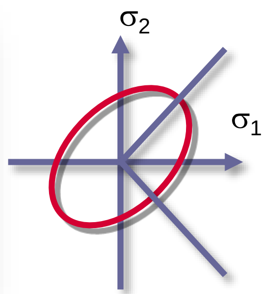
Offers to the industry of FGU

Validation of Mat-Files by comparing and validating to real forming process

Standard

Yielding parameters:

- Uniaxial tensile test according to ISO Standard
- Yield strength
- Hardening coefficient (n-value)
- Anisotropic coefficients (r-values)



Hardening Behaviour:

- Uniaxial tensile test according to ISO Standard
- Several load conditions, strain rates, temperatures, quenching rates, etc. by using Gleeble system

Forming Limits :

- Nakajima-Test according to ISO Standard 12004-2 (also under elevated temperatures up to 120°C)
- Strain evaluation by optical GOM Aramis System

- Failure Prediction for Edge-Crack Sensitivity using Diabolo-Test or Hole Expansion Test for defined cutting specifications
- Material characterisation for enhanced hardening models like kinematic hardening (coming soon)

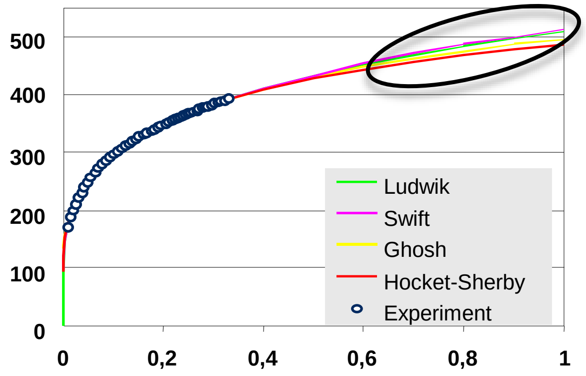
Offers to the industry of FGU

Validation of Mat-Files by comparing and validating to real forming process

Standard

Data preparation:

- Preparation of yield locus
- Extrapolation of hardening curve using well-known models



Creation of Mat-Files:

- Data optimisation according to special requirements of simulation tools
- Export into special data format

Validation:

- Design and manufacturing of validation tools
- Comparison of results by using several measuring equipment

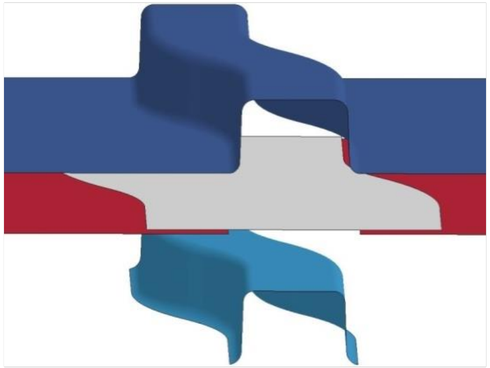
Contact: Forschungsgesellschaft Umformtechnik mbH
Kornbergstraße 23
70176 Stuttgart/Germany

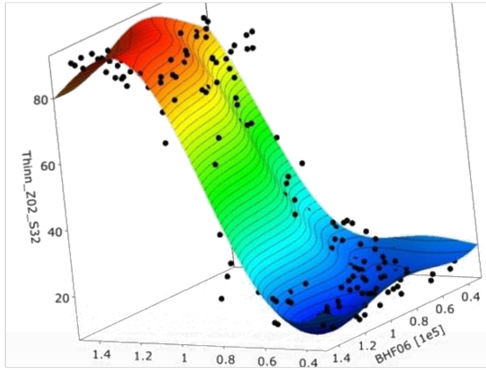
Mail to: held@fgu-mbh.de
http://www.fgu-mbh.de

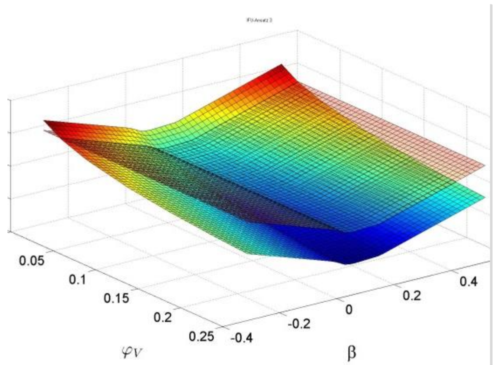
FGU Forschungsgesellschaft Umformtechnik mbH

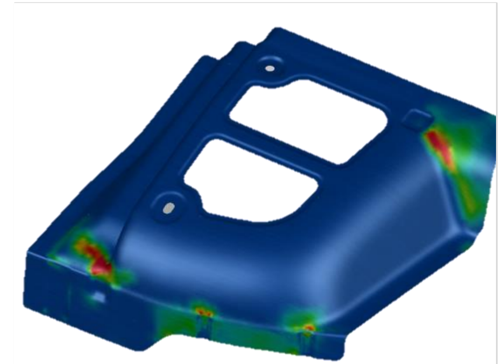
Summary and Outlook

- Simulation of S-Rail geometry using high strength steel (DP1000) in order to reduce springback behaviour
- Stress contribution of inner, middle and outer fibre was evaluated to visualize reasons for springback
- Pendular drawing shows severe reduction of springback behaviour
- System to control forming processes is under development at the IFU using LS-Dyna
- IFU-FLC criterion for non-linear strain paths was introduced and shows good accordance to reality
- Approach for IFU-Wrinkling criterion for wrinkles 2nd order is under development using different surface stresses
- Offer to the industry of FGU:
  - Big variety of material characterisation methods and possibilities available
  - All equipment to validate simulations quality is available (tool shop/press/evaluation e.g.) for external customers as well









Thank you for your attention!

Univ. Prof. Dr.-Ing. Dr. h.c. Mathias Liewald MBA

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