How New Stamping Technologies Can Help?

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https://ercnsm.osu.edu - 1986
https://cpf.osu.edu - 2005

EWI/CPF Workshop – October 15, 2015
Columbus, Ohio
• EWI-Forming Center, use of 160 ton hydraulic press and CDT and bulge test tooling
• Honda R&D and Honda Engr – Material Testing / Forming of Al Using the Honda die set
• Shiloh – Use of a die set built for forming AHSS
• Aida-America – Use of 300 ton Servo Press with 25 ton CNC hydraulic cushion
• Nucor and POSCO - AHSS materials
• Blanking and Hydraulic Cushion Effects with non-CPF members
Outline
Forming Trends in Automotive Industry

• Lightweighting
• Use of New Materials – High Strength Aluminum Alloys / Advanced High Strength Steels (AHSS)
• Challenges in Processing / Forming New Materials
• Lubrication and Friction in Metal Forming
• Use of Servo Drive Presses and CNC Hydraulic cushions
• Process Simulation / Importance of Stress/Strain Data
• Hot Stamping (PHS)
• Future Developments and Challenges
• Summary / Conclusions
Drivers for Lightweighting – Automotive

- Safety Regulations
- Profit
- COST
- Design
- Materials
- Processes
- Lubricants
- Presses
- Miles per gallon
- Pollution/CO₂ Emission per mile
- Customer / Society
Crashworthiness

Passenger Zone

Crumple Zone

A-pillars

B-pillars

Door beams

Roof rail

Intrusion Resistance

Ultra High Strength
(Hot Stamping)

Absorbing Energy

High Strength + Elongation
Materials Used in Automotive Stamping

- **7xxx Al alloys for automotive components (Take density into account)**

![Graph showing materials used in automotive stamping](graph.png)

7xxx Aluminium suitable for lightweight crash-resistant components
- high specific strength
- high residual elongation

**Quelle:**
- voestalpine
- ThyssenKrupp

Courtesy: LKR Leichtmetallkompetenzzentrum, 2012
• DP 980 – DP 1200 steels are used by various OEM’s and suppliers

• UHSS – DP 1200 (by Nippon Steel/Sumitomo Metals/Kobe Steel) is used for B-Pillar in selected Nissan models

• R&D is being conducted in Japan for forming 1400 Mpa steels to produce structural parts

• Main challenges are: formability, springback, press and tool deflection
Aluminum in Automotive Industry

- The most commonly used Aluminum alloys in automotive industry:
  - 5083-O, 5182-O, 5754-O, 6014, 6022, 6063-T6, 6111-T4, 6016-T4, 7020-T6, 7022-T6, 7075-T6

Example of aluminum application in automotive construction:
(Source: Audi A8)
Comparison of 7xxx and HS steel for automotive - FE simulation

- AA7075 has a high strength to weight ratio with yield strengths comparable to those of DP and TRIP advanced high strength steels.
- 7075-T6 has the potential to be formed for structural automotive components as an alternative to boron steel.
- All results showed same crash performance.
- Mass saving was 40% when formed with AA 7075-T6.

Courtesy: Aleris, 2012
Use of Al Alloys in Automotive Industry

- Conventional Stamping of Closures (Door, Tail Gate, Trunk lids, bonnets), 5xxx and 6xxx in nearly all high end vehicles

- Warm/Hot Forming – Benteler / Jaguar / AMAG / Aleris / Alcoa / Ford / AP&T / GM / Tesla and others / Production and Prototype

- Production Capacity for Al Alloys
THE DOOR SIDE CRASH BEAM IN THE NEW BMW i8 (Press Hardened 7xxx ALUMINUM)

Requirements:
- High yield strength (400 MPA) to reduce the intrusion.
- High ductility for structural integrity.

Solution:
- AlZnMgCu sheet with an optimised process is a good compromise between high yield strength and ductility.
- Heat treatment and optimisation of the cathodic dip painting are very important for the corrosion.
- Warm forming technology is used.

BMW i8: door side crash beam
1 kg lighter than steel
Material Characterization

Viscous Pressure Bulge (VPB) Test

- Downward motion clamps the sheet
- Before Forming:
  - Stationary Punch
  - Pressure Transducer
  - Test Sample
  - Viscous Medium
  - Laser Sensor

- After Forming:
  - Continued downward motion forms the bulged sheet

Viscous Pressure Bulge (VPB) Test
Material Characterization - Flow Stress (Tensile/Bulge Tests)

Viscous Pressure Bulge (VPB) Test

Material, DP600, 1 mm

Uniform Strain from Tensile Test = 0.16

Useful strain from Bulge Test = 0.49

Tensile data with Power Law ($\sigma = K \varepsilon^n$)
Cup Draw Test

Friction – Cup Draw Test

Lubrication performance:

Higher BHF before fracture

Successfully Formed Cup
Fractured Cup

Shorter Perimeter
Challenges:
1) Higher contact pressure and higher temperature are detrimental for lubricants,
2) Temperature and pressure additives are needed

Ref: Kim et al 2009
Servo Tandem Line at Suzuka (Japan) Plant (Honda)
Servo press characteristics

Crank or Link press
Fixed Motion

Free motion press

Cycle time of mechanical press
Cycle time of Free motion press

Slide Position

Minimum stroke length
Forming length
Standstill at BDC

Time

(1) Variable stroke length
(2) Best speed for materials
(3) Improve accuracy by dwelling at BDC
(4) Other Process at BDC (Multi Process)
(5) Prevention of noise and shock at contact or breakaway of tools
(6) Synchronize with feeder

(a) Holding
(b) Bottoming
(c) Re-striking

Backward
Servo-Hydraulic Cushion (Courtesy-Aida)

Closed Hydraulic Circuit

During Down Stroke, Cushion Pressure Generates Power

Power Regeneration: Approx. 70%

Motor Torque Direction

Pump Rotation Direction

Power Direction

Pressure Sensor

S/M

Linear Scale

Cushion Pressure Generates Power
Forming of AHSS in a Servo press

DP980 with 1.4mm thickness

Shiloh Die

Flange length at different locations is measured from experimental samples and compared with simulation results.
Deep drawing of DP980 shows the maximum temperature observed on blank is about 97 °C for 25mm stroke and 219 °C for 55mm stroke.

Surface heat transfer is between blank and tooling is not considered. Room temperature is 20 °C.
Forming of Al 5182-0 in a Servo Press - Experiment/Simulation

Case I
BHF=250KN
Ram velocity 5SPM
Stroke 110mm

Simulation for similar conditions

- Some wrinkle at flange
- No wrinkle at wall
Different ram speed and BHF profiles were used in the tryouts.

Note: 1) The speed vs stroke curves were obtained from press. 2) The blank holder force curves are input to the press.
Hot Stamping

At ~950°C (1750°F) Austenite

3-5 min in Furnace

Quenched in the die >27°C/s (~49°F/s)

Mn-B alloyed steel (As delivered) Ferrite-Pearlite

Quenched Martensite

Hot Stamping

FE Simulation of cooling channel analysis

After 10 stampings.
Hot Stamping

FE Simulation of parts with tailored properties

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
1. Forming AHSS (DP, TRIP, TWIP):

- lower formability (ductility) and higher probability of fracture
- variations in mechanical properties from batch to batch
- higher forming forces and high sheet/die interface pressures & temperatures / press deflection
- Excessive tool wear, rapid increase in forming force and large reverse tonnage
- large springback due to large tensile strength
2. Forming of Al Alloys

- Becoming popular because of considerable weight savings
- Presents challenges in formability and tendency to fracture
- Presents opportunities for weight savings by using high strength Al alloys (thru warm forming)

3. Use of Servo Presses

- Increase productivity
- Offers flexibility in improving formability and effectiveness of lubricant by changing forming speed
- Have the potential to improve formability of AHSS and high strength Al alloys (possible competition to Hot Stamping Technology)
Summary / ongoing work at CPF
(in cooperation with CPF members)

- Determination of flow stress (Biaxial/Bulge test/ Frictionless Dome test)/ Formability
- Evaluation of lubricants (Cup draw test)
- FE Simulations (AHSS, Al Alloys, Warm Forming/ Hot Stamping)
- Stamping of AHSS and Al 5182-0 in a 300 ton servo press with CNC hydraulic cushion-effects of ram speed, dwell, BHP
- Bending and Springback (Thin Copper alloys and 1-1.5mm thick AHSS)
- Prediction of Thinning and Fracture/ Edge cracking/ Determination of FLD with 3 points
Contact Information

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Non-proprietary information can be found at web site:

https://ercnsm.osu.edu