



Requirements of Forging Dies for Aluminium

Stuttgart, 14.05.2019

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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!



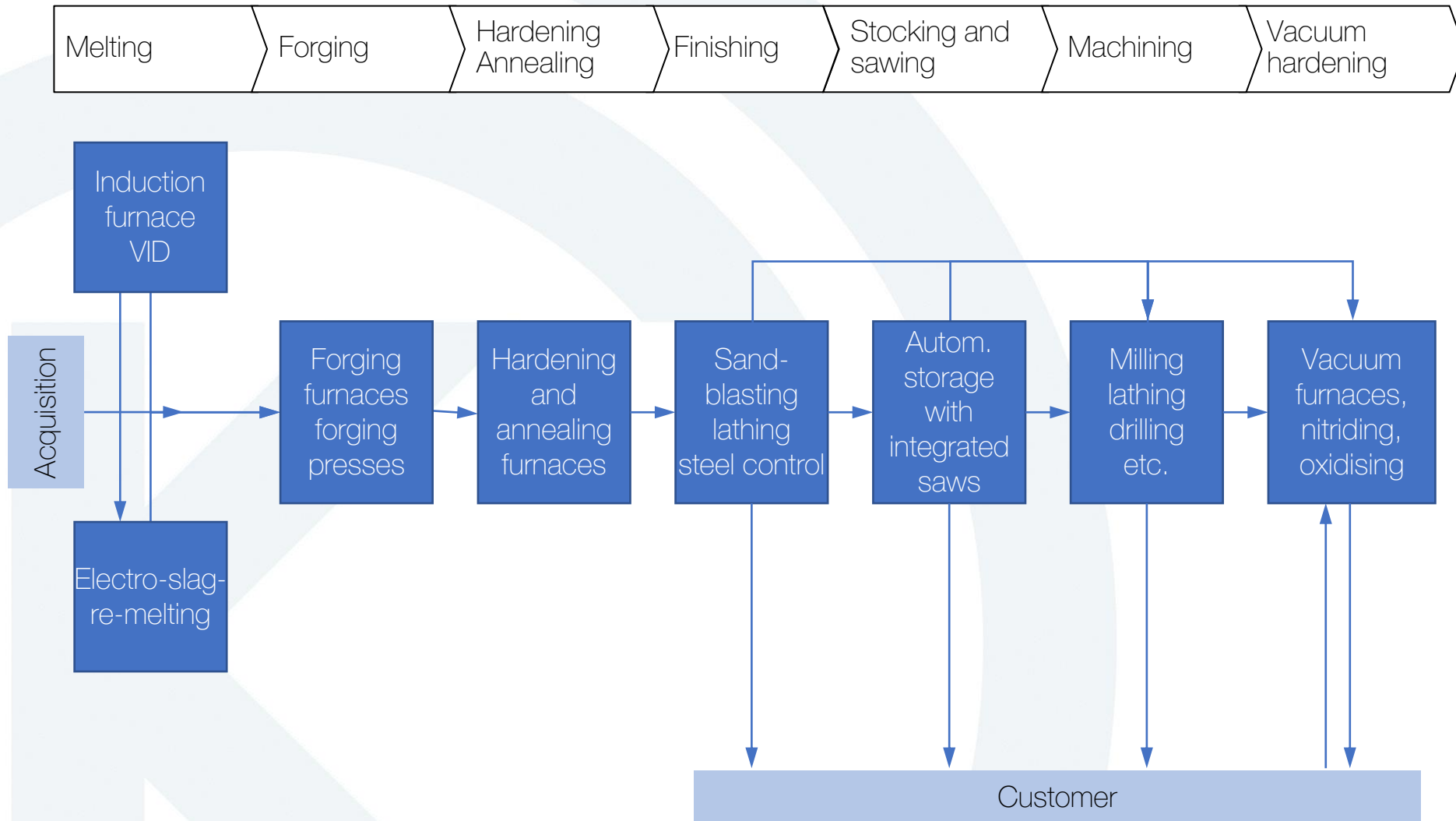
Tradition

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

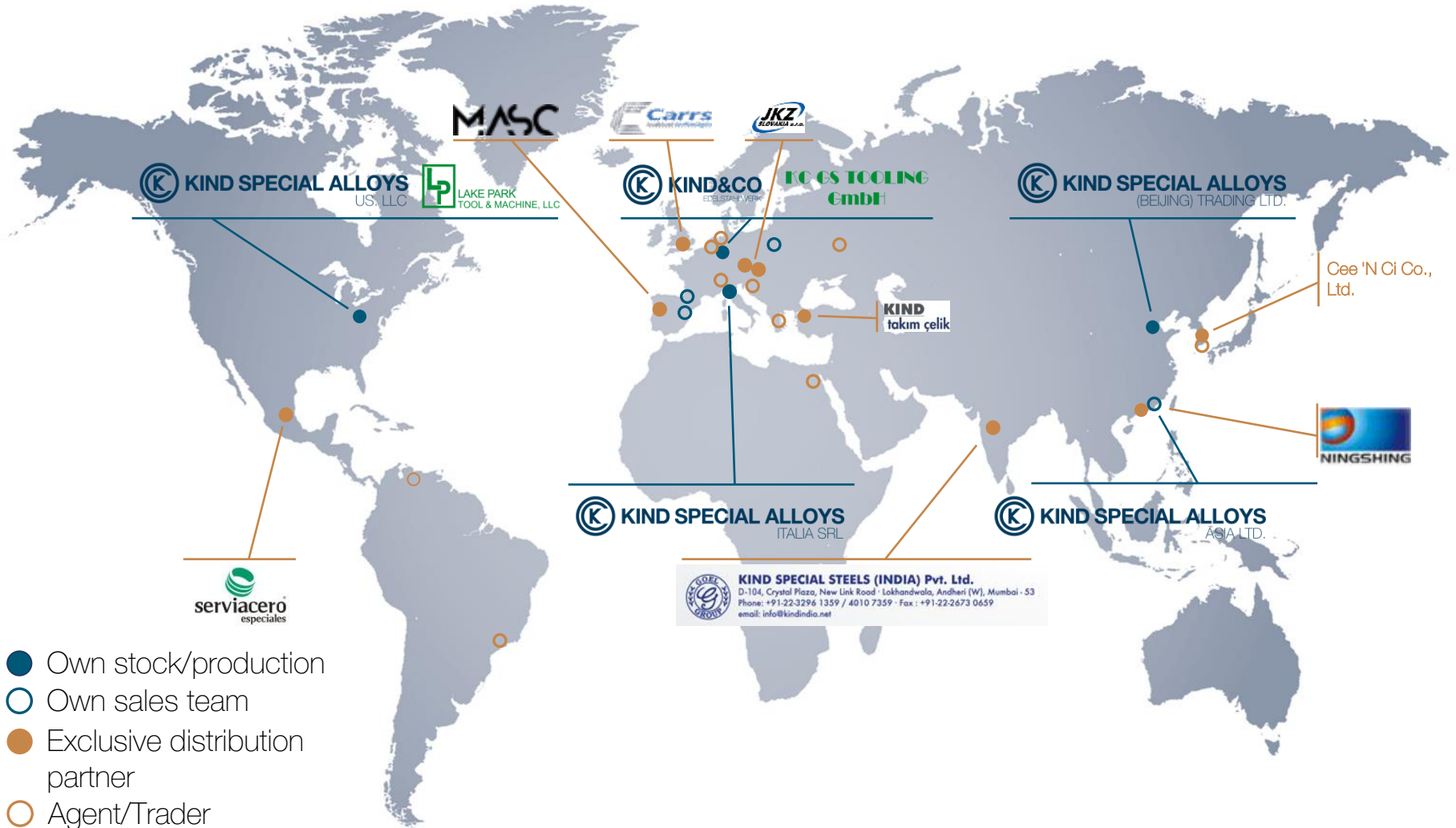
Modernity

- Up to date production technology
 - Professionalism in service
 - Quick decision processes
 - Internationality

Continuous production process: Expertise in every step of the value chain



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

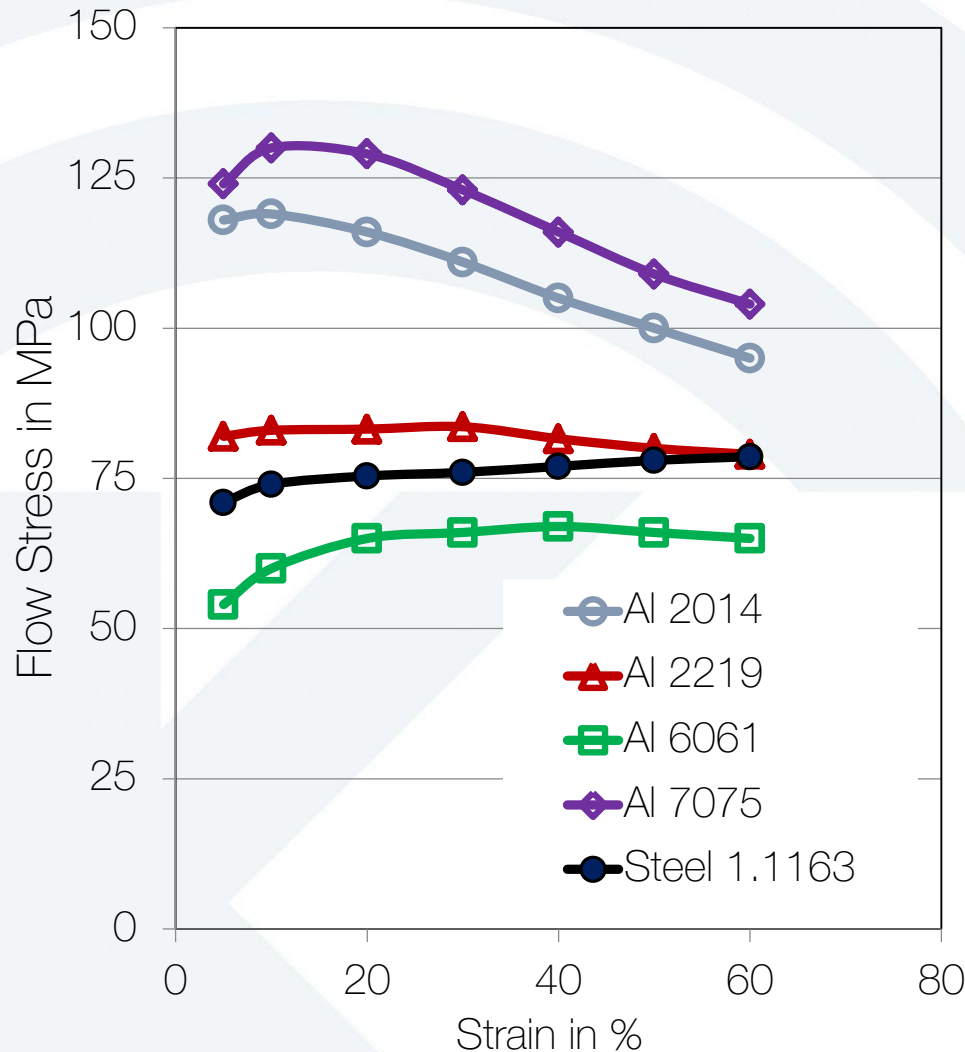


- Forged aluminium components contribute to automotive light weight and can today be found in many modern cars.



- 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}

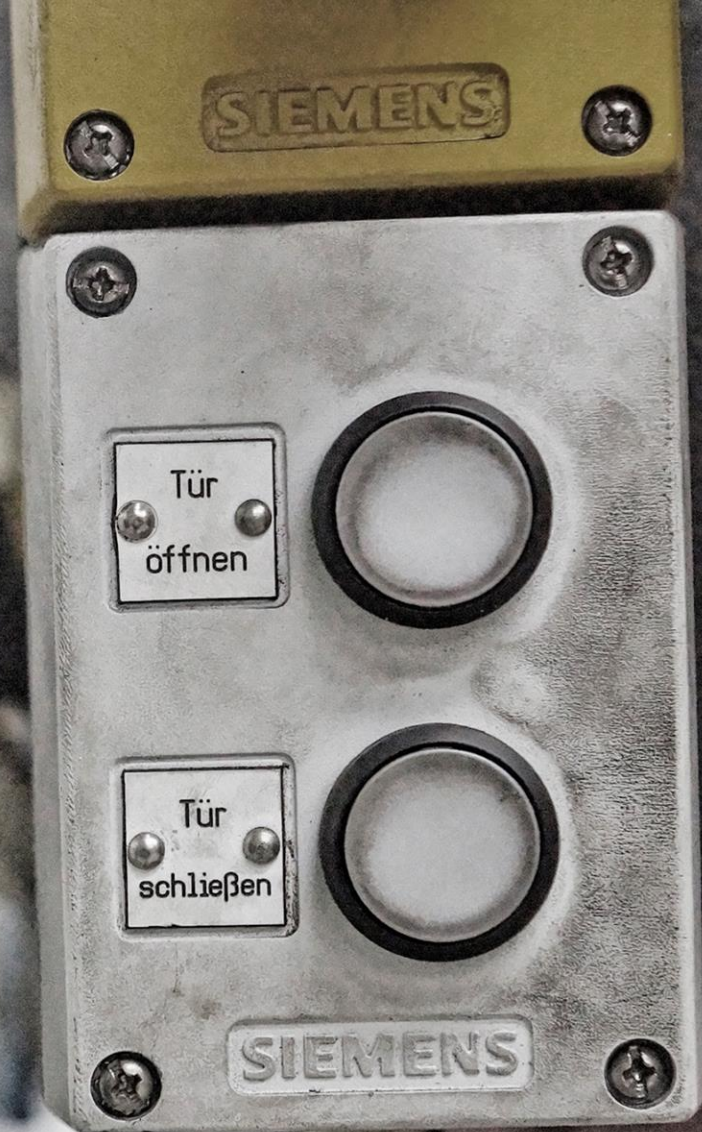
Requirements on tool steels are derived from specific deformation behaviour and loads on dies

| Process parameters | Loads on tools | Requirements |
|---|--|--|
| <ul style="list-style-type: none">• 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 |

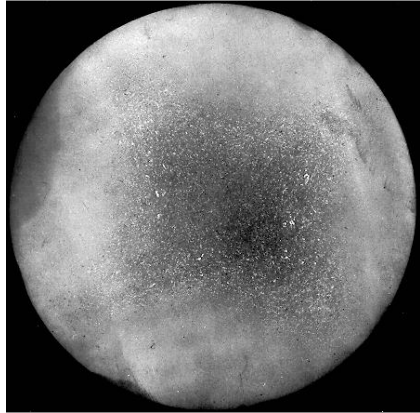
Successful forging of aluminium requires premium hot-work tool steels

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

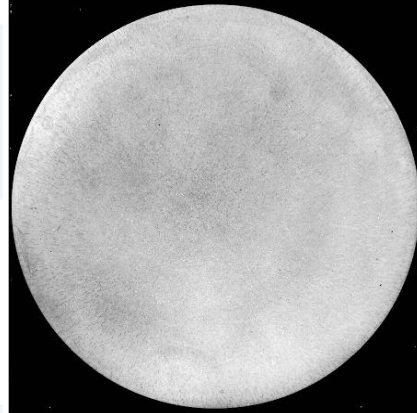


Macro- and microhomogeneity improve significantly through the ESR process, thus the toughness



Not remelted hot-work tool steel (macrostructure).

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

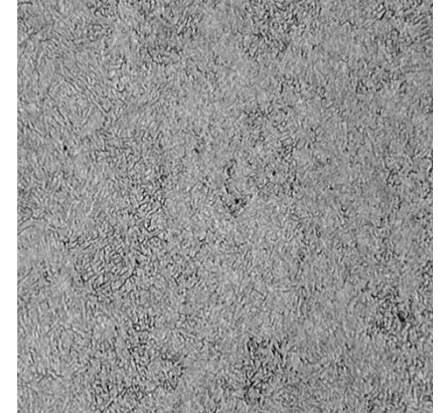


Remelted hot-work tool steel (macrostructure).

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



Banding in a hot-work tool steel not remelted (microstructure)



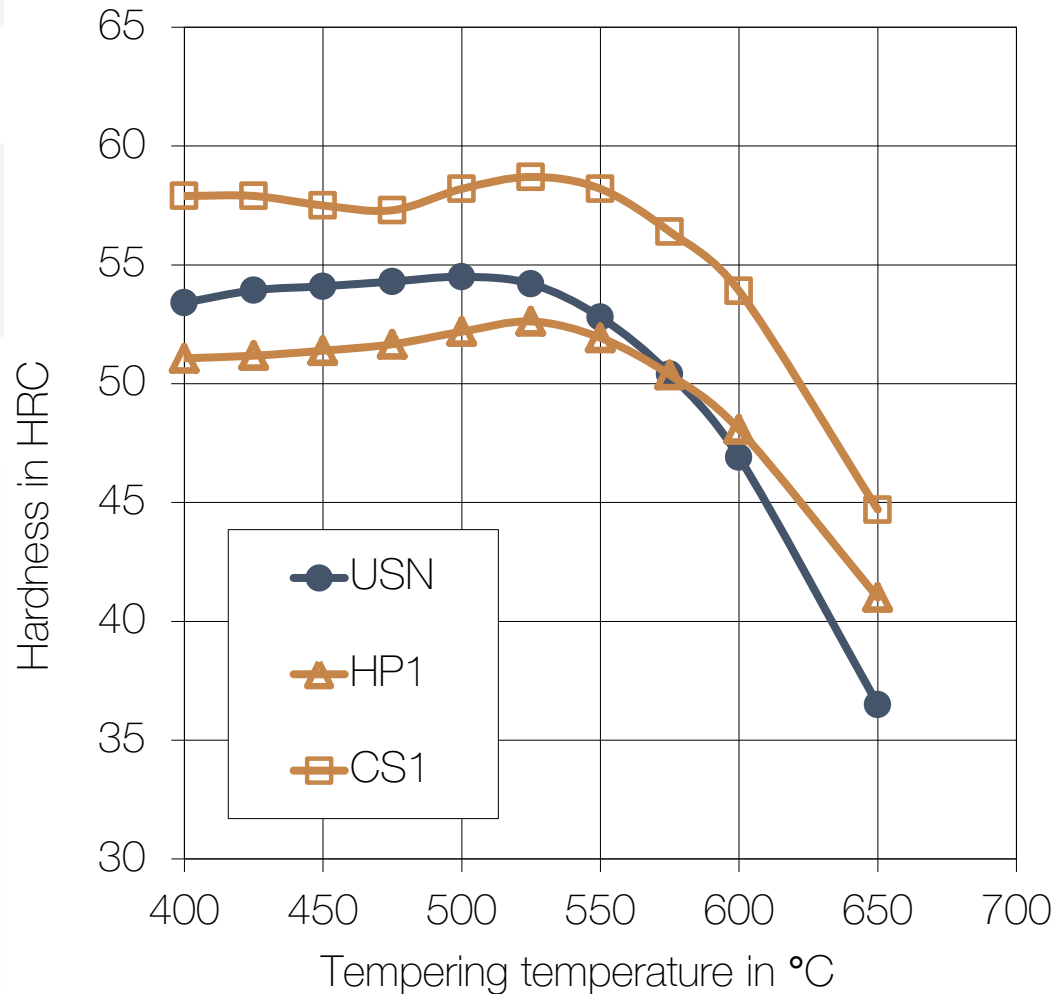
High microhomogeneity in a remelted hot work tool steel (microstructure)

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

| Steel designation | | | Alloy composition in mass.-% | | | | | | |
|-------------------|----------|------|------------------------------|------|------|------|------|------|----|
| Brand | Mat.-No. | AISI | C | Si | Mn | Cr | Mo | V | Nb |
| USN ESR | 1.2343 | H11 | 0,37 | 1,00 | 0,40 | 5,20 | 1,20 | 0,40 | - |
| HP1 | - | - | 0,35 | 0,20 | 0,30 | 5,20 | 1,40 | 0,55 | + |
| CS1 | - | - | 0,50 | 0,30 | 0,40 | 5,00 | 1,90 | 0,55 | + |

- 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.

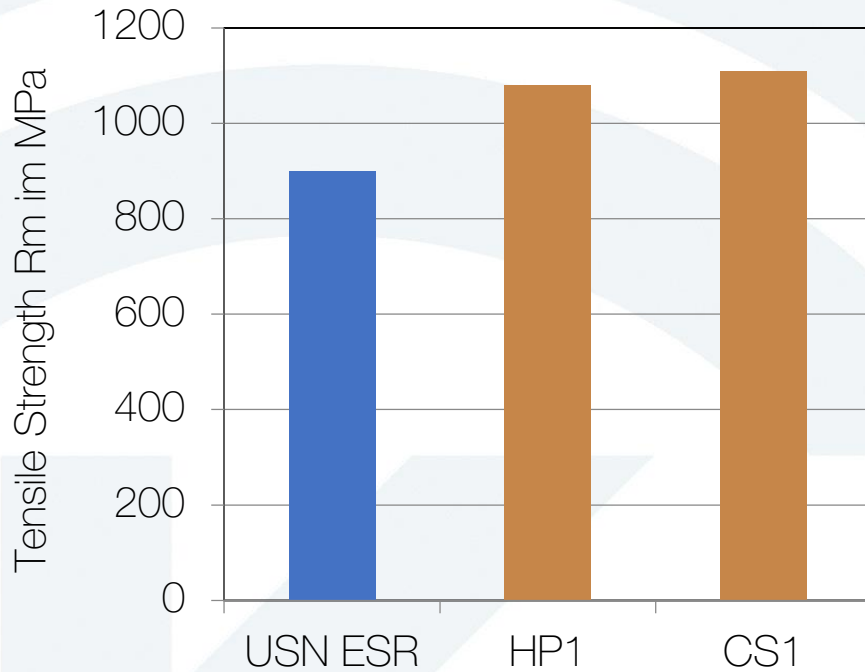
Tempering diagrams prove increased tempering resistance of HP1 and particularly CS1



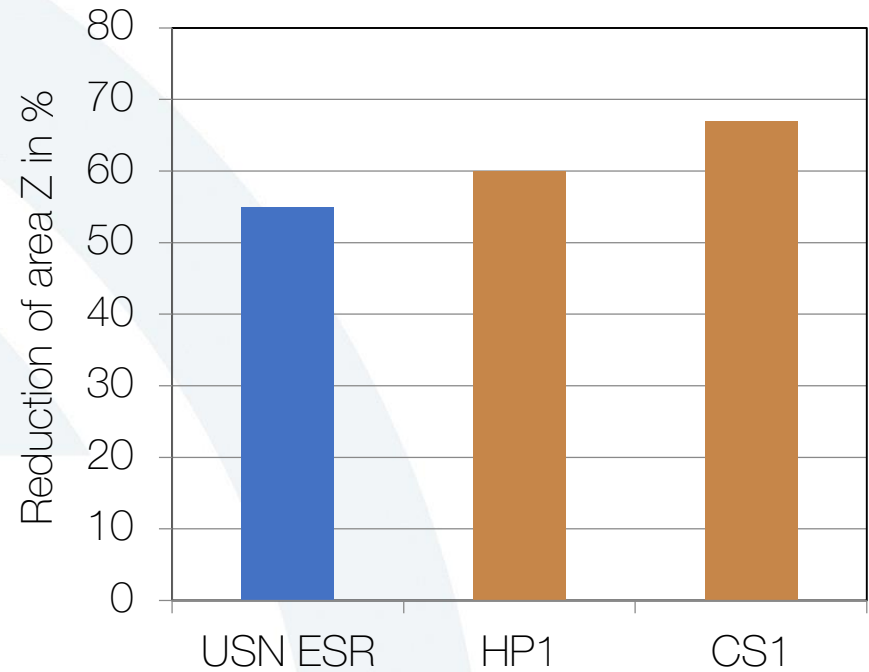
- Tempering curves help to select tool steels with high tempering resistance.
- Tempering resistance is the resistance of a steel against softening during operation.
- Increasing tempering resistance:
USN ESR => HP1 => CS1

● Good standard grade
□ △ Premium grades

Additionally HP1 and CS1 provide improved high-temperature strength and increased toughness



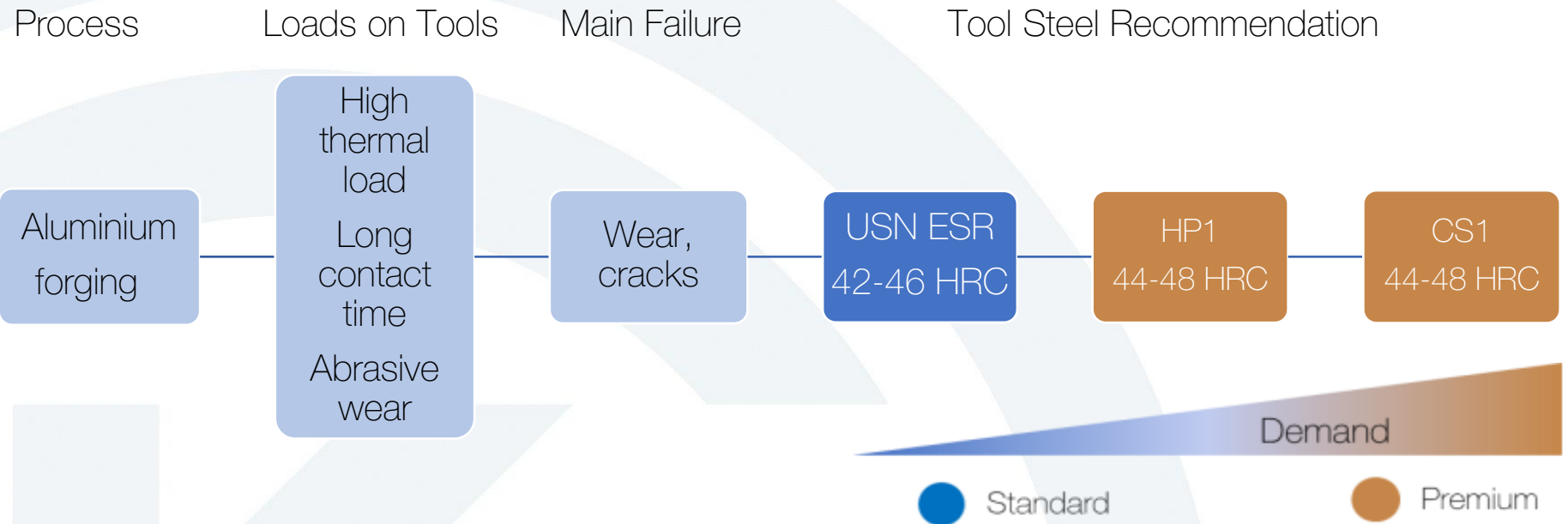
- High-temperature strength R_m measured at 550 °C*



- Reduction of area Z describes toughness, measured at 550 °C*

* All steels hardened + tempered to $R_m=1500$ 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.

- Forged aluminium parts increasingly penetrate the transportation industries, wherever 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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