Introduction to Hot Stamping and Trends

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Center for Precision Forming (CPF)

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CPF – Current Projects

- Material Characterization
- Friction / Lubrication
- Process Simulation / Forming Al & AHSS
- Die Wear in Forming AHSS
- Edge Quality in Blanking / Shearing
- Hot Stamping of UHSS
- Servo Drive Presses and Hydraulic Cushions
Crashworthiness

Crumple Zone

Passenger Zone

Crumple Zone

Images from: media.Daimler.com
Crashworthiness

Passenger Zone

Crumple Zone

A-pillars

Roof rail

B-pillars

Door beams

Intrusion Resistance
Ultra High Strength

Absorbing Energy
High Strength + Elongation

Ref: Hilfrich 2008.
Summary of Hot Stamping

- Mild Steels
- Conventional High Strength Steels
- Advanced High Strength Steels
- 2nd Generation AHSS
- Aluminum Alloys

Higher Press Forces

Better Formability

Ultimate Tensile Strength (MPa)

Total Elongation (%)

- IF
- Mild
- BH
- CMn
- Al
- HSLA
- TRIP
- DP, CP
- MART
- PHS
- L-IP
- Aust. SS
- TWIP
Summary of Hot Stamping

- Specific Strength (MPa/(kg/m³))
- Total Elongation (%)

- Mild Steels
- Conventional High Strength Steels
- Advanced High Strength Steels
- 2nd Generation AHSS
- Aluminum Alloys

- Lightweight Potential for Energy Absorption
- Lightweight Potential for Intrusion Resistance
- Higher Springback

- IF
- Aust. SS
- TWIP
- L-IP
- BH
- CMn
- TRIP
- HSLA
- DP, CP
- MART
- PHS

- Lightweight Potential for Intrusion Resistance
- Higher Springback
Summary of Hot Stamping

- Mn-B Alloied steel (as delivered): Ferrite & Pearlite
- Heated >950°C: Austenite
- 3-5 min.s in Furnace
- Quenched in the die >27°C/s
- Quenched Martensite
- Indirect Process:
- Direct Process:
Mass % of hot stamped steel in BIW

- Volvo XC90 20%
- Volvo XC90 44%
- VW Passat 19%
- VW Golf VII 28%
- SAAB 9000 7%

Hot Stamping - Trends

Parts per year (in millions)

- Year 1987: 3 million per year (1987)
- Year 1997: 8 million per year (1997)
- Year 2007: 95 million per year (2007)
- Year 2013: >20 Parts/Vehicle

- 4 Parts/Vehicle
- 6 Parts/Vehicle
- 8-10 Parts/Vehicle
- 210+ lines around the world +55 planned

Hot Stamping - Trends

Ref: Macek 2006, Image from: IIHS.
Hot Stamping - Trends

Tailor Rolled Blanks
Tailor Welded Blanks
Tailored Hot Stamping

HSLA 340 (50 ksi)
22MnB5
1500 MPa (215 ksi)

Hot Stamping - Trends

Tailored Heating (Austenitizing)
Tailored Quenching
Post Tempering

Hot Stamping - Trends
Our simulations aim to predict the final properties of hot stamped components:

1) Presence of defects: cracks, wrinkles or local necking,
2) Hardness distribution (both in uniform and in tailored parts),
3) Cooling channel analysis,
4) Distortion of the final part.
Microstructure Evolution

Mechanical Field
- Mechanical material properties,
- Volume change due to phase transformation.

Thermal Field
- Thermal material properties,
- Latent heat due to phase transformation.

Fluid Mechanics
- Heat transfer to the coolant medium.

Heat generation due to plastic deformation.

Thermal expansion.

Phase transformation depends on stress and strain.

Microstructure depends on temperature.

Ref: Åkerström 2006, Porzner 2012.
## Finite Element Simulation of Hot Stamping

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*Only needed in tailored parts*
Crack prediction in a Side Member Reinforcement

Colors other than gray: Thinning >20%.
Predicting Defects

Heated Dies \((T_i = 450\,^\circ C)\)

Cooled Dies \((T_i = 20\,^\circ C)\)

Blank \((T_i = 850\,^\circ C)\)
Predicting Defects

Crack / wrinkle prediction in a tailored part

With one-piece blankholder

20 kN

Crack
Wrinkles in the soft area
Non-symmetric draw-in
Hardness Distribution

Die Quenching Optimization

Martensite phase fraction

- Min = 0.00
- Max = 1.00
- Values: 0.14, 0.00, 1.00, 0.85, 0.71, 0.57, 0.42, 0.28

4 seconds die quenching

10 seconds die quenching
Hardness Distribution

Air Quenching Stage

Ref: Shapiro 2009.
Results

Hardened zone:
- 485 – 515 HV
- 1500 – 1590 MPa
  (~220 – 230 ksi)

Soft zone:
- 310 – 330 HV
- 920 – 1020 MPa
  (~135 – 150 ksi)

Literature:
[George 2011], 400°C dies = 790-840 MPa
[Feuser 2011], 450°C dies = ~850 MPa
Cooling Channel Analysis

Cooling channel performance

1.3 mm 22MnB5 “roof rail”
Mass produced for a European car.
Cooling Channel Analysis

Cooling channel performance – tailored part

1.2 mm 22MnB5 “B-pillar”
Ongoing work: Distortion in Tailored Parts

Ref: Porzner 2012.
Summary and Conclusions

Several case studies were used to develop, calibrate and validate material models, conversion factors and methods to predict:

1) Defects (cracks, wrinkles, local necks),
2) Vickers hardness, yield and ultimate tensile strengths,
3) Cooling channel / heating cartridge performance,
4) Distortion in a non-uniform part.
1) New materials with even higher strength: More lightweight potential and increased productivity.

2) New coatings: better corrosion properties and friction conditions.

3) New heating, forming and quenching methods to improve productivity.

**High Strength (USIBOR 2000, MBW1900, HPF 2000)**

**22MnB5 (USIBOR 1500, MBW1500, HPF1470)**

**High Elongation (DUCTIBOR 500, MBW500)**


**Competition:** DP, TRIP, TWIP, and 3gAHS Steels with high YS and UTS.
As of September 2013:

- 15 CPF Reports (Literature review and FE simulations), (5 in the last 6 months) [confidential to members],
- 6 Stamping Journal R&D Updates (+1 more in progress),
- 6 Conference Proceedings (+1 more submitted),
- 1 Book Chapter in “Sheet Metal Forming: Vol 2: Processes and Applications”, (see next slide),
- And a new “Hot Stamping” book in progress!
Questions / Comments?

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References can be sent upon request.