Numerical Analysis of High Speed Roller Hemming Processes

Dr. Jens Baumgarten, ME Strategies & Planning
Dr. Peter Plapper, ME Body
Bamberg, October 20, 2005

Adam Opel AG

Outline

- Introduction
- Motivation
- Target
- Approach
- Results
- Conclusion and Outlook

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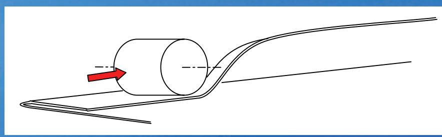
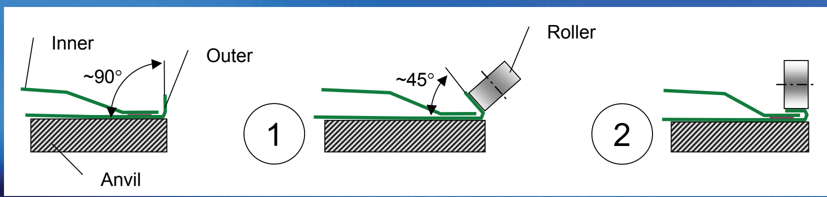
Introduction
Roller hemming process

Principle of roller hemming



- Flange is bent in a continuous process using a robot-manipulated roller
- Incremental forming process

2-step 90°-roller hemming process



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Introduction
Roller hemming technology implementation

Model	Components to be roller hemmed	Plant	Capacity
Tigra	Doors, hood, roof, tailgate	Heuliez	Medium
Zafira	Hood	Bochum	High
Combo	Tailgate	Azambuja	Low
Saab Cadillac	Doors, hood, tailgate	Trollhättan	Low
Astra RHT	Doors, a-pillar	Antwerp	Low
Saab 606	Hood, tailgate	Trollhättan	Medium
Next Generation Vectra	All closures	Rüsselsheim	High

GME‘s Vision

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Introduction
High speed roller hemming technology

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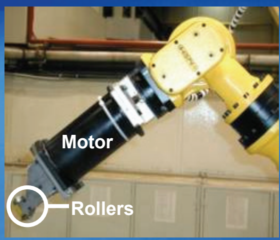
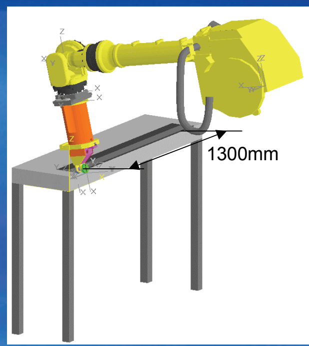


"Dynamic High Speed Roller Hemming" tool with driven rollers (patent pending)

→ Facilitates hemming speeds of up to **1400 mm/s**

Complete system (robot and hemming fixture for 3305 Astra HB3)



Experimental straight-edge / straight-surface process for fundamental investigations

→ Modeled in this study

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Motivation

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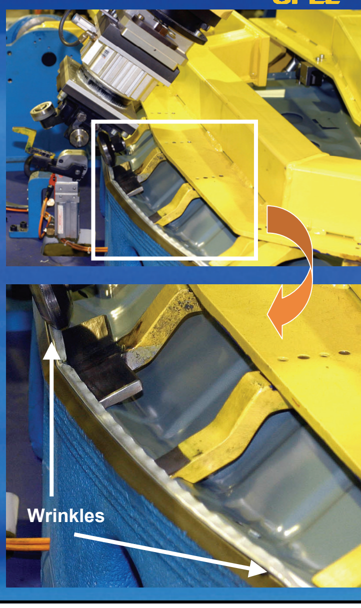
Pre-hem wrinkling

- Wrinkles can occasionally be not fully flattened out during final-hemming
- Impairs the final part's quality in terms of surface and flushness conditions

→ One of the most significant problems associated with roller hemming



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Target

Provide tangible recommendations for optimized process design to minimize pre-hem wrinkling

Understand underlying physical processes

Systematically identify influence of major process parameters

Current situation:
- Literature/suppliers yield very limited data
- In-depth theoretical analysis still to be performed

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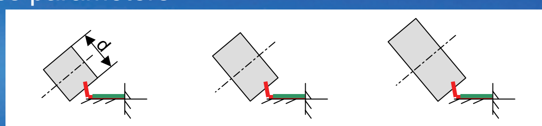
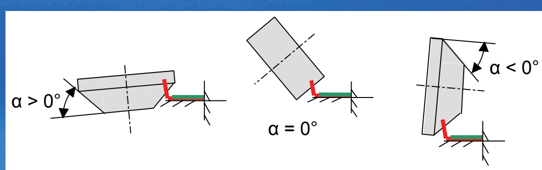
Approach
Sensitivity analysis by means of FEA

Investigated major process parameters

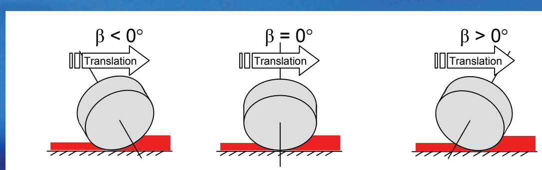
- Pre-hem roller diameter d:
  d = 20mm; 40mm; 60mm



- Pre-hem roller taper angle α:
  $\alpha > 0°$; $\alpha = 0°$; $\alpha < 0°$
  ($\alpha_4 = -60°$; $\alpha_5 = -75°$)



- Pre-hem roller lead angle β:
  $\beta < 0°$; $\beta = 0°$; $\beta > 0°$



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Approach
Model

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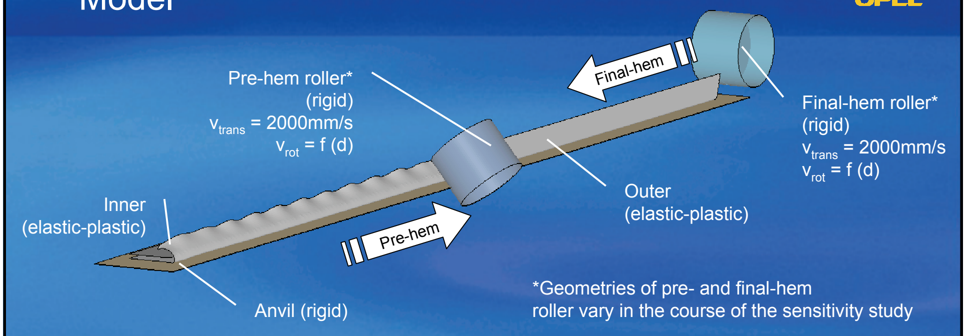
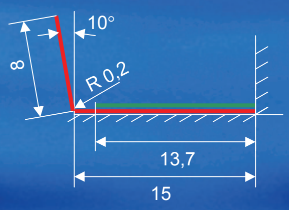


*Geometries of pre- and final-hem roller vary in the course of the sensitivity study

Workpiece:
- Length of „inner“ and „outer“ = 300mm
- Sheet thickness „outer“ = 0.75mm
- Sheet thickness „inner“ = 1.7mm
- Material: mild steel



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Approach
FEA details

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Numerical parameters
- LS-DYNA (Version 970, MPP, single precision)
- Shell elements (type 16, full integration, 7 thru-thickness integration points)
- Material model 24: piecewise linear plasticity

Meshing guidelines for hem radius
- 4 elements on 90° hem radius
- Element size = 0.2mm
- Aspect ratio = 1.0

Computing resources
- p550 (IBM) with 4 Power5 CPUs, 4x4=16Gb Memory
- Expense: approx. 6,4 hours

Analysis procedure

Pre-hemming (explicit)

↓

Final-hemming (explicit)

Both hemming steps are simulated in a single run

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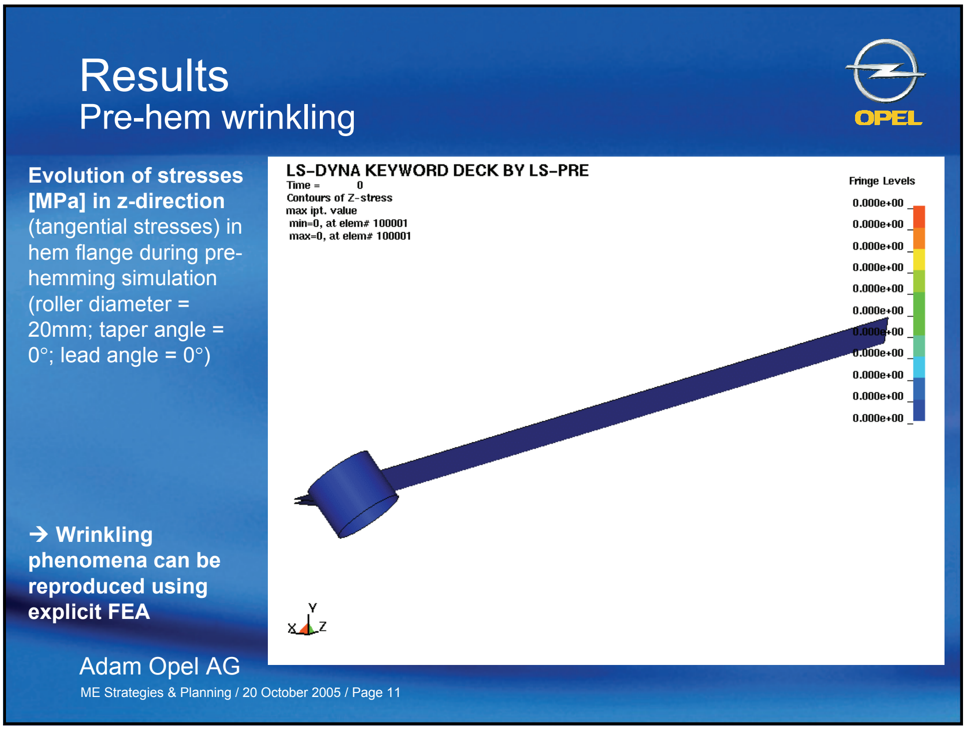
Results
Pre-hem wrinkling
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Evolution of stresses [MPa] in z-direction (tangential stresses) in hem flange during pre-hemming simulation (roller diameter = 20mm; taper angle = 0°; lead angle = 0°)
→ Wrinkling phenomena can be reproduced using explicit FEA
LS-DYNA KEYWORD DECK BY LS-PRE
Time = 0
Contours of Z-stress
max ipt. value
min=0, at elem# 100001
max=0, at elem# 100001
Fringe Levels
0.000e+00
Y
X
Z
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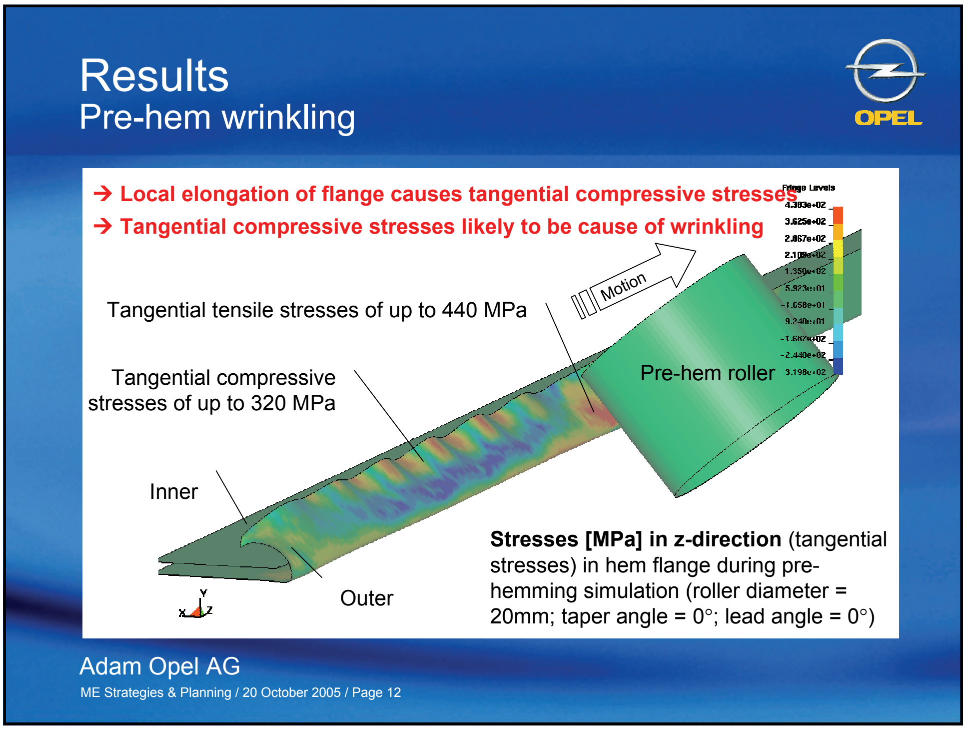
Results
Pre-hem wrinkling
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→ Local elongation of flange causes tangential compressive stresses
→ Tangential compressive stresses likely to be cause of wrinkling
Fringe Levels
Motion
Tangential tensile stresses of up to 440 MPa
Tangential compressive stresses of up to 320 MPa
Pre-hem roller
Inner
Outer
Stresses [MPa] in z-direction (tangential stresses) in hem flange during pre-hemming simulation (roller diameter = 20mm; taper angle = 0°; lead angle = 0°)
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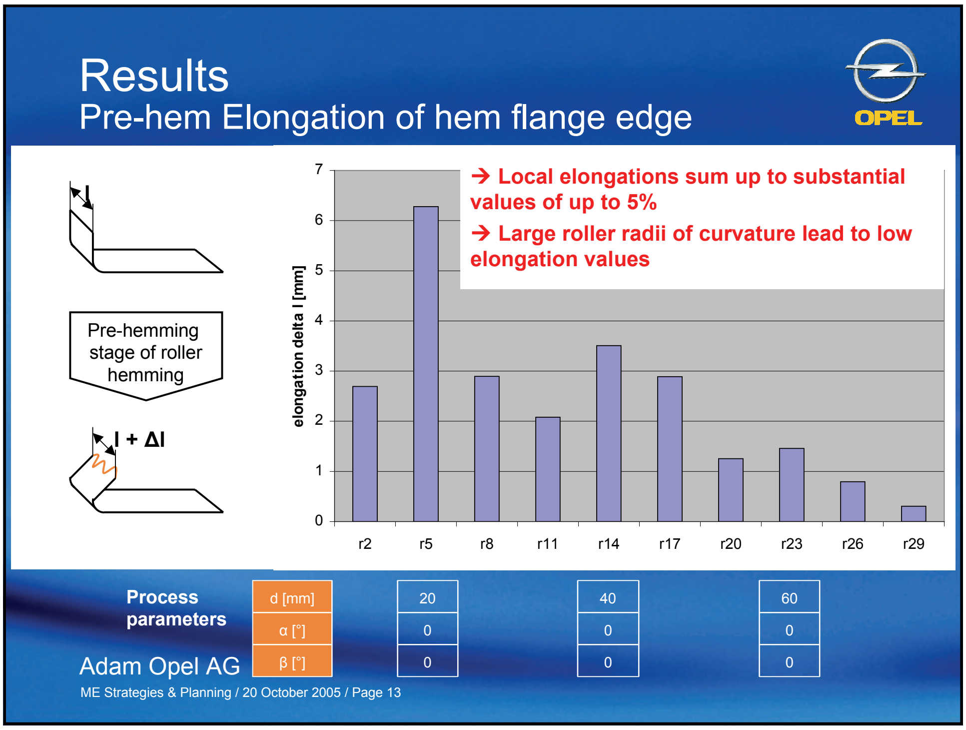

Results
Pre-hem Elongation of hem flange edge
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Pre-hemming stage of roller hemming
l
l + Δl
→ Local elongations sum up to substantial values of up to 5%
→ Large roller radii of curvature lead to low elongation values
elongation delta l [mm]
0
1
2
3
4
5
6
7
r2
r5
r8
r11
r14
r17
r20
r23
r26
r29
Process parameters
d [mm]
α [°]
β [°]
20
0
0
40
0
0
60
0
0
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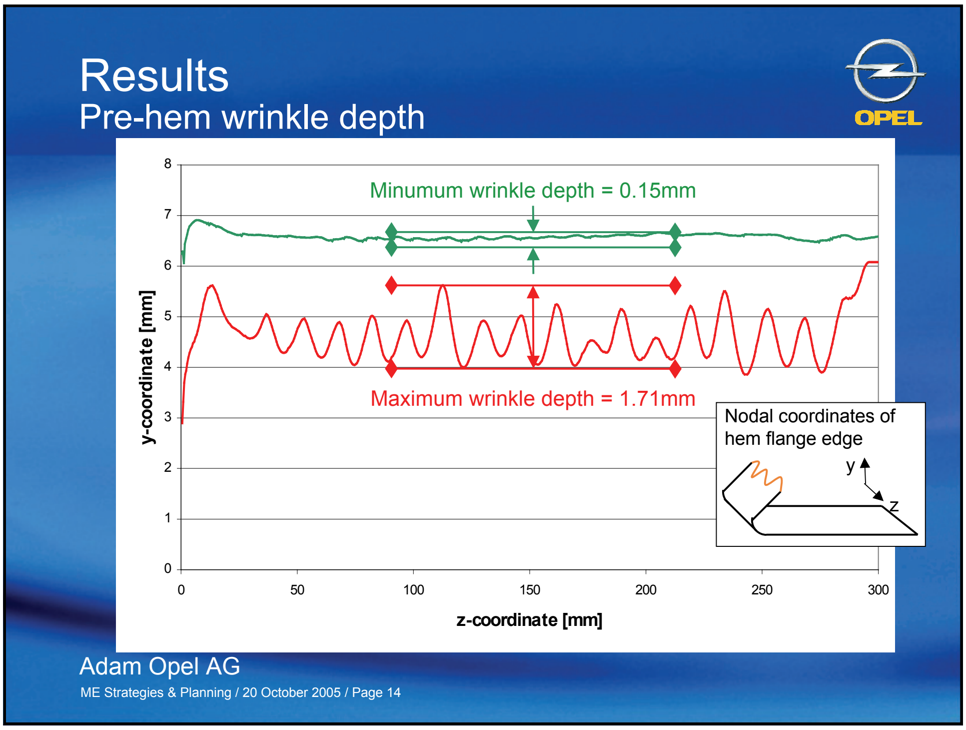

Results
Pre-hem wrinkle depth
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Minumum wrinkle depth = 0.15mm
Maximum wrinkle depth = 1.71mm
Nodal coordinates of hem flange edge
y
z
y-coordinate [mm]
0
1
2
3
4
5
6
7
8
0
50
100
150
200
250
300
z-coordinate [mm]
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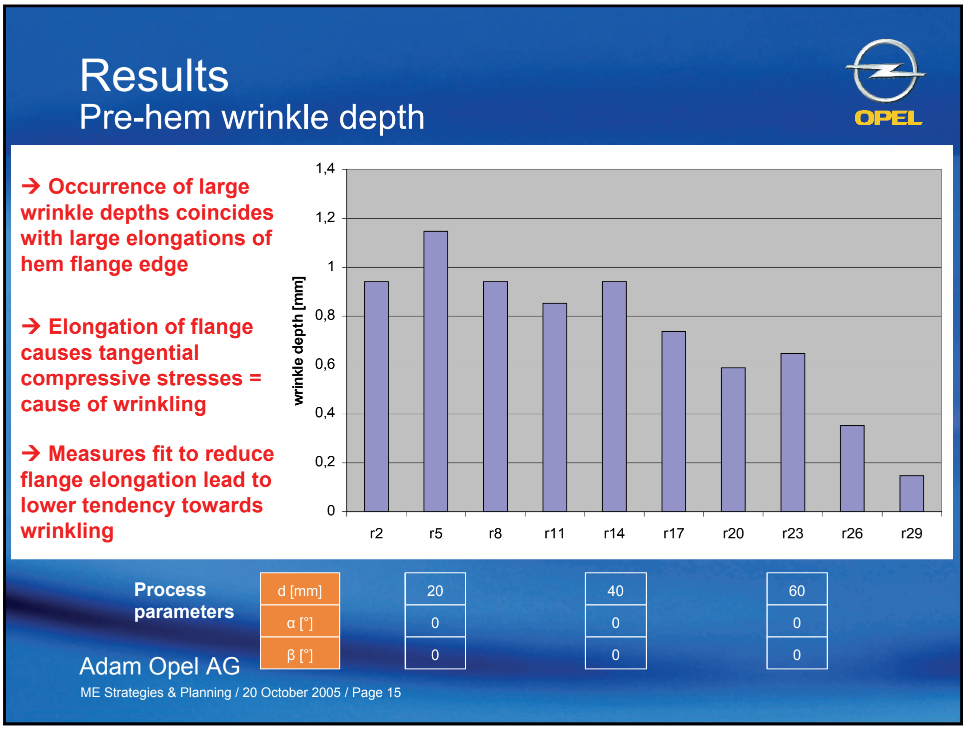
Results
Pre-hem wrinkle depth
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→ Occurrence of large wrinkle depths coincides with large elongations of hem flange edge
→ Elongation of flange causes tangential compressive stresses = cause of wrinkling
→ Measures fit to reduce flange elongation lead to lower tendency towards wrinkling
wrinkle depth [mm]
0 0,2 0,4 0,6 0,8 1 1,2 1,4
r2 r5 r8 r11 r14 r17 r20 r23 r26 r29
Process parameters
d [mm] 20 40 60
α [°] 0 0 0
β [°] 0 0 0
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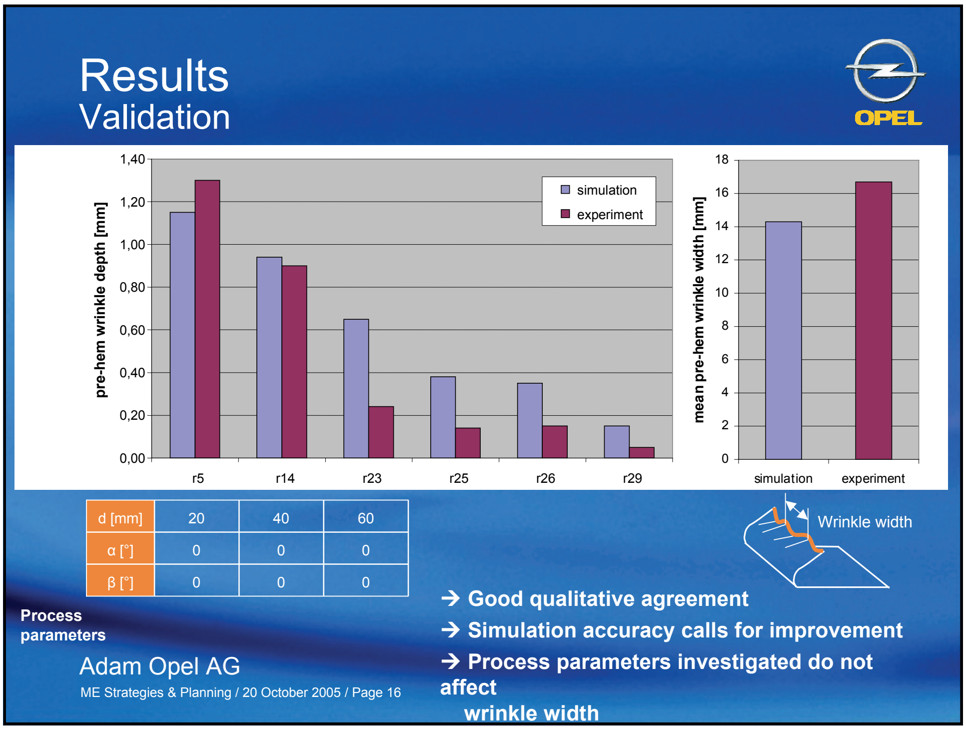
Results
Validation
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pre-hem wrinkle depth [mm]
0,00 0,20 0,40 0,60 0,80 1,00 1,20 1,40
r5 r14 r23 r25 r26 r29
simulation
experiment
mean pre-hem wrinkle width [mm]
0 2 4 6 8 10 12 14 16 18
simulation experiment
d [mm] 20 40 60
α [°] 0 0 0
β [°] 0 0 0
Process parameters
Wrinkle width
→ Good qualitative agreement
→ Simulation accuracy calls for improvement
→ Process parameters investigated do not affect wrinkle width
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Conclusion and outlook

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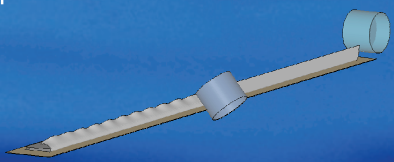
Conclusion
- Straight-edge/straight-surface high speed roller hemming process modeled using LS-DYNA
- Pre-hem wrinkling phenomena reproduced
- Good qualitative agreement simulation/experiment
- Recommendations for an optimized process design developed and validated

Outlook
- Model curved-edge/curved-surface processes
- Improve simulation accuracy
- Model production process



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