Efficiency-improved Forming with Reduced Trimming in Combination with precise Calibration

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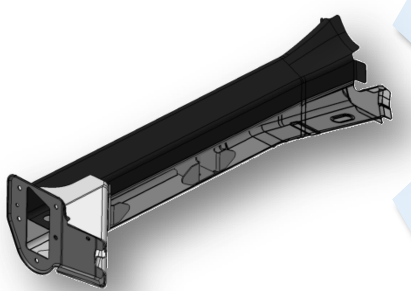
ThyssenKrupp Steel Europe

ThyssenKrupp

“Trim-Free Calibrating Deep-Drawing” of high strength steel parts

What is this all about?

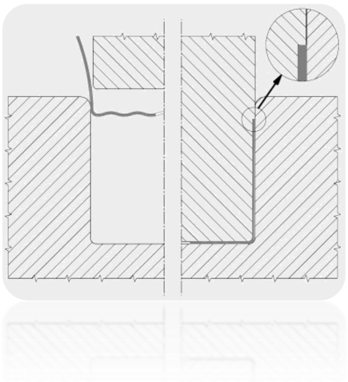


Brief introduction of the ThyssenKrupp InCar®plus project

The InCar®plus front longitudinal member concept

"Trim-Free Calibrating Deep-Drawing"

A method for efficient manufacturing of automotive body parts



The ThyssenKrupp InCar®plus project

Innovation in body, powertrain and chassis & steering

Highlights:

- 30 projects with more than 40 individual solutions
- Lightweight, cost-competitive, green and high-performing

Body:
Innovative steel technologies for economical lightweight design

Powertrain:
Optimized internal combustion engines and efficient electric drives for the mobility of tomorrow

Chassis & Steering:
Comfort and safety – performance driver for more functionality, while retaining lightweight design targets

Overview of InCar®plus subprojects

Lightweight, cost-competitive, green and high-performing

Steel Wheels | Seating | Doors | Exhaust System | Electric Motor Demonstrator | High Strength Electrical Steel

A-Pillar

Body

Powertrain

eTDC – Drivetrain Components

Front Longitudinal Member

Function Optimized Camshaft

Sandwich Material Applications

Hybrid Cylinder Head Cover

Hood

Fuel Cell

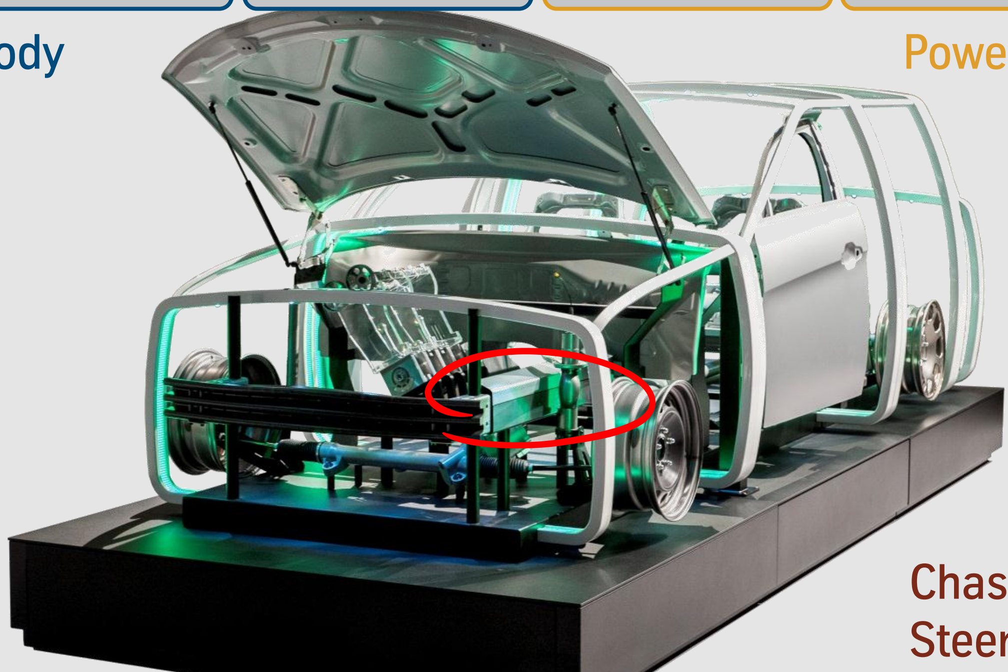
Bumper Systems

Presta Oil Separation System

B-Pillar

Chassis & Steering

Sliding Shiftable Cam System



Cockpit Cross Member | Steer-by-Wire | Lightweight Hybrid Steering Shaft | ThermoTecWire | Hollow Steering Rack | Acoustic Optimized Electric Motor

Super Imposed Actuator (SIA) | Damper Tubes | Column Electric Power Steering | Integrated Variable Damping Valve | CFRP Lightweight Steering Column | Hybrid Drive Concepts

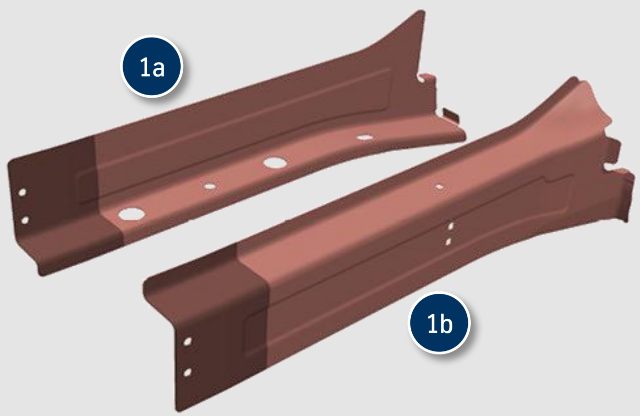
ThyssenKrupp Steel Europe

ThyssenKrupp

The InCar®plus front longitudinal member concept

Lightweight design due to modern materials and innovative manufacturing

InCar®plus Reference

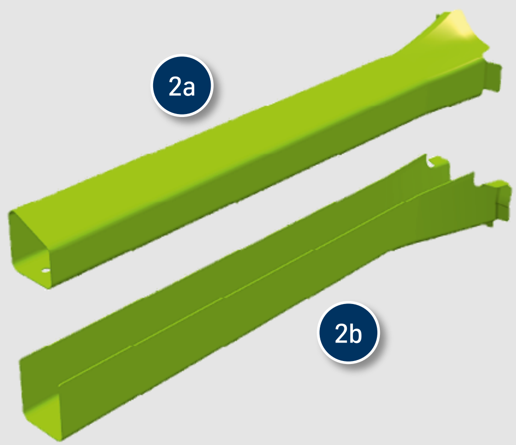


InCar®plus Reference

No.	Name	Material	Thickness	Mass
1a	Con. outer shell part	DP-K® 440Y780T	2,00 mm & 1,80 mm	3,75 kg
1b	Con. inner shell part	DP-K® 440Y780T	2,00 mm & 1,80 mm	3,81 kg
			Gross weight per vehicle:	15,12 kg

23% weight reduction
same performance

InCar®plus Concept I

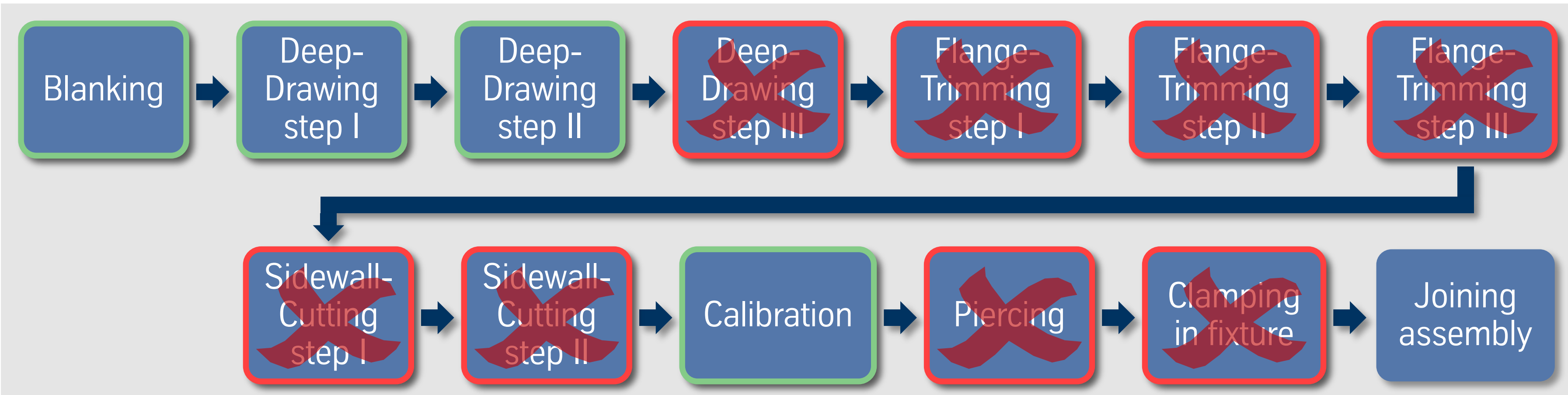


InCar®plus Concept I

No.	Name	Material	Thickness	Mass
2a	Concept T³-profile	MHZ 500	1,50 mm	2,85 kg
2b	Concept U-profile	CP-W® 660Y760T	1,40 mm	2,98 kg
			Gross weight per vehicle:	11,66 kg

Typical cold forming process chain for sheet metal parts

Present situation of conventional process versus desired situation



Conventional processes according to this scheme are **well-known and safe**, but they generate **high costs** due to

- usage of presses and transfer equipment
- Manufacturing and maintenance of tools
- scrap material
- energy consumption

Is there a chance to **avoid inter-mediate steps** which do not belong to main forming stages?

Yes! Modify remaining steps to achieve a faster and cost effec-tive manufacturing.

Problem: Arising **shape deviations** create a con-siderable **quality issue.**

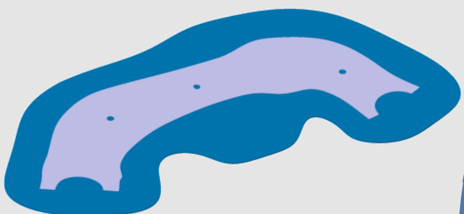
Appearing shape deviations in cold forming processes

… and consequential avoidance strategies

Disadvantages:
- Investment costs
- Maintenance costs
- Energy costs
- Time requirement

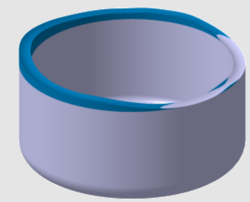
Global shape deviations

general shape deviations through the technologically necessary allowance of materials at the edge of the blank



Local shape deviations

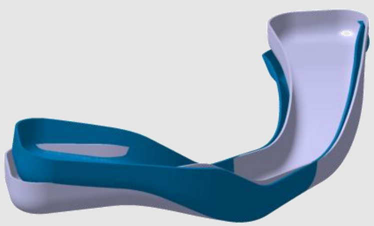
local shape deviations at edge of the part due to inhomogeneous drawing conditions and anisotropic material behaviour during forming ("earing")



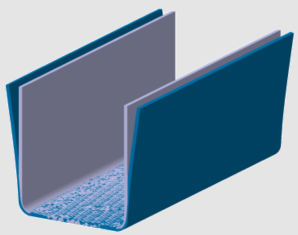
full-circumferential edge-trimming

Drawing of a **predetermined blank** with a subsequent **compression stress superimposition** ("Trim-Free Calibrating Deep-Drawing")

stress superimposition (e.g. stretch-forming)



global shape deviations due to elastic springback ("distortions") after forming



local shape deviations on connecting edges or reference surfaces through elastic springback after forming

Disadvantage:
- Requires additional edge trimming due to earing

Algorithm for efficient determination of minimised blank shapes

Implemented using commercial FEM-solver LS-DYNA® and proprietary MATLAB® code

1 **Input:** Initial blank shape and desired boundary curve of final part

2 Forming simulation using initial blank shape

→ Part with wavy boundary

3 a) Mapping of desired boundary onto wavy part mesh

b) Remapping of desired boundary onto initial blank mesh

4 **Output:** Forming simulation using corrected, minimised blank shape

→ Part with smooth boundary

Initial blank

Wavy edged rect. cup

Corrected blank

Final rectangular cup

LS-DYNA®

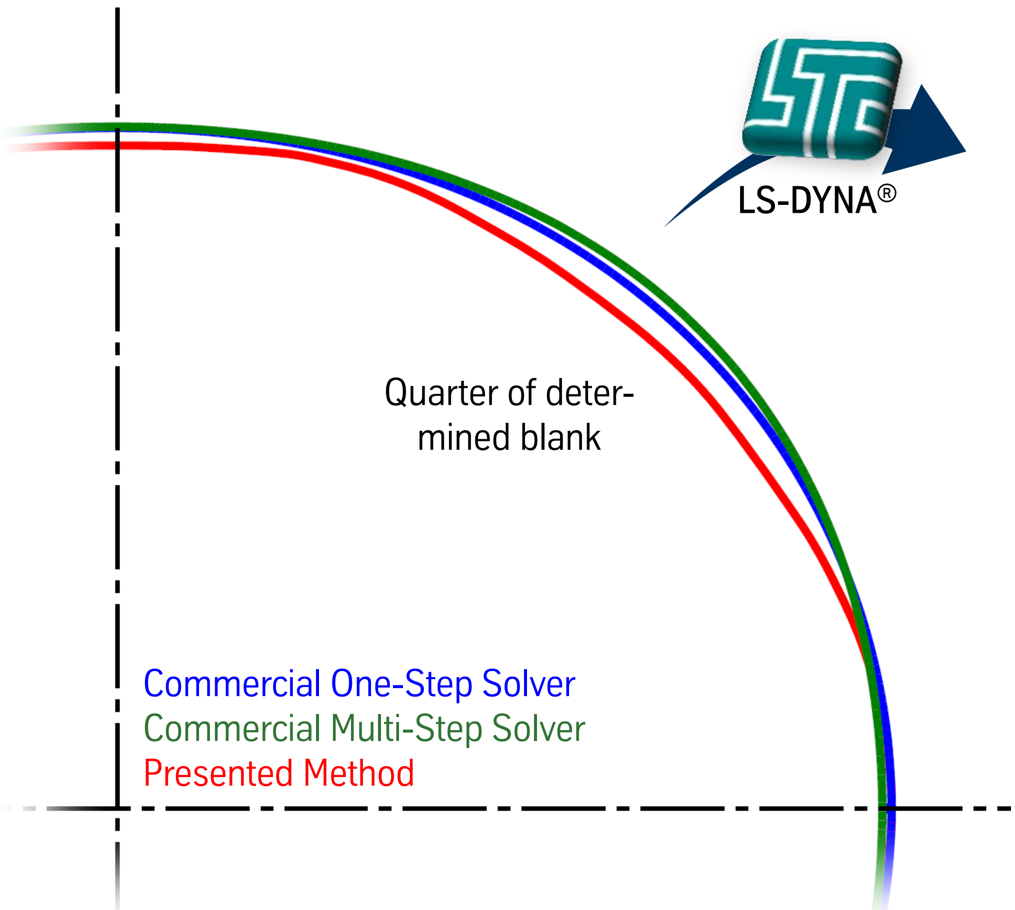
MATLAB®

LS-DYNA®

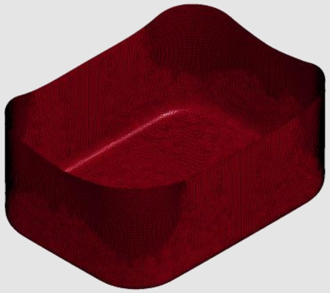
Corrected blank gets additional material allowance for subsequent calibration process of about 2%!

Benchmark with commercial blank determination software

Calculating the optimal blank shape for a rectangular cup with a height of 30 mm



One-Step Solver
$30\ mm^{+4,45}_{+0,90}$
Calc. Time*: 3,2 min
~60.000 Knoten



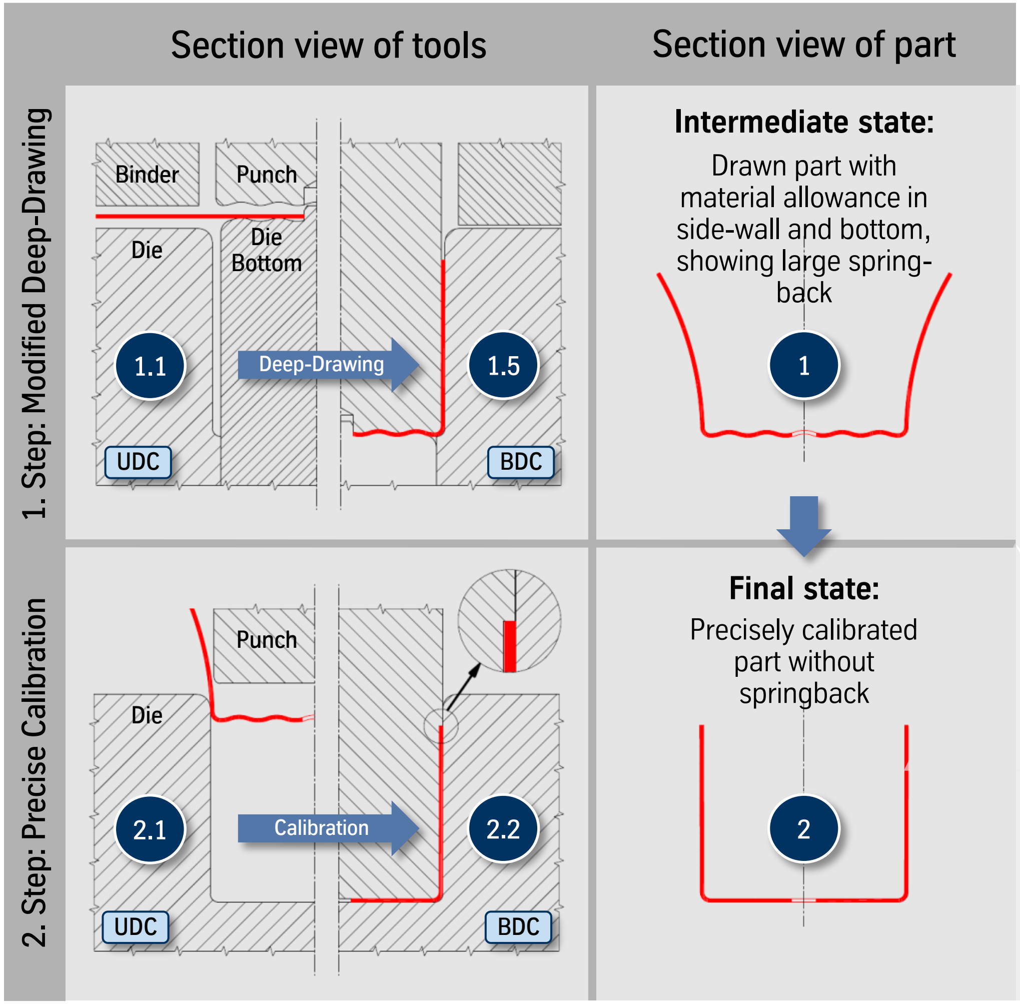
Multi-Step Solver
$30\ mm^{+5,65}_{+0,05}$
Calc. Time*: 1,3 min
~60.000 Knoten

Presented Method
$30\ mm^{+0,61}_{-0,07}$
Calc. Time*: 2,4 min
~60.000 Knoten

*Used computer: Intel Core 2 Duo 2,4MHz, 4GB RAM

Trim-Free Calibrating Deep-Drawing: Procedural schematic

Manufacturing of precise forming parts at the example of a hat-profile



1. Step: Modified Deep-Drawing

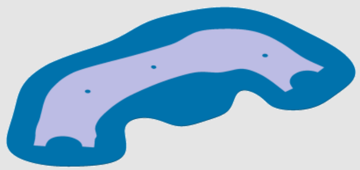
- **1.1** Starting Position: Lifting of punch, binder and bottom
- **1.2** Inserting blank using inner and outer guide pins for positioning
- **1.3** Closing binder and die, leaving a distance greater than sheet thickness
- **1.4** Clamping of blank between punch and die bottom for preforming and final fixation
- **1.5** Deep-drawing until BDC, still with distanced binder

2. Step: Precise Calibration

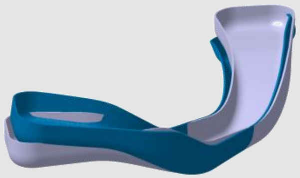
- **2.1** Starting Position: Insertion of drawn part with material allowance into calibration die
- **2.2** Precise calibration of part until BDC to eliminate all shape deviations

… and what happened to the mentioned shape deviations?

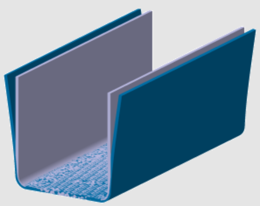
Elimination of shape deviations using Trim-Free Calibrating Deep-Drawing



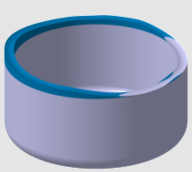
Does not occur due to usage of a predetermined shape of the blank



Is reduced to acceptable minimum due to stress super-imposition



Is reduced to acceptable minimum due to stress super-imposition



Can not be removed as usual because of the absence of a final trimming process

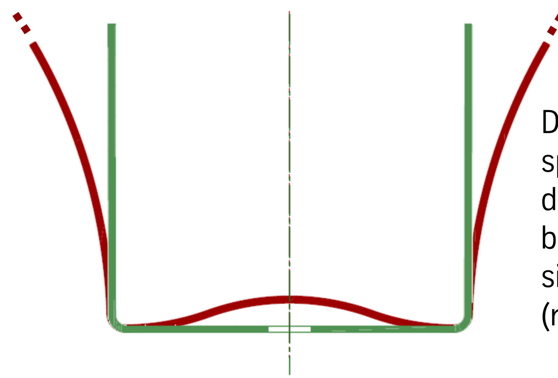
Small (positive) deviation at edge of drawn part can still be accepted!

Part is equipped with additional material allow-ance of ~2%

Height of side-wall is reduced to final height during cali-bration step

The material allowance should

- be distributed as evenly as possible within the entire cross-section of the drawn part,
- be designed as an extension in all sections aligned in direction of the compression, and
- distributed as waves in all sections which are transverse to the direction of compression.



Drawn hat-profile (after springback) with exten-ded side walls and wavy bottom to get a compres-sion allowance of ~2% (red); final part (green)

Requirements for application of Trim-Free Calibrating Deep-Drawing

Modifications to conventional deep-drawing to reduce common influences

Determination of the blank shape with compression allowance 1

- drawn part must be near ideal calibration shape (= final shape + allowance)
- blank shape profile tolerance must be within a value of ±0.15 mm

Positioning and fixation of predetermined blank 2

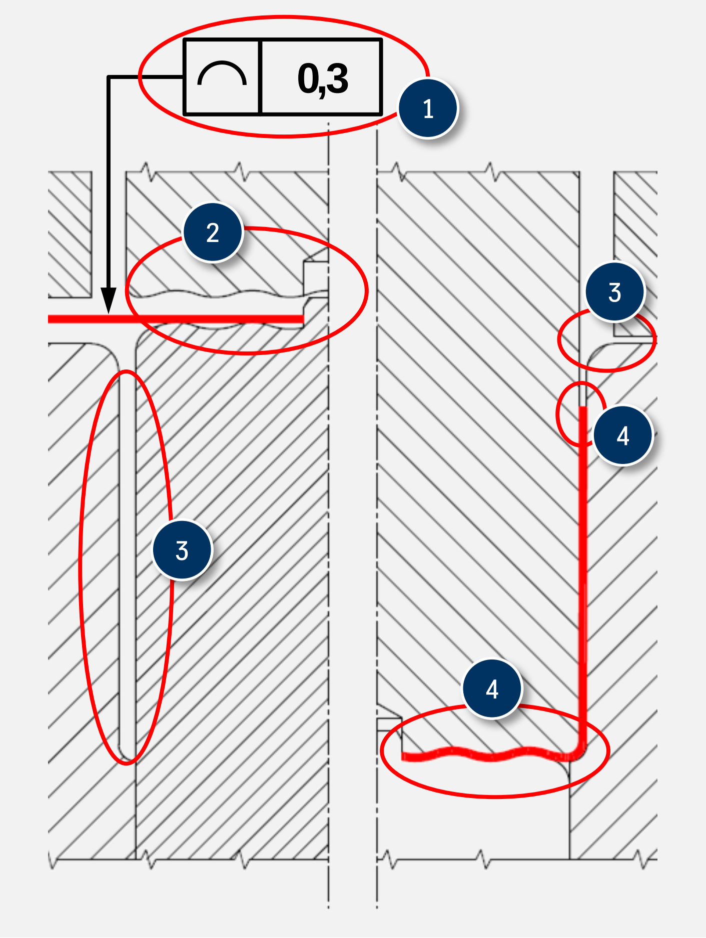
- blank must be fixed before start of process by external positioning pins
- guide pins within bottom contour have proven to be helpful
- Movable, at start raised die bottom clamps blank with die during forming

Realization of uniform forming conditions during drawing 3

- draw gap is ~110% of sheet thickness to reduce influence of sheet batch fluctuations, tool tolerances and locally different friction conditions
- binder is distanced by ~15% of sheet thickness to avoid full surface contact

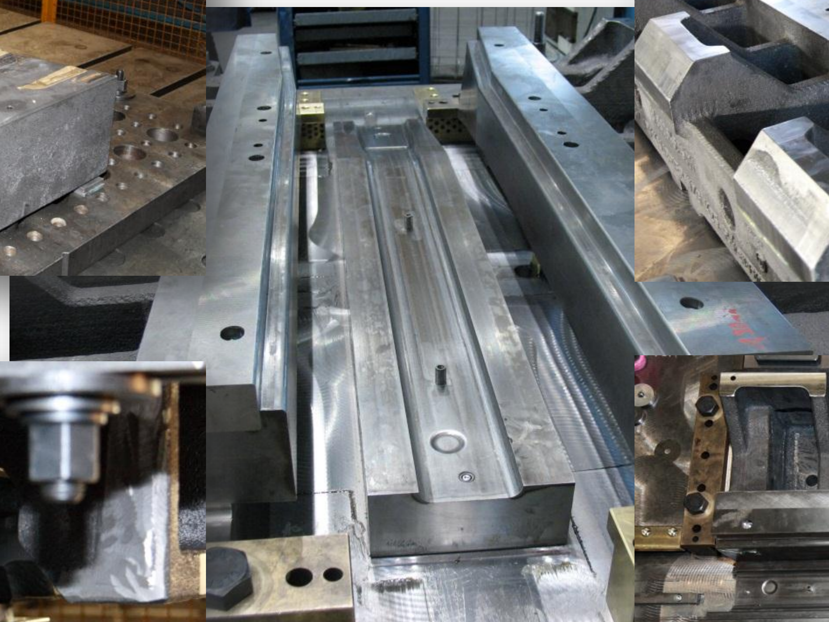
Homogeneous compression material during calibration 4

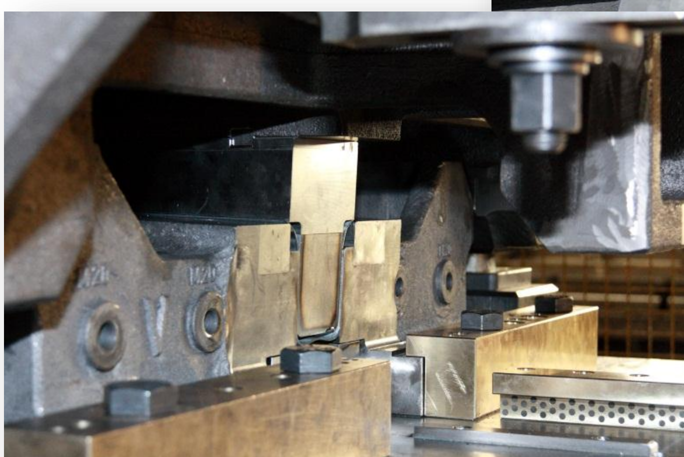
- Compression of bottom and side walls must occur simultaneously
- peak-to-peak amplitude of bottom waves = absolute allowance in side walls

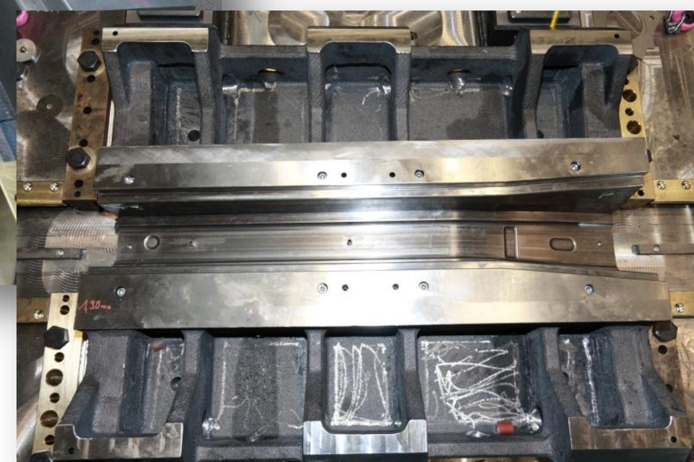


Implementation of Trim-Free Calibrating Deep-Drawing

Tool design and manufacturing by ThyssenKrupp System Engineering GmbH







Results of first manufacturing try-out of longitudinal member

Parts with and without flange produced in same tool-set using different tool-inserts

Longitudinal Member without flange

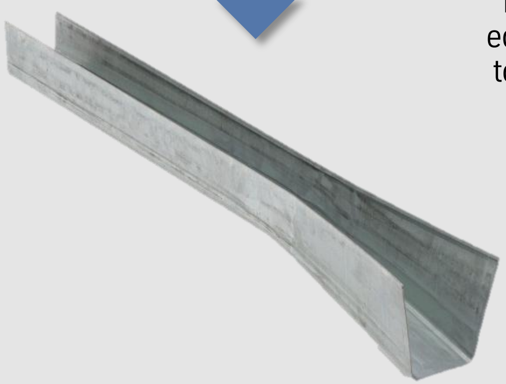
Part after drawing stage

Maximal deviation of edge between part and tool **before calibration**:

+52 mm

max. side wall height: 125 mm

Final part after calibration stage



Maximal deviation of edge between part and tool **after calibration**:

CP-W® 800: **+8 mm**
MHZ 500: **+6 mm**

Longitudinal Member with flange

Part after drawing stage

Maximal deviation of edge between part and tool **before calibration**:

+57 mm

max. side wall height: 140 mm

Final part after calibration stage

Maximal deviation of edge between part and tool **after calibration**:

CP-W® 800: **+6 mm**
MHZ 500: **+4 mm**

Deviation of edge after calibration is small enough to guarantee simple joining process!

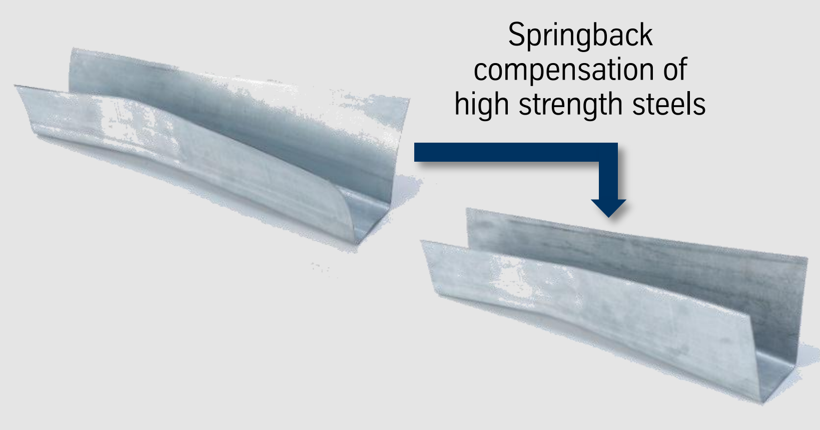
General benefits of Trim-Free Calibrating Deep-Drawing

Efficient method for manufacturing of precise sheet-metal parts

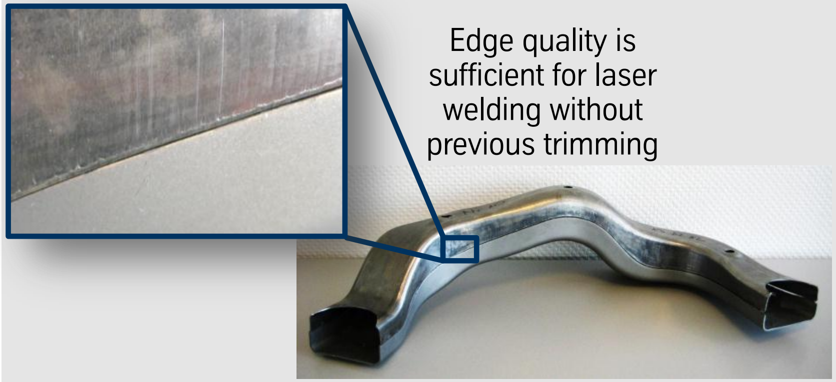
Benefits

- Highly increased rate of material utilisation
- Drastic shortening of process chain; higher productivity; less number of presses; less part transfer; reduced energy consumption; reduced manufacturing costs
- Simple tool sets; less tool production costs; less maintenance costs
- Small achievable tolerances even when using high strength steels due to compensation of springback and improved edge quality
- Better crash performance of parts because of superimposed compression stress
- Smaller strains during forming especially at the edges, thus better endurance of parts or extended forming potential for complex shaped products because of increased freedom in design
- Subsequent joining operations easier due to reduced clamping efforts; better joining results at lower costs
- No scrap material to be diverted from tool without trimming stages
- Increased lightweight design possibilities
- User gains advantages in competition due to know-how
- Hot forming application intended; trimming of hot formed parts is cost-intensive and should be avoided as much as possible

Longitudinal member before and after calibration



Lightweight rear cross member assembly



Thank you for your attention!