Requirements of Forging Dies for Aluminium

Stuttgart, 14.05.2019
Agenda

• Brief profile of the KIND&CO Group
• Forging of Aluminium
• Tool Steels for Forging of Aluminium
• Conclusion
Globally operating hot-work tool steel specialist

Brief profile of the Kind&Co Group

- Tradition and modernity
- Continuous production process
- Global network
Tradition and modernity: The best of both worlds!

Tradition
- Experience and know-how
- Sustainability
- Commitment and respect in cooperation
- Linked with our home region

Modernity
- Up to date production technology
- Professionalism in service
- Quick decision processes
  - Internationality
Continuous production process: Expertise in every step of the value chain

- Melting
- Forging
- Hardening
- Finishing
- Stocking and sawing
- Machining
- Vacuum hardening

Acquisition

Induction furnace VID

Electro-slag re-melting

Forging furnaces
Forging presses

Hardening and annealing furnaces

Sand-blasting lathing steel control

Autom. storage with integrated saws

Milling lathing drilling etc.

Vacuum furnaces, nitriding, oxidising

Customer
Global network with uniformly high service standards
Forging aluminium – different from steel and complicated

Forging of Aluminium

- Forged aluminium components increasing in transportation
- Forging aluminium different and more difficult than forging steel
- Threefold requirements on tool steels
Forged aluminium components increasingly penetrate transportation industries

• Forged aluminium components contribute to automotive light weight and can today be found in many modern cars.

• Light weight is a permanent topic in the aircraft industry.

• Forged aluminium components cover a wide range of dimensions.
Forging aluminium is different and more complicated than forging steel

- Flow curves characterize the deformability of metallic materials.
- High-strength alloys of the 7 series show significantly higher flow stresses than those of carbon steels.
- Forging of aluminium alloys requires strict control of forging temperatures:
  - 420 – 470 °C for alloys 2014 and 2219,
  - 430 – 480 °C for alloy 6061,
  - 380 – 440 °C for alloy 7075.
- Aluminium tends to stick to the forging dies. Sticking hinders the flow of aluminium resulting in
  - Stresses in the die surfaces
  - Cracks in the forging tools.

Aluminium: measured at 370 °C, strain rate 10 s⁻¹
Steel: measured at 1205 °C, strain rate 10 s⁻¹
Requirements on tool steels are derived from specific deformation behaviour and loads on dies

<table>
<thead>
<tr>
<th>Process parameters</th>
<th>Loads on tools</th>
<th>Requirements</th>
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| • Slow forging process  
• Long contact times  
• Isothermal forging process of aluminium | High thermal loads on dies | High tempering resistance (to prevent softening) |
| Friction/sticking between aluminium and die | Stresses induced in surface of the die | High toughness (to prevent cracks) |
| Hard Al oxide layers | Abrasive wear of the die | High wear resistance |
Successful forging of aluminium requires premium hot-work tool steels

Tool steels for forging of aluminium

- ESR for toughness
- Suitable hot work tool steels for Al forging
- Tailored property combinations of HP1, CS1
- Recommended hardness values
Macro- and microhomogeneity improve significantly through the ESR process, thus the toughness

- The dark discolouration in the core corresponds to the solidification-related enrichment with alloying elements (positive segregation).

- The uniform colouring of the disc describes the high macroscopic homogeneity of the steel.

Kind&Co recommends ESR hot-work tool steels for aluminium forging

<table>
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<tr>
<th>Steel designation</th>
<th>Alloy composition in mass.-%</th>
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<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>USN ESR</td>
<td>0,37</td>
</tr>
<tr>
<td>HP1</td>
<td>0,35</td>
</tr>
<tr>
<td>CS1</td>
<td>0,50</td>
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</tbody>
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- The special grades HP1 and CS1 are based on the principle of highest cleanliness.
- The concentrations of P, S, and trace elements like Al, Cu, and Zn (which are negatively influencing toughness) have been drastically reduced.
- Niobium (Nb) prevents grain growth during heat treatment.
Tempering diagrams prove increased tempering resistance of HP1 and particularly CS1

- Tempering curves help to select tool steels with high tempering resistance.
- Tempering resistance is the resistance of a steel against softening during operation.
- Increasing tempering resistance: USN ESR => HP1 => CS1

<table>
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<tr>
<th>Tempering temperature in °C</th>
<th>Hardness in HRC</th>
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<tbody>
<tr>
<td>400</td>
<td>65</td>
</tr>
<tr>
<td>450</td>
<td>60</td>
</tr>
<tr>
<td>500</td>
<td>60</td>
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<td>550</td>
<td>55</td>
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<tr>
<td>600</td>
<td>55</td>
</tr>
<tr>
<td>650</td>
<td>50</td>
</tr>
<tr>
<td>700</td>
<td>45</td>
</tr>
</tbody>
</table>

- Good standard grade
- Premium grades

Sophisticated Materials Solutions
Additionally HP1 and CS1 provide improved high-temperature strength and increased toughness.

- High-temperature strength Rm measured at 550 °C*
- Reduction of area Z describes toughness, measured at 550 °C*

* All steels hardened + tempered to Rm=1500 MPa
The more demanding the forging the better the die life using premium tool steels HP1 or CS1

- Standard requirements in aluminium forging can be fulfilled with USN ESR at a hardness of 42-46 HRC.
- Special grade HP1 provides improved high-temperature strength and toughness allowing to increase the hardness to 44 – 48 HRC for better wear resistance.
- Special grade CS1 is characterized by a unique combination of very high high-temperature strength and toughness allowing a hardness range of 44 – 48 HRC for further improvement in wear resistance.
Conclusion

- Forged aluminium parts increasingly penetrate the transportation industries, where ever light weight design provides benefits.
- Aluminium poses more challenges to forges than steel due to higher flow stresses and sticking.
- Therefore, dies for aluminium forging require hot-work tool steels with sufficient tempering resistance, high-temperature strength, and increased toughness.
- For maximum toughness, Kind&Co recommends hot-work tool steels produced via Electro-Slag-Remelting.
  - USN ESR should be used for standard applications (small series depth, less complex geometry).
  - HP1 offers improved high-temperature strength and toughness for high volume parts and/or complex geometries.
  - E.g., for small geometric tolerances in the forging, we recommend the newly developed grade CS1 because of even better wear resistance and highest toughness.
Thank you for your attention!

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