3D “flexible roll forming” of profiles with discontinuous cross sections.
A new production method for flexible and cost effective production of automotive components

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Overview

• What is 3D roll forming?
• History of flexible roll forming for 3D-profiles
• Results of recent research & development projects
• data M’s new concept to reach industrial accuracy
• Benefits by light weight design of RF components
• Why transitions with constant change of curvature?
• Subsequent steps: laser welding & hydro forming
• Future targets and outlook in 3D ...
What is 3D Roll Forming?

Roll Forming of Profiles with discontinuous Cross Sections

(3D Roll Forming, Flexible Roll Forming, … )
What is 3D Roll Forming?
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- 1st try out line at PtU/ Germany
- Concept of Prof. Schmöckel & Dr. Adrian Istrate

- 1st try out line at PtU/ Germany
- Concept of Prof. Schmöckel & Dr. Adrian Istrate
- Feasibility of process proven but...
- ...still poor tolerances
- COPRA® AMC (adaptive motion control) developed by data M SMS
1st Generation Line: PROFORM (2009)

- Flexible roll forming line for automotive parts (European R&D Project PROFORM; 2007-2010 with 23 project partners including Daimler and FIAT)
- R&D of forming strategies (design and simulation) and hardware concepts

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1st Generation Line: PROFORM (2009)

COPRA® AMC (Adaptive Motion Control) by data M SMS:

- Integration of complete process chain (uncoiling, levelling, laser trimming, flexible roll forming, electromagnetic forming, inductive heating and cut off)
- Easy user interface and programming of new shapes

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1st Generation Line: PROFORM (2009)

Simulation and Measuring of Warping Effects

Manufacturing without blank holders, Basic prototype in ZStE 340
(Radius in transition zone 500 mm)

- Warping and deviation effects of more than 5 mm!
- This is still too much for an industrial acceptance!
Simulation and Measuring of Warping Effects

- Simulation shows warping effects (yellow and blue areas) clearly because of stretching and compression zones in the flexible rolled edges of the sheet

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Strip Edge Strain in Flexible Roll Forming

Required:
- Design to match material and production process
- Adapted forming method(s)

limits of various kinds of material:
- soft deep drawing steel
- High tensile steel
- ultra high tensile steel

Transition radius of a flexible roll formed profile

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• Warping effects could be significantly reduced compared to 1st generation

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2nd Generation: data M SMS (2010)
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Concept of 3rd Generation: data M SMS (2011)

- data M’s new concepts for bipods and self riding blank holders

Patented self riding blank holder system

Patented Bipod-stands

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Concept of 3rd Generation: data M SMS (2011)

BiPod (parallel kinematics) Technology in the Forming Stands

- data M's patented bipod-system for more flexibility and higher accuracy in flexible roll forming:
  Presented at Tube & Wire Düsseldorf/ Germany 2010

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Patented self riding blank holder to better guide the sheet between the stands and avoid warping and scratching of the surface (principle sketch)
Investigation of the influence of the self riding blank holder:

- Simulation shows only a fracture of warping than before - with the use of the self riding blank holder at the critical points
3rd Generation Line – Our offer to Industry:

- Proof of industrial acceptable tolerances in production
- Fast production speed of 20m/min and more
- Making of industrial prototypes of 3D profiles meeting industrial tolerances and quality norms
- Our customers have to be able to show real parts to their OEMs
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Strategies for Light Weight Design by...

...Material
High Tensile Steels, Titanium, Aluminum, Magnesium, Plastics

...Design
Structured or crowned sheets; use of crimpings or embossings

...Concept
Construction method with advantageous „Function vs. Weight“ relationship

...Manufacturing Method
Tailored Blanks; Tailored Tubes; Patchwork Technique; Bonded Blanks (Source: Volkswagen)

Source: www.leichtbau.de
Material Light Weight Design with CFRP ... ???

- Example: Aldi CFK-Trailer
- 3000 kg Weight Reduction!
- 50% Reduction at same stiffness as steel
- But, at what Price?

Source: www.lightweightdesign.de
or Form Light Weight Design with 3D-Steel-Profiles???

- What about 3D-Steel-Profiles instead of CFK?
- More than 3000 kg weight reduction?
- But, at considerable lower prices than with CFRP?

Source: www.lightweightdesign.de
Load Matching Design

• Variant 1: Weight reduction by reduced reaction force: 10-20%

• Variant 2: Higher load capacity by increased profile height:

  \[ l = \frac{B \cdot H^3}{12} \]
  double height means \( 2^3 = 8 \) times higher load capacity
  either: 700% more load with only 50% increased weight
  or: 60% weight reduction at double load capacity

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Train derails at transitions from straight to radius element

"Wilde Maus" is a roller coaster without inversions; Speed limited to 30 mp/h
Curve Progression during Flexible/ 3D Roll Forming

Testing of different forming paths:
What tolerances are really needed?

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Roll Forming Speed vs. Radius

Flexible roll Forming Speed depending on transition radius

limits of various kinds of material:
- soft deep drawing steel
- high tensile steel
- ultra high tensile steel
- aluminum

Transition radius of a flexible roll formed profile

Strip edge strain in %

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# Why Forming Speed Counts

- **Roll Forming Speed:**
  - 10 m / min
  - 20 m / min
  - 30 m / min
  - 30ft / min
  - 60 ft / min
  - 90 ft / min
- **1m-parts / hour:**
  - 600
  - 1,200
  - 1,800
- **3m-parts / hour:**
  - 200
  - 400
  - 600
- **1m-parts / shift:**
  - 4,800
  - 9,600
  - 14,400
- **1m-parts / week:**
  - 75,000
  - 150,000
  - 225,000
- **3m-parts / week:**
  - 25,000
  - 50,000
  - 75,000
- **1m-parts / month:**
  - 300,000
  - 600,000
  - 900,000
- **1m-parts / year:**
  - 3,600,000
  - 7,200,000
  - 10,800,000
- **3m-parts / year:**
  - 1,200,000
  - 2,400,000
  - 3,600,000
- **12m parts and longer…**
  - (36ft parts and longer…)

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Seven at one Blow - or 11...?

By clever arrangement of profiles-ends it is possible to produce complete parts families simultaneously.
Seven at one Blow

- Whole Profile-Families can be made without change of tool
- Domino-Effect: Combination by means of suitable transitions of profile ends
- New profile shapes require change of SW-program only
- Prototypes and small series of parts can be made
- Short delivery time when changing a profile geometry
- To develop standard cross-sections suiting this production method?
- To define standards for complete families of parts?
- Platform strategies?
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Subsequent Steps of 3D Roll Forming: Welding

- 3D-roll forming to produce a closed profile with variable cross section – for later hydro forming
Subsequent Steps of 3D Roll Forming: Welding

- Coupled Thermal / Mechanical Analysis
- Adaptive Meshing in Welding Area
- Welding Speed
- Welding Criterium (Pressure, Liquidus Temperature, etc.)
- Material Phase Transformation (% Martensite, % Austinite, % Ferrit, etc. with rapid calculation algorithms)
Demands on Subsequent Steps

- Higher accuracy needed for welding to close the shape exactly
  - On laser welding distance of edges lower than 0.5 mm
  - On HF-welding more tolerance is acceptable
  - TIG-welding especially suitable for high-strength-steels
- 1:2- or 1:3- relations of cross sections for hydro forming
  - With flexible roll form optimized preforms a wider range of part families for the automotive industry could be made
  - Hydro forming only needed for exact calibration of the shape
  - Combination of advantages: High flexibility with high velocity and lower costs to an overall effective production system

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Subseq. Steps: Hydro Forming

3D-profiled optimized preform

Comparison of the sheet deformations at 50 and 90 % filling of the IHU-process

Final IHU-Geometry

Effective strain

- Optimized preforms achieve higher deformation degrees on hydro forming

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Targets and Outlook in 3D Roll Forming (excerpt)

- Development of profile-intensive Body-in-White-Structures
- Increased stiffness with reduced weight by means of closed 3D profiles
- Different profile dimension on one machine
- Load matching profile shapes with continuous curvature for
  > sustainable production (reduced weight)
  > higher productivity
- Forming of long and heavy members or structures
Long (truck) Members, heavy wall thickness

Profiles of three different thicknesses and 8 geometries - in total 48 different beams
Profile intensive Body-in-White-Structure

Source: DURA Automotive/ PROFORM

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Variation in Height...

... advanced developments in 3D Roll Forming

Typical Automotive Part.

Elongation in certain transition zones

Compression in certain transition zones

CAD & FEA
Design & Verification

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We are convinced of flexible roll forming technology and realise the advantages of this innovative technology. Therefore we are making following offer to industry:

- data M is performing the feasibility studies for this new technology
- data M is developing the tooling and machine concept
- data M is developing the computer control
- Plus: data M produces the profile on our prototyping- and research line

Introducing this new technology to industry.