Afton Chemical’s Key Driver Seminar:

Forming Trends in the Automotive Industry and Their Impact on Lubrication—

The Drive to Lightweight Materials

by

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CPF Objectives

• Improve existing metal forming processes/products and develop new innovative processes, tooling and equipment

• Conduct projects in close cooperation with industry and transfer the results to the member companies

• Train and educate engineers in the fundamentals and practice of metal forming science and technology
CPF Member Companies

- Dayton
- Chrysler
- Nucor Steelmaking Group
- National Manufacturing Co., Inc.
- TE Connectivity
- POSCO
- Houghton
- Quaker
- Altair
- Scientific Forming Technologies Corporation
- EWi - Edison Welding Institute
- AIDA America
- IMRA
- ESI Group
- Shiloh
- ITC
- Honda

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Outline
Forming Trends in Automotive Industry

• Lightweighting

• Use of New Materials – High Strength Aluminum Alloys / Advanced High Strength Steels (AHSS) / Other Materials

• Challenges in Processing / Forming New Materials

• Factors Affecting Lubrication in Metal Forming

• Various Tests to Evaluate Lubricants

• Future Developments and Challenges

• Summary / Conclusions
Drivers for Lightweighting – Automotive

- Regulations
- Profit
- COST
- Pollution/CO₂
- Emission per mile
- Miles per gallon
- Customer / Society

Design Materials Processes Lubricants
Crashworthiness / Safety

Crumple Zone

Passenger Zone

Crumple Zone

Images from: media.Daimler.com
Crashworthiness

Passenger Zone

Crumple Zone

Roof rail

A-pillars

B-pillars

Door beams

Intrusion Resistance

Ultra High Strength (Hot Stamping)

Absorbing Energy

High Strength + Elongation
AHSS content has rapidly increased in auto structures.

- Content is driven by the need for improved *fuel economy* and *crash safety*.

**Graph:**
- Fuel economy for passenger cars and light trucks.
- Line graph showing increasing trends from 1975 to 2025.

**Diagram:**
- Car frame with arrows indicating crash safety improvements.

**Ex. Requirements for IIHS Top Safety Pick**
- Frontal Crash, 1995
- Side Impact, 2003
- Rear Impact, 2004
- Roof Crush, 2010
The Need to reduce CO₂ Emissions is the #1 Driver globally for increased use of Aluminum

- **Weight Reduction**: 100kg
- **Fuel Reduction**: 0.3 - 0.5 L/100km
- Reduction includes secondary measures: 0.8 – 1.1 kg CO₂ /100km

Lightweight is key to sustainable mobility, globally

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**Auto CO₂ Emission Trend**

- **July 2011**
  - New CAFE standards for American vehicle fleets by 2025
  - CO₂ emissions reduced by 102 g/km

- **April 2012**
  - China’s Energy Saving and New Energy Auto Industry Development Plan 2012-2012
  - CO₂ emissions reduced by 112.5 g/km

Source: International Council on Clean Transportation
Which Materials for Specific Applications and How to Shape Them

Density of steel: 7.8 gr/cm³
Density of Al: 2.7 gr/cm³

Formability vs. Total Elongation (%)

Ref: Grote 2009.
Weight Distribution – Weight Saving Potential (Magna)

Vehicle Weight Distribution

- Car Body: 39%
- Chassis: 15%
- Powertrain: 16%
- Interior: 6%
- Electrical: 15%

Primary weight reduction will happen in Car Body, Chassis and Powertrain
Lightweight Performance (Novelis)
Aluminum Moving to Smaller Segment (Novelis)
2015 Ford F150

About 95% of the body is Aluminum-Frame Chassis is mostly AHSS

700 pounds weight reduction
Sheet Metal Forming (Stamping) process is affected by a variety of parameters:

1. Workpiece material / Blank
2. Tooling/coating
3. Interface (lubrication)
4. Deformation zone
5. Equipment/Press
6. Part Quality
7. Environment
System Approach in Sheet Metal Forming
Example- Deep Drawing

Process with wet-film lubricant

Decoiling and cutting

Stacking Blanks (dry or pre-oiled)

Pre-Oiling (optional)

Additional Oiling (optional)

Deep Drawing + subsequent blanking operations

Degreasing (optional)

[Courtesy: M. Pfestorf, 2005, BMW]
System Approach in Sheet Metal Forming

Example - Deep Drawing

Process with dry-film lubricant

Decoiling / Recoiling with Lube coating by immersion or spraying

Decoiling and cutting

Stacking Blanks

Deep Drawing + subsequent blanking operations

[Courtesy: M. Pfestorf, 2005, BMW]
Factors that affect friction and lubrication in forming sheet metal

**Sheet material**
- Material properties
  - Flow stress/UTS
  - Surface finish
  - Thermal properties
- Surface coating
  - Micro hardness
  - Chemical composition
  - Thermal behavior
- Geometry (thickness)

**Production conditions**
- Stroke rate
- Ram speed
- Humidity/temperature
- Machine characteristics

**Forming tool**
- Die material
  - Hardness
  - Surface finish
  - Thermal properties
- Die coating
  - Micro hardness
  - Thermal properties
  - Adhesion strength
- Geometry (contact length and pressure)

**Friction and lubrication in sheet metal forming**
- Lubricant failure
- Friction increases
- Galling (adhesive wear)
- Scoring of workpiece
- Tool life reduction

**Lubricant**
- Viscosity
- Film thickness
- Pressure stability
- Temperature stability
- Pressure additives
Factors that affect friction and lubrication in forming sheet metal

• **Process Variables** (at Sheet/Tool Interface)
  - Temperature
  - Pressure
  - Displacement and Relative Velocity
  - Coefficient of Friction (COF)

• **Other Variables**
  - Storage stability
  - Application and minimum quantity / removal
  - Effect on welding/painting
  - Corrosion effects
  - COST
Different tribological tests may be necessary to evaluate lubrication at various die locations.

Region 1: flange deformation; Region 2: bending and unbending; Region 3: bending and stretching; Region 4: large friction with little deformation.
Tribological Tests to Evaluate the Performance of Lubricants

- Ball Scratching Test
- Slider-on-Sheet Test
- Strip Reduction Test
- Strip Draw Test
- Draw Bead Simulation
- Twist Compression Test (TCT)
- Cup Draw Test (CDT)
Scratch and Slider Tests

a) Ball scratching test
[Carlsson et al. 2001]

b) Slider-on-sheet test
[Heide et al. 2003]
Strip Reduction Test

a) Strip reduction test
[Olsson et al. 2004]

b) Cross sectional view
[Olsson et al. 2004]
Strip Draw Tests

a) Strip draw test
[Vermerulien et al. 2001]

b) Draw bead simulator for galling
[Vermerulien et al. 2001]
The Twist Compression Test (TCT)

The tool is rotated under axial force. The torque is measured. The COF is calculated in real time.
Deep drawing test was used successfully for evaluating lubricants by various European manufacturers. CPF is further developing this test for quantitative ranking of lubricants.
As blank holder pressure ($P_b$) increases, frictional stress ($\tau$) increases based on Coulomb’s law.

$$\tau = \mu \cdot P_b$$

where $\tau$ = the frictional shear stress
$\mu$ = the coefficient of friction
$P_b$ = the blank holder pressure

Coulomb’s law
Cup Drawing Test (CDT)

Performance Evaluation Criteria:

• The max. drawing load attained
• The max. applicable blank holder force without failure of the cup
• Measurement of draw-in length, $L_d$, or perimeter of flange in a drawn cup
• Evaluation of lubricant build-up on the die for dry film lubricant
Lubricants are ranked based on the highest constant BHF that can be applied in the deep drawing before the cup fails.

Load-stroke curves of formed vs. fractured cups

BHF = 50 tons
Test speed = 65 mm/sec
FE (Finite Element) simulation of cup drawing

- Temperature distribution at the final drawn cup

(Sheet material : DP590 and Thickness=1.24 mm)
[FEM Code: DEFORM-2D]
Draw-in length for various lubes tested under different Blank Holder Force, BHF (metric tons)
Summary
Trends in Lightweighting

• To increase crush resistance and to improve fuel consumption OEM’s are using high strength steels (AHSS) and Al alloys (Hot Stamping of Mn-B steels, AHSS, use of servo drive presses, cold and warm forming of Al alloys)

• This trend presents new challenges and opportunities for suppliers of stamping lubricants and additives

• Tests that are practical and emulate production conditions are needed to evaluate new lubricants/additives for new materials
Summary / Evaluation of Lubricants and Additives

• Laboratory tests used to evaluate the performance of lubricants (and additives) must emulate the production conditions at material/tool interface (i.e. pressure, relative velocity, temperature, surface/coating conditions)

• Several tests are available for rapid and preliminary evaluation of lubricants (twist compression, strip draw, stamping lubricant tester, etc.)

• Cup Draw Test, conducted to emulate the interface conditions (pressure, velocity, temperature) encountered in production, gives best results in evaluating the lubricity of various lubricants
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Non-proprietary information can be found at web site:
www.ercnsm.org
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THANK YOU!