Evaluation of tribosystems for sheet metal forming

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Summary:

Focus on phasing out environmentally hazardous lubricants has led to extensive experimental testing of tribosystems. Multi-stroke testing is used to evaluate resistance towards lubricant film breakdown. The presentation includes industrial examples of evaluation for deep drawing and ironing based on the simulative tests: bending under tension, strip reduction and drawbead testing. Production conditions are determined by physical measurements and numerical simulations and replicated in laboratory testing. Lubricant film breakdown is evaluated based on measured forces, torque, roughness and visual inspection of tool surfaces. Parameter studies in the laboratory are used to give feedback to the production for improvement of tool life or replacement of the tribosystem. The presentation also includes results for severing processes, where four-ball testing and high-temperature pin-on-disc testing are used to evaluate the lubricant ability to bond to the tool and workpiece surfaces. The temperature range at which the lubricant additives are activated is revealed for each lubricant, and a clear distinction of the performance of the different lubricants for a specific punching process is made by comparing the process temperature to the temperature range of activated additives.
Marcel Moghadam, Esmeray Üstüniagiz and Chris Valentin Nielsen

Evaluation of tribosystems for sheet metal forming

Department of Mechanical Engineering
Technical University of Denmark
Environmentally benign tribosystems for sheet metal forming

REACH
(Registration, Evaluation, Authorization, and Restriction of Chemicals)

• Improved protection of human and environmental health

• Restricted use of hazardous chemicals:
  – Acute toxicity
  – Irritants
  – Sensitization
  – Carcinogenicity
  – Genotoxicity
  – Aquatic toxicity
  – Bioaccumulation

• Waste reduction and process optimization for prolonged tool and lubricant life
Two types of evaluations of lubricants

1. Off-line testing of tribosystems with conditions close to production conditions

2. Physical and chemical evaluation of lubricant ability to bond to tool and workpiece surfaces
Off-line testing of tribosystems with conditions close to production conditions
Off-line testing of tribosystems with conditions close to production conditions

Universal Sheet Tribo-tester (UST)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sliding length</td>
<td>0 - 500 mm</td>
</tr>
<tr>
<td>Sliding speed (mm/s)</td>
<td>0 - 150 mm/s</td>
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<tr>
<td>Cycle time (spm)</td>
<td>0 - 95spm</td>
</tr>
<tr>
<td>Load, Axis 1 (kN)</td>
<td>0 - 50 kN</td>
</tr>
<tr>
<td>Load, Axis 2 (kN)</td>
<td>0 - 50 kN</td>
</tr>
<tr>
<td>Load, Axis 3 (kN)</td>
<td>0 - 100 kN</td>
</tr>
</tbody>
</table>
Off-line testing of tribosystems with conditions close to production conditions

Universal Sheet Tribo-tester (UST)

1. Strip drawing with flat dies
2. Draw bead testing
3. Drawing with tangential compression
4. Bending under tension
5. Bending with tangential compression
6. Strip reduction testing
7. Strip-tension testing
8. Hemispherical stretching
Off-line testing of tribosystems with conditions close to production conditions

Off-line testing of tribosystems with conditions close to production conditions

1. Evaluation of production platform
2. Preparing laboratory test
3. Laboratory testing
4. Production testing

Industrial case involving deep drawing: Grundfos A/S

1. Evaluation of production platform

Industrial case involving deep drawing: Grundfos A/S

1. Evaluation of production platform

Industrial case involving deep drawing: Grundfos A/S

2. Preparing laboratory test

Industrial case involving deep drawing: Grundfos A/S

3. Laboratory testing

Industrial case involving deep drawing: Grundfos A/S

4. Production testing
   a) EN 1.4301, Rh
   b) DP 800, F1
   c) DP 800 test die 3
   d) DP 800, F2

Industrial case involving deep drawing: Grundfos A/S

Comparison of laboratory testing and production testing
(1500 strokes with 40 strokes/min)

<table>
<thead>
<tr>
<th>Workpiece material</th>
<th>Lubricant</th>
<th>Lab</th>
<th>Lab</th>
<th>Prod</th>
<th>Prod</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>EN 1.4301</td>
<td></td>
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<td>EN 1.4162</td>
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<td></td>
<td>DP 800</td>
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<td>V4E</td>
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<td>V40</td>
<td></td>
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<tr>
<td>Anticorital 3802-39 S</td>
<td></td>
<td>Prod</td>
<td>Prod</td>
<td></td>
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<tr>
<td>Anticorital PLS 100 T</td>
<td></td>
<td>Lab</td>
<td>Lab</td>
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<tr>
<td>Rhenus SU 166 A</td>
<td></td>
<td>Prod</td>
<td>Prod</td>
<td>Prod</td>
<td>Prod</td>
</tr>
</tbody>
</table>

Industrial case involving ironing: Grundfos A/S

Stainless steel bearing plate for pump hydraulics

1. Deep drawing
2. Reverse drawing
3. Redrawing
4. Punching
5. Collar drawing & ironing

Process route

Industrial case involving ironing: Grundfos A/S

Galling leading to scoring of workpiece surface

Strip material: EN 1.4301
Lubricant: Rhenus 722086

Industrial case involving ironing: Grundfos A/S

Industrial case study: Emission gas recirculation (EGR) component

Material: Steel 1.4301, 1.5mm sheet thickness.

Lubricant: Castrol Iloform BWN 205.

Production method: 1-step stamping operation

Onset of galling at approximately 200 strokes.

Die material: Sleipner, hardened to 60 HRC, polished to an average roughness of approximately 0.05μm.

Possible defects: Fracture, wrinkling, wear on drawbeads

Goal of investigation: Evaluation of the applicability of non-chlorinated lubricants

Industrial case study:
Emission gas recirculation (EGR) component

1. Counter-holder/ejector 5. Blank holder
2. Draw punch 6. Draw cushion
3. Punch holder 7. Top plate
4. Forming die 8. Press bed

Industrial case study: Emission gas recirculation (EGR) component

ATOS Triple Scan
MV560 lens setup
3mm reference points

Industrial case study:
Emission gas recirculation (EGR) component

Initial drawbead geometry

Drawbead geometry after die tryout

20-30% reduction in thickness for automotive components

Industrial case study:
Emission gas recirculation (EGR) component

Industrial case study: EGR component

Industrial case study: Emission gas recirculation (EGR) component

Physical and chemical evaluation of lubricant ability to bond to tool and workpiece surfaces
Wear and lubrication in punching and blanking operations


Wear and lubrication in punching and blanking operations

Roller lubricators

Lubrication channels

Wear and lubrication in punching and blanking operations

Wear behavior and load bearing capacity

Test material: Ø12.7mm, 100Cr6
Test duration: 60 min.
Rotational speed: 1420 RPM
Test load: 300 N

Test material: Ø12.7mm, 100Cr6
Test duration: 1 min.
Rotational speed: 1420 RPM
Test load: Increased incrementally until welding is achieved

High-temperature pin-on-disc test

Bruker Universal Mechanical Tester Tribolab™

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Disc material</td>
<td>AISI M3:2, hardened to 64 HRC</td>
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<tr>
<td>Surface roughness</td>
<td>Ra = 0.08 μm</td>
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<tr>
<td>Test load</td>
<td>16 N</td>
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<tr>
<td>Rotational velocity</td>
<td>0.2 mm/s</td>
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<tr>
<td>Heating rate</td>
<td>6 °C/min</td>
</tr>
</tbody>
</table>

Temperature development during testing

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