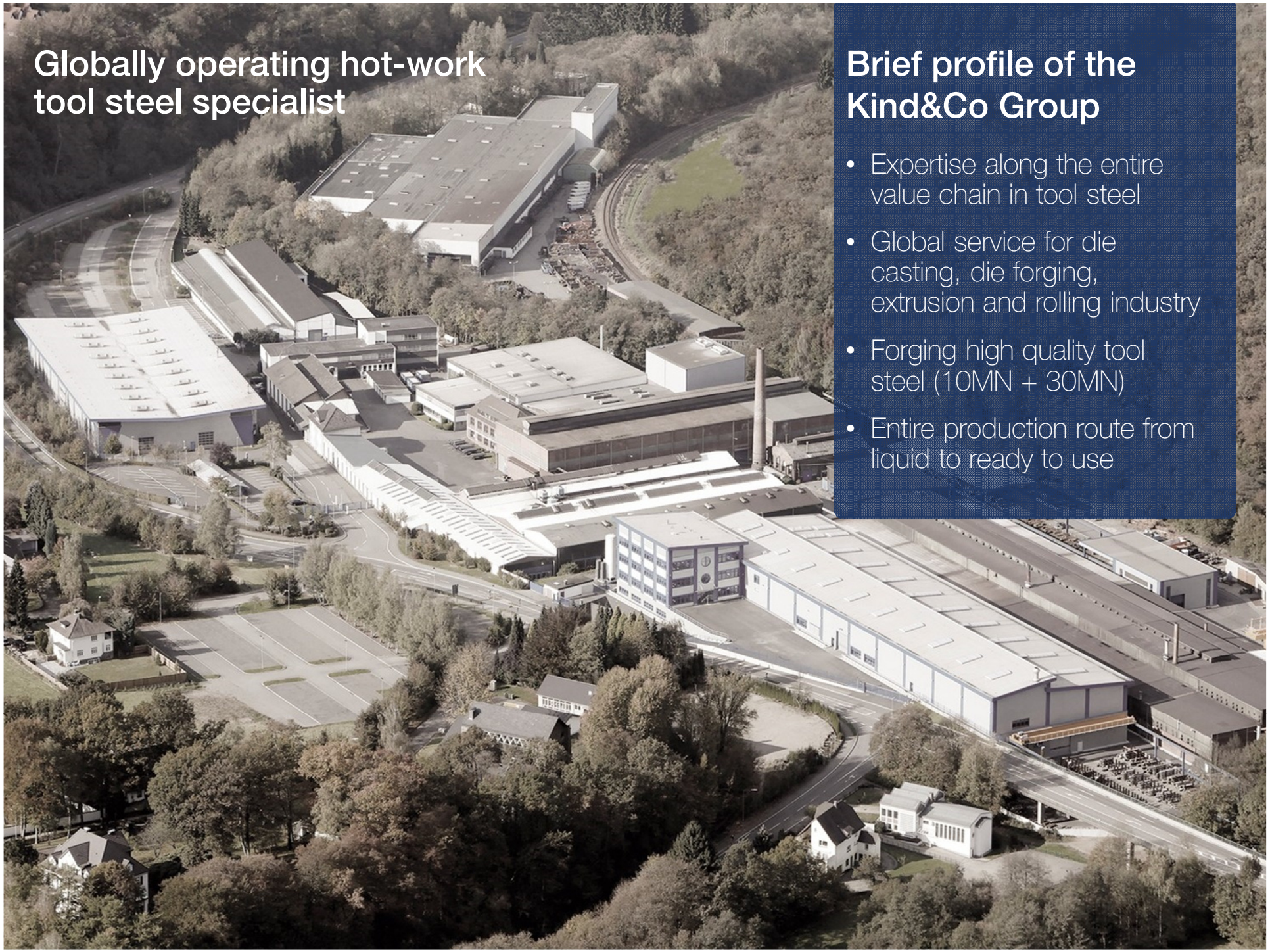
KIND&CO
EDELSTAHLWERK

Best practice for copper alloy extrusion toolings

IWCC Technical Seminar, Milan, February 2024

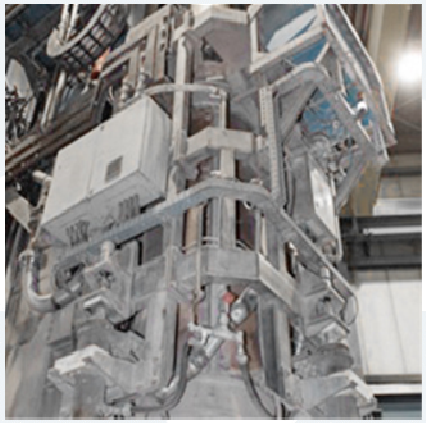


Brief profile of the Kind&Co Group

- Expertise along the entire value chain in tool steel
- Global service for die casting, die forging, extrusion and rolling industry
- Forging high quality tool steel (10MN + 30MN)
- Entire production route from liquid to ready to use

Kind&Co operates and provides expertise in every step of the value chain

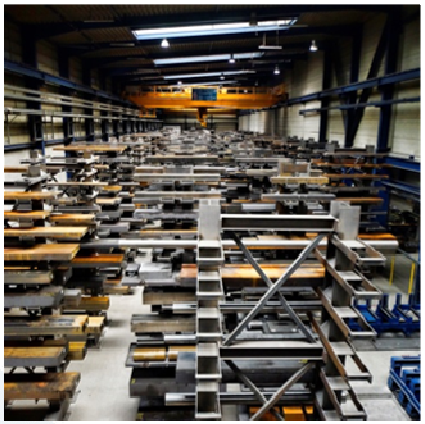
Melting
ESR-Remelting



Forging

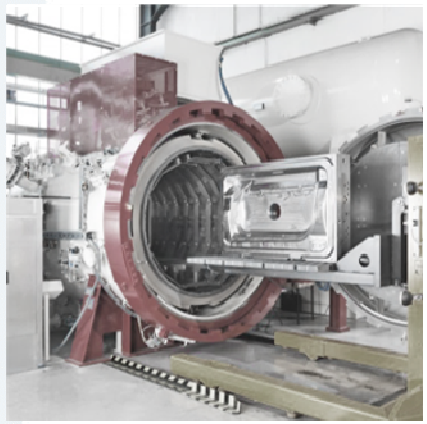
Hardening
Annealing

Stocking and
sawing

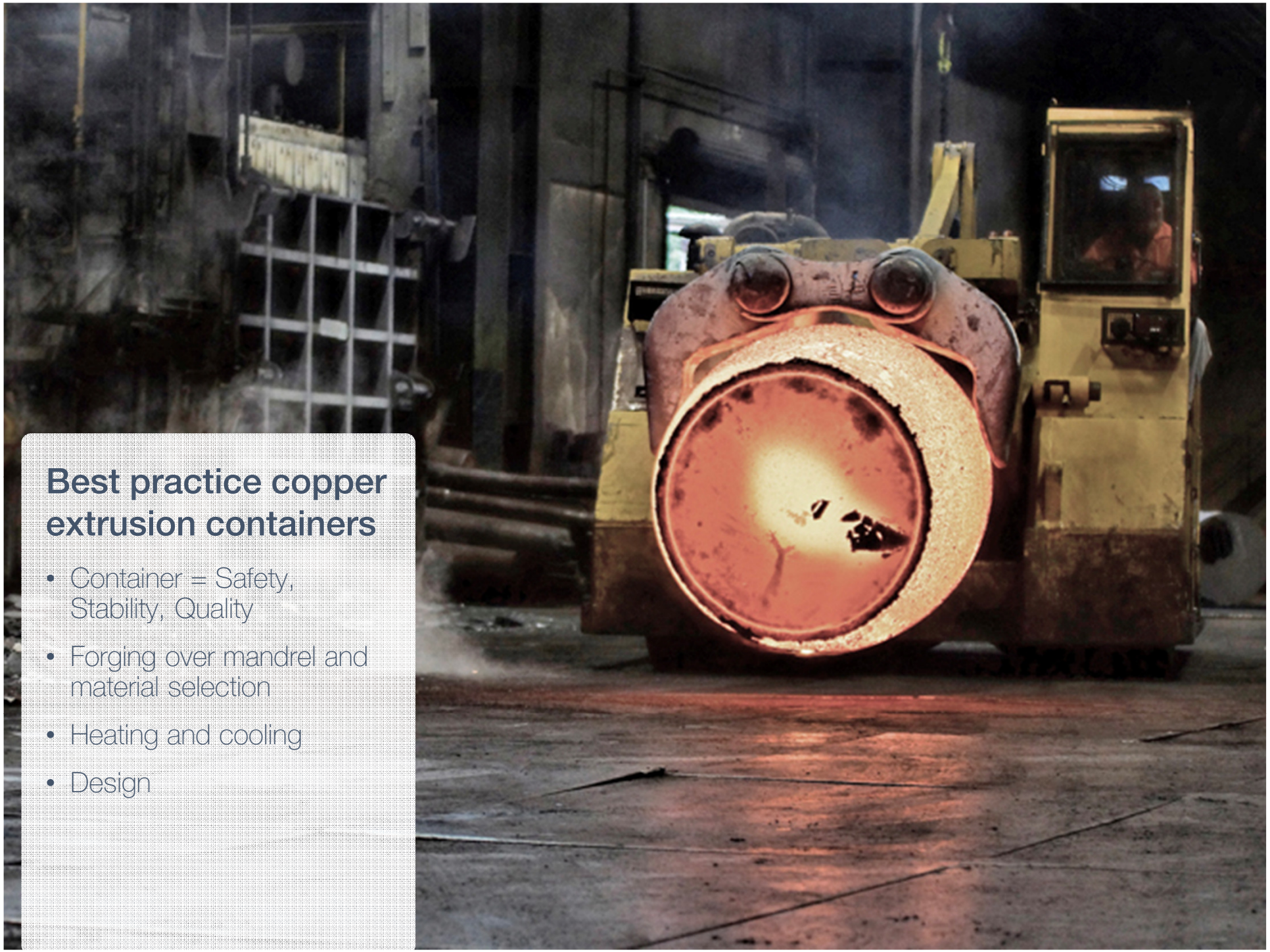


Machining

Vacuum hardening
Nitriding/annealing



Kind&Co Group: A global network with uniformly high service standards



Best practice copper extrusion containers

- Container = Safety, Stability, Quality
- Forging over mandrel and material selection
- Heating and cooling
- Design

The container is jointly responsible for work safety, process stability and product quality

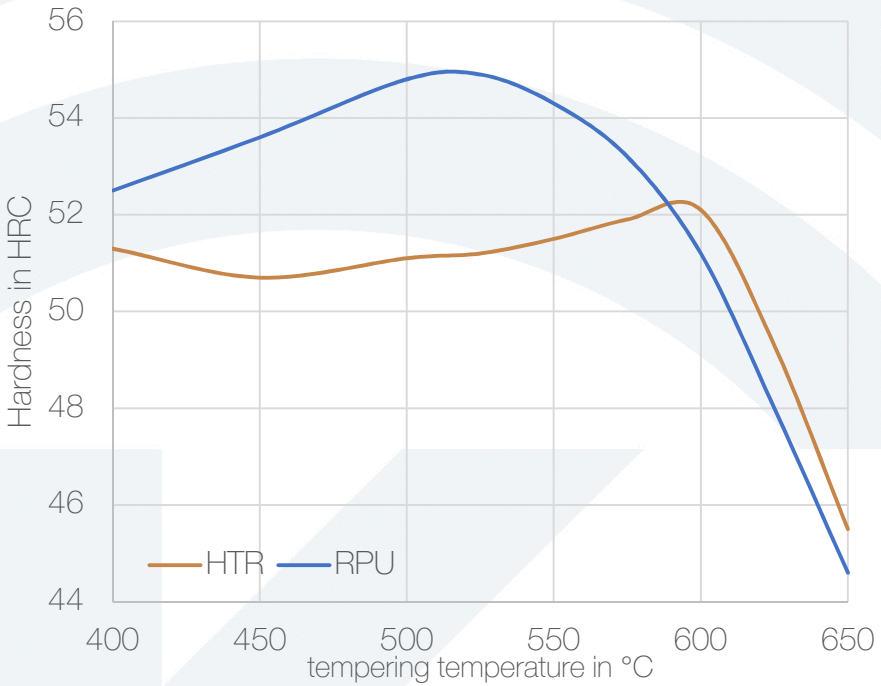
- In an extrusion line the container forms the heart of the die package.
- In the container and in the extrusion die the entire forming to produce the desired profile and thus the adjustment of product properties and product shape takes place.
- Tasks of the container are:
  - Work safety: The safe absorption of the applied extrusion pressure or the safe prevention of total failure due to cracks or plastic deformation during production.
  - Process stability: Maintaining a bore that is as cylindrical and dimensionally stable as possible over the course of the extrusion process, but also over several thousand cycles.
  - Ensuring product quality: Good and consistent product quality requires stable conditions and a quasi-continuous process, in particular constant thermal conditions during the extrusion cycle and over many cycles.

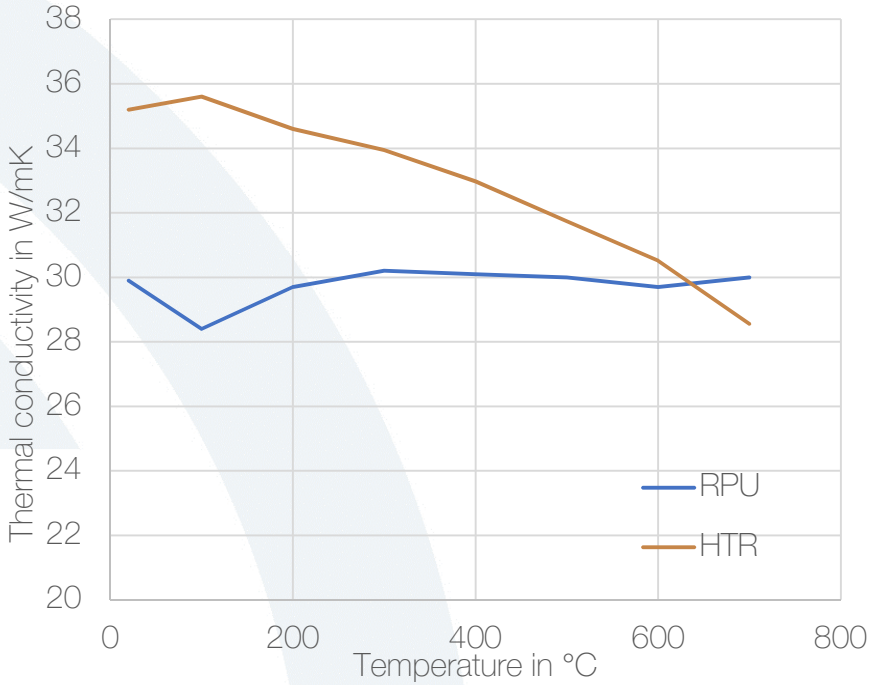
Kind&Co mantles for extrusion container are forged over the mandrel

Mantle forged over the mandrel

- The forging strategy has significant influence on the performance of a mantle.
- liners larger than 8" bore diameter are individually forged over a mandrel.
- This results in higher deformation of the mantle wall which has a positive effect on the microstructure and thus on toughness.

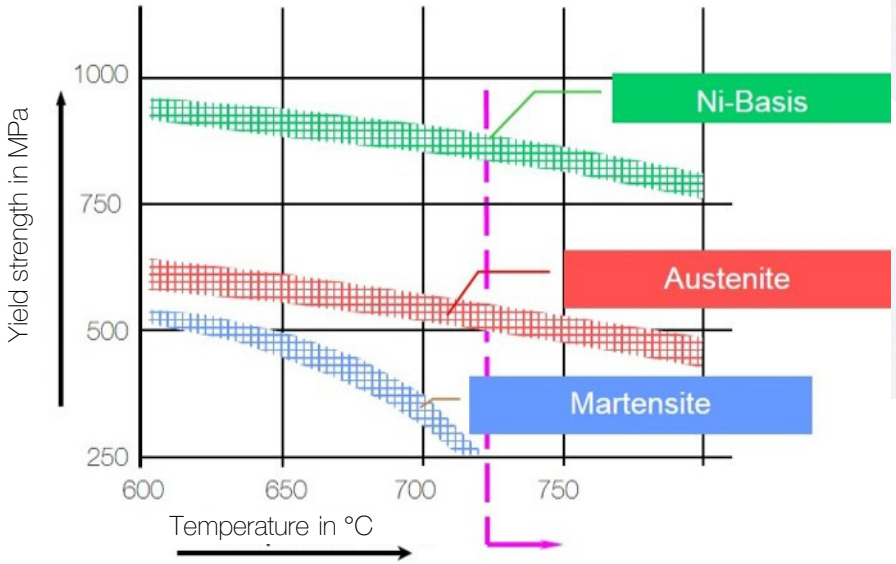
Heavy metal intermediate liners perform best if they are made of HTR

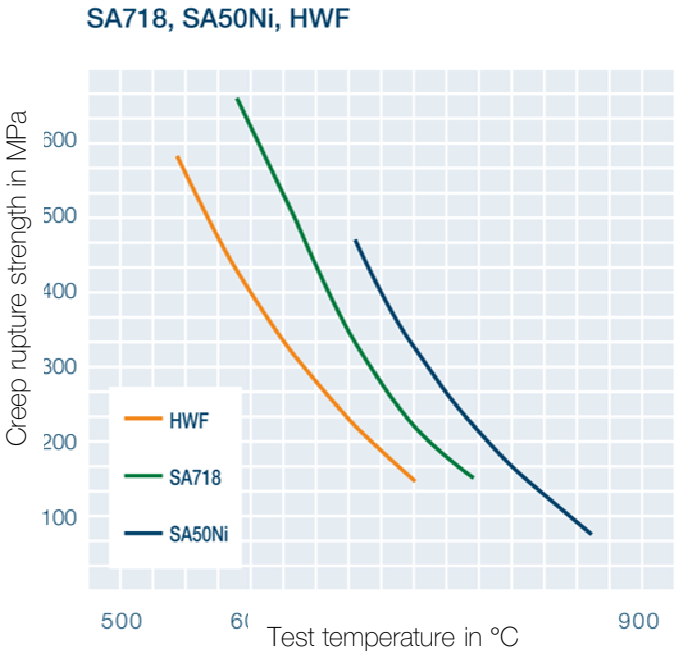




- The high thermal loads require high toughness and high-temperature strength.
- If the standard RPU material is used, the intermediate liner must also be replaced with every 2nd change of the inner liner.
- The premium grade HTR with significantly higher high-temperature strength and improved thermal conductivity achieves lifetime of 3 to 4 inner liners.
- When using a nickel-based inner liner (SA718) with its significantly better service life, the premium grade HTR is recommended for the intermediate liner in any case.
- In general Kind&Co recommends intermediate liners with a strength of 1250 – 1400 MPa.

For heavy metal extrusions the inner liner made of SA718 is the best solution





- The inner liner is exposed to high pressing temperatures of 700 - 1050°C (brass to cupronickel) at moderate pressing pressures.
- At these temperatures only austenitic materials such as HWF and SA718 can be used.
- SA718 generally offers a 2-3 times longer lifetime compared to HWF.
- Austenitic materials are provided solution annealed and aged for heat treatment. The material HWF reaches a strength of 1000-1150 MPa. The Ni-based alloy SA718 offers the advantage of a higher strength of 1250-1400 MPa.
- Due to its higher high-temperature strength the SA718 inner liner shows better dimensional stability at the conical sealing face to the tool package and thus a better performance.
- The dimensional accuracy of the SA718 inner liner bore remains almost cylindrical over a high number of cycles. Radial deformation and waisting effects, which occur with HWF inner liners due to the coefficient of thermal expansion, are hardly present.
- The wear pattern of the SA718 inner liner shows a finer distributed network of cracks with the consequence that the risk of undesirable contamination on the pressed product is lower.

Better profile quality due to less heat crack network with SA718 inner liner

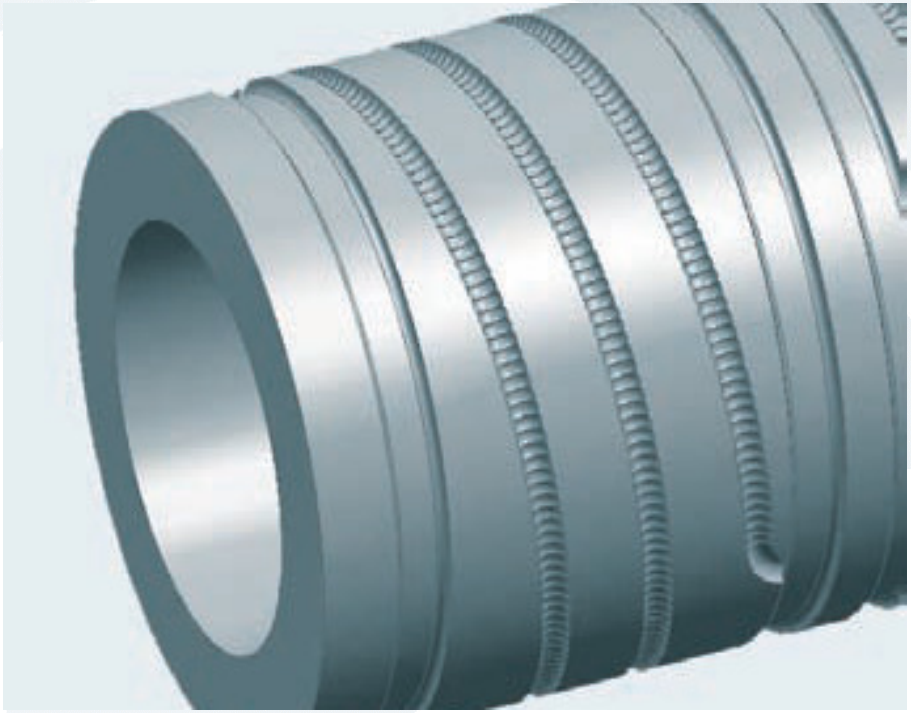
HWF inner liner after approx. 30.000 pressings

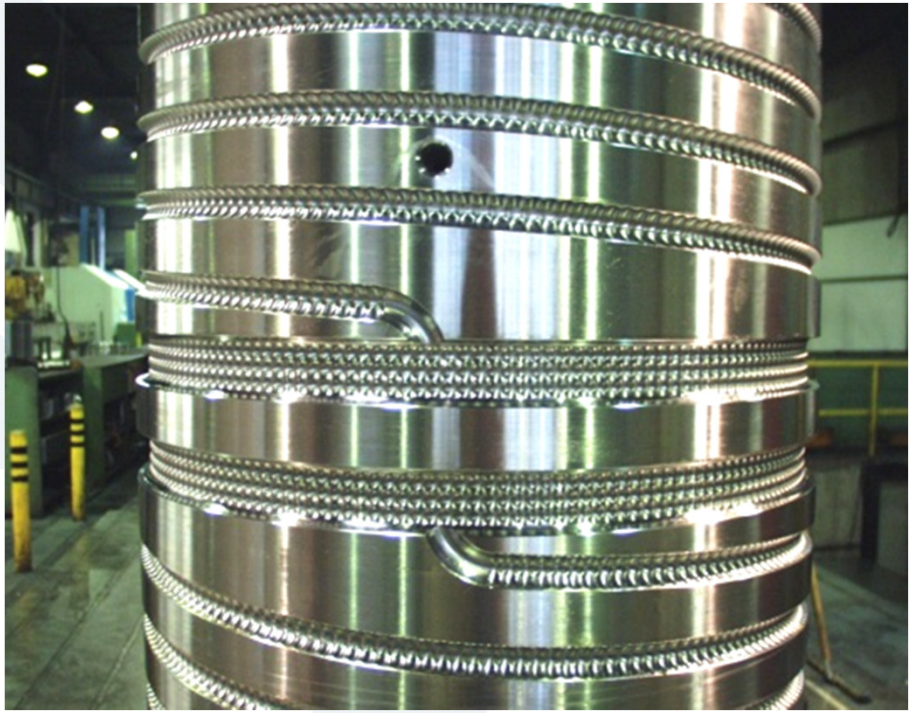
- Bore surface has a strong heat crack network and is heavily contaminated with pressed material and oxidation residues
- Bore diameter is strongly radially deformed
- Inner sleeve cone is severely damaged
- Inner sleeve can no longer be used

SA718 inner sleeve after approx. 100.000 pressings

- Bore surface has only a slight heat crack network, hardly any adhesions
- Bore diameter from punch to die side cylindrical
- Inner sleeve taper slightly damaged
- Inner sleeve can still be used

WT-cooling: Intensification of the cooling effect by turbulent air flow

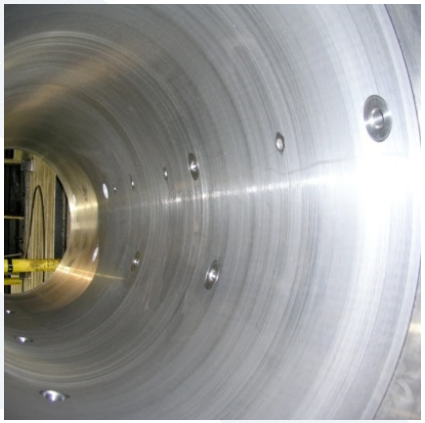




- A special construction of the air cooling is the WT cooling. Here, a wave-like cooling spiral is produced by milling.
- This type of cooling spiral creates a turbulent air flow in which the air in the cooling channel is better mixed. There is thus a higher temperature gradient on the wall of the duct which leads to the increased cooling effect.
- Temperature peaks are thus reduced even more effectively.
- If necessary the wave-shaped cooling spiral can also be applied only locally.

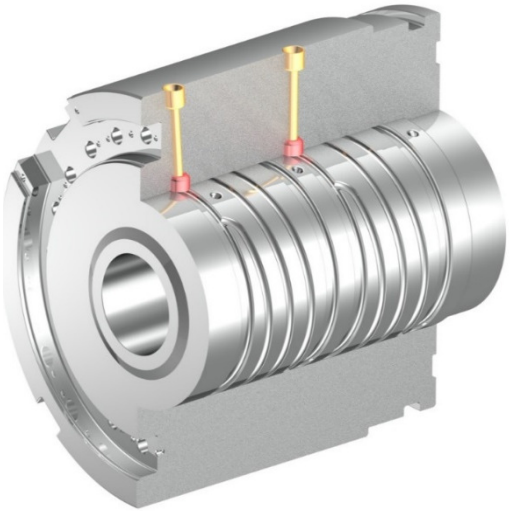
Air Protect (AP) system reliably prevents contact of the cooling air with the container mantle

Cracks in longitudinal direction of the mantle bore



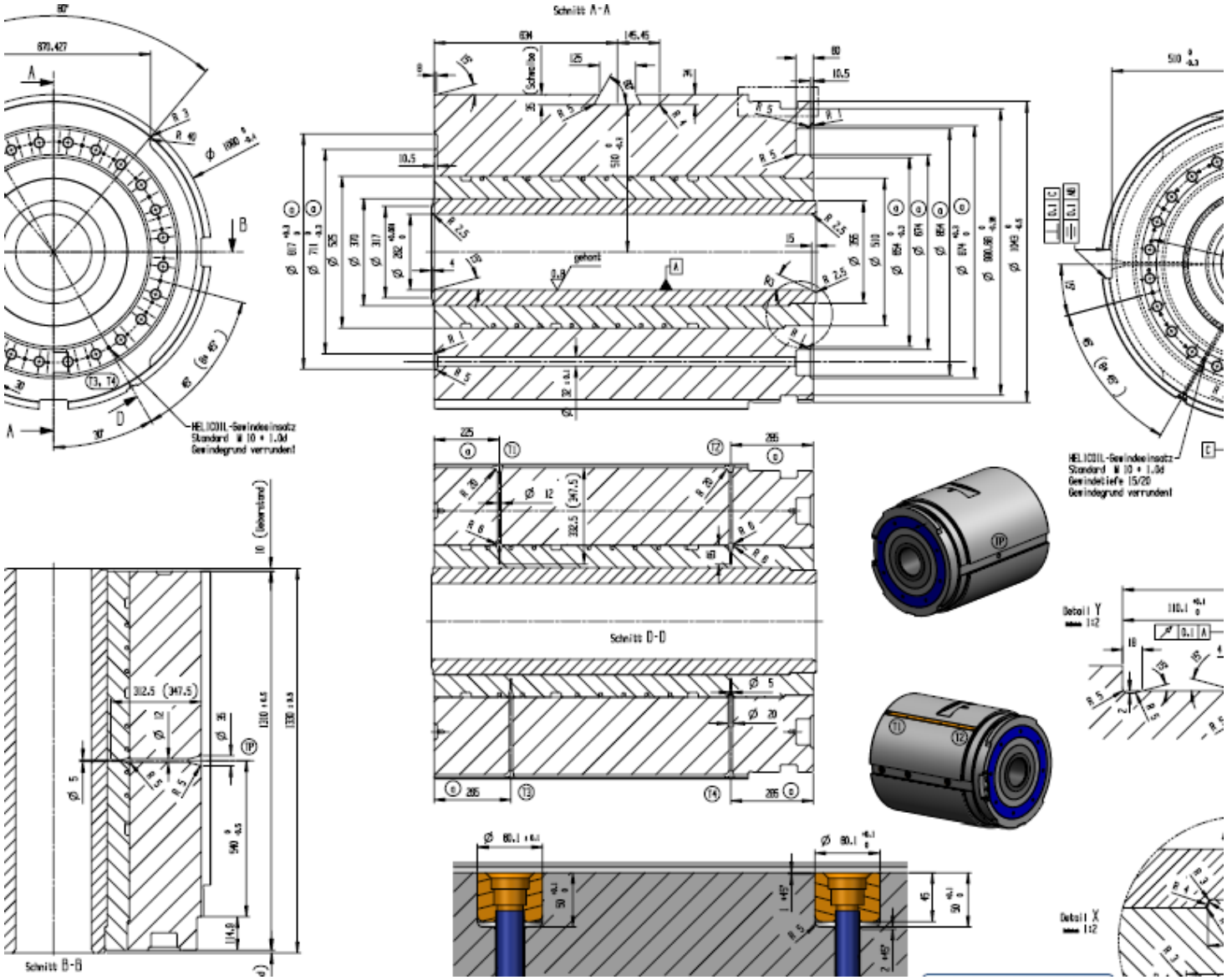
Container, AirProtect system (new)

Container, Air-Protect-System (after use)



- In the past cracks in the mantle bore of air-cooled containers have repeatedly been observed. After detailed investigations, oxidation, corrosion and thermal shock were found to be the cause.
- To eliminate this cause a protective tube can be used for the air inlets, which is shrunk firmly into the mantle and remains there.
- The AP system insulates the preheated mantle from the cold air and prevents thermal shock and corrosion.

Modern design of 3 parts-container combined with premium grades (USN/HTR/SA718) for best performance to extrude copper alloys



Best practice relining process

- Process documentation
- Inspections done
- Shrink-in and -out

Incoming inspection consisting of visual inspection, dimensional inspection, crack inspection

Visual inspection

- Before the work is started according to the P.O., the delivery status of the container is documented.
- Special attention is paid to additional and necessary repairs.

Dimension control

- Important functional dimensions (keyways) are checked.
- If the tolerance on the keyways is exceeded, we suggest welding operation as a repair method and discuss it with the customer.

Crack control by means of boroscope

- Especially the air inlet bores of cooled containers as well as the thermocouple bores of uncooled containers are checked 100% for possible cracks.

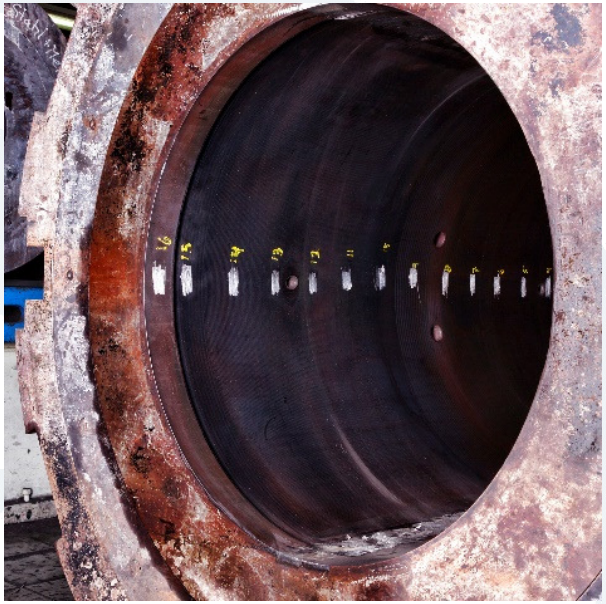
Crack control by means of Magna-Flux testing

- The mantle bore is checked for cracks at the critical cross holes.
- Such cracks are repaired by welding or by installation of an insert to avoid further cracks at these critical areas.

Incoming inspection consisting of visual-, heating-, dimensional-, crack-, and strength inspection

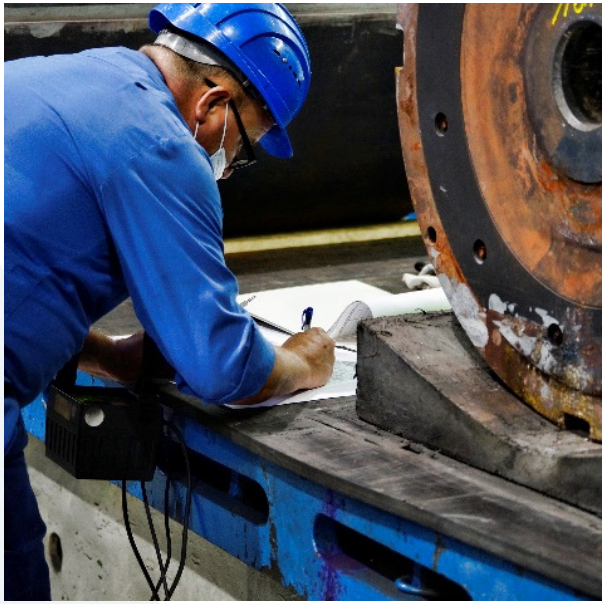
1st heating system control

- Especially after transport residual moisture may be present inside heating elements.
- Therefor the measurement is repeated after shrink-out, if necessary.



Hardness control

- Especially when copper alloys will be extruded, container can soften.
- For safe use, the hardness levels are checked every 100mm.
- All measured values should be above 1000MPa.



Incoming report

- The incoming report shows the condition of the container and may shows deviations from the P.O..
- Based on this report, necessary additional work has to be discussed with the customer.

The safe and reliable thermal shrink-out of liners requires years of experience and know-how in the process

- Container is placed in a furnace to preheat to approx. 350 - 400°C for several hours.
- According to a fixed rhythm, several containers are preheated at the same time and then shrunk out one after the other.

- Preheated container is held above the shrink-out position by means of a hanging device.
- Inner sleeve is flooded with cold water permanently. Over-floating to container mantle has to be avoided.

- After approx. 3 - 15 minutes (depending on the size/length of the container) the inner liner is cooled sufficiently, the inner liner detaches from the shrinkage and can be pulled out of the container vertically by crane.
- After 1-2 days of cooling work can be continued.

Premium stem for heavy metal extrusion

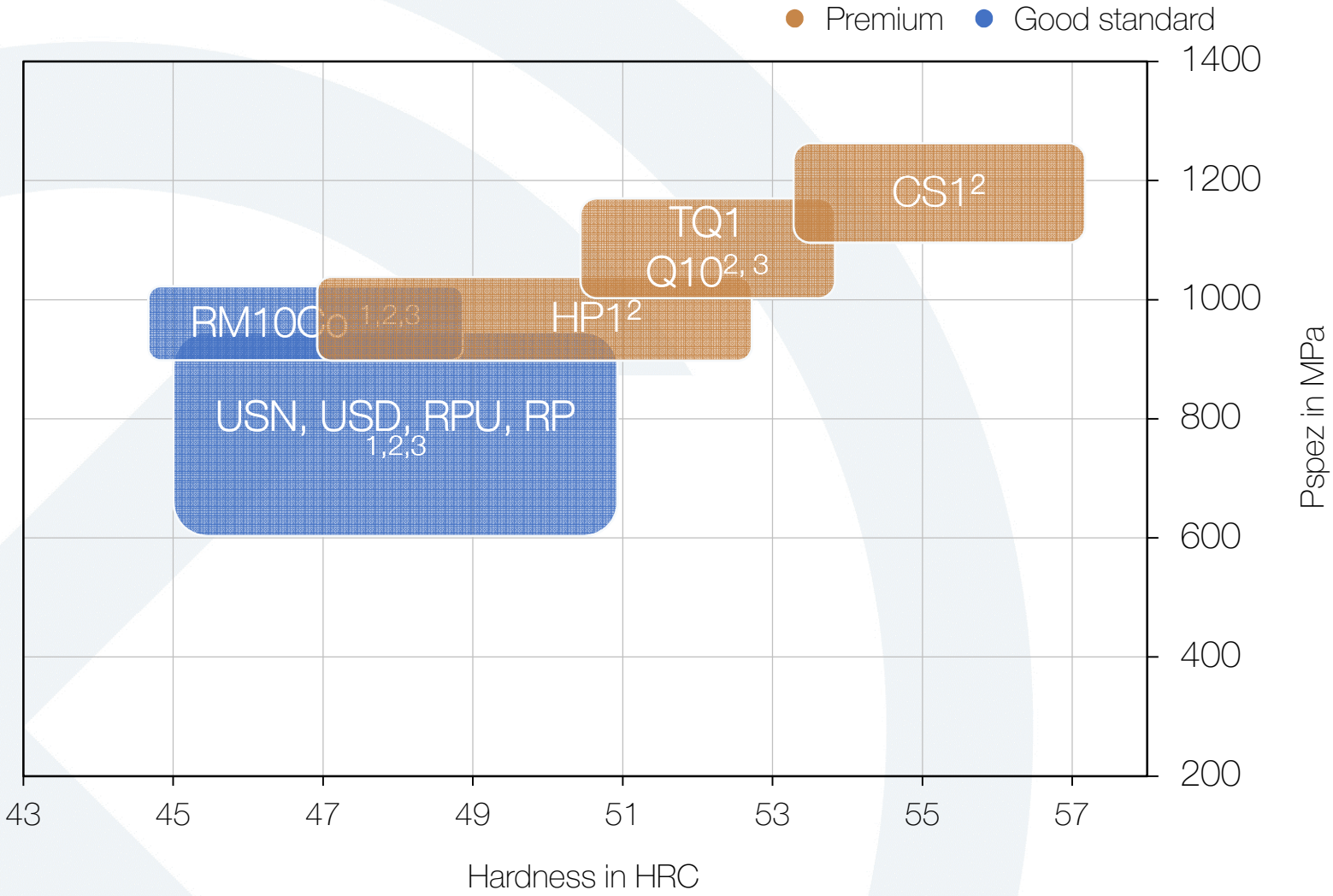
- Selection of premium tool steel based on customer demands
- Individual forgings close to finish dimension
- FEM Analysis to eliminate critical stress area

The range of stem materials: from common hot work tool steels to high-strength premium solutions

Specific pressure load	Brand	Material - No.	Hardness in HRC	Application H = Heavy metal S = Steel extrusion L = Light metal
Low up to 600 MPa	USN	1.2343	45-47	L / H
	USD	1.2344	45-47	L / H
	RP	1.2365	45-47	L / H
	RPU	1.2367	45-47	L / H
High up to 1000 Mpa	USN[1]	1.2343	46-51	L / H
	USD[1]	1.2344	46-51	L / H
	RP[1]	1.2365	46-51	L / H
	RPU[1]	1.2367	46-51	L / H
	RM10Co[1]	1.2888	45-49	H
	Q10	Premium steel	47-53	L / H
	HP1[2]	Premium steel	47-53	L / H / S
	TQ1[2]	Premium steel	51-54	L / H / S
Ultra high up to 1250 Mpa	TQ1[2, 3]	Premium steel	51-54	L / H / S
	CS1[2, 3]	Premium steel	53-57	L / H / S

1 Depending on the dimensions, ESR (electro-slag remelted) steel must be used
2 Only available in ESR version
3 Determination of the stem hardness after evaluation and in consultation with the customer.

Premium grades should be used in the demanding areas with regard to hardness and pressure load



[1] Depending on the dimensions, ESR (electro-slag remelted) steel must be used.
[2] Determination of the stem hardness after evaluation and in consultation with the customer.
[3] Production possibilities are dependent on the diameter
[4] P spec is the specific pressure load

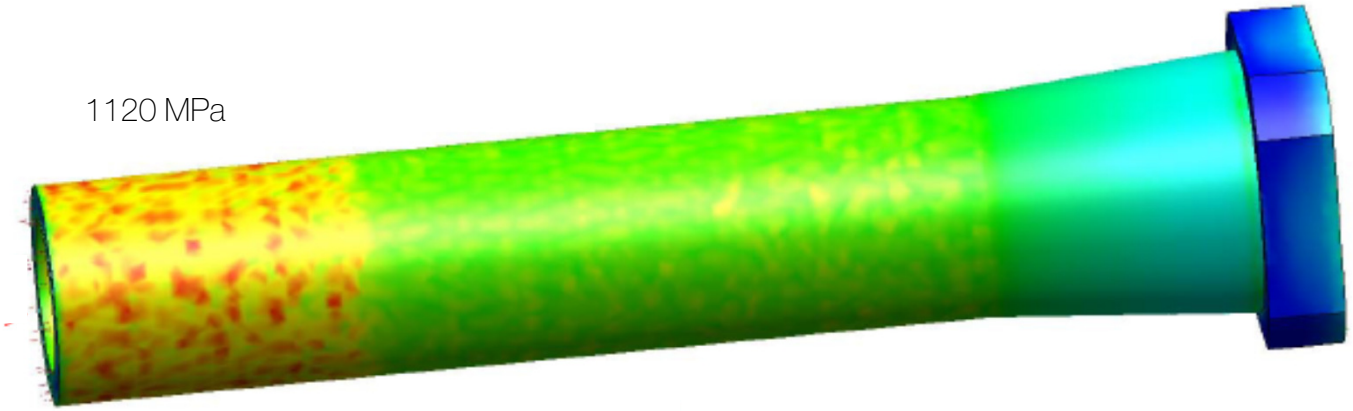
Near-contour forged stems allow the fibre-directed forging of the stem

- Incorrect steel selection cannot be compensated. But the forging design as a near-contour forged press stem is also very decisive. Fibre-directional forging is of great importance for the durability of the press stem.
- The use of high-quality steels, the best possible forging design, and the most careful controls ensure the highest level of quality for Kind&Co stems.
- The checks do not only cover the purity and analysis of the steel, but also precise adherence to the dimensions, delivery specifications, and fulfilment of the mechanical-technological parameters.

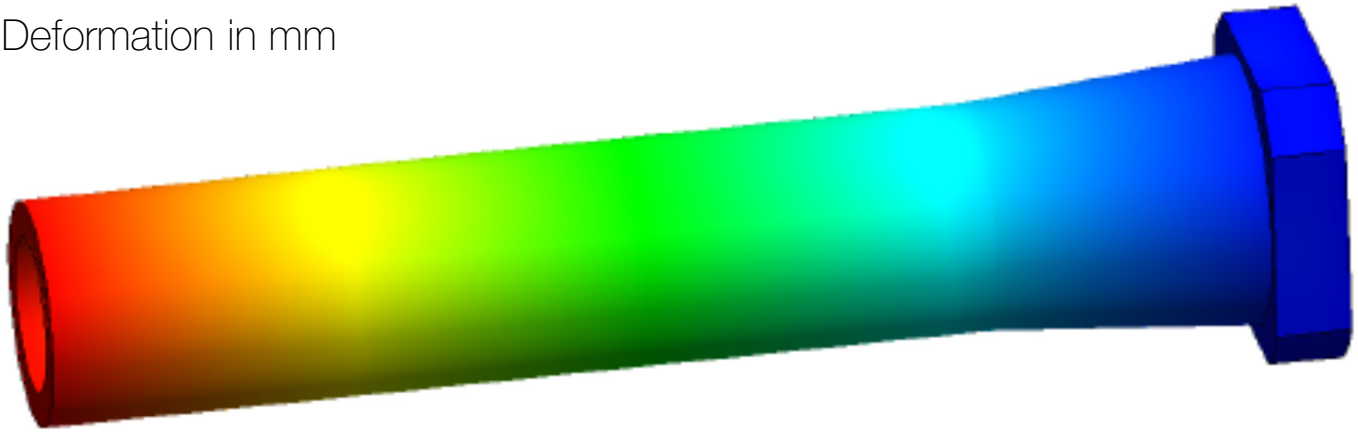
FEM simulations support the demonstation of critical loads and deformations

Stem load in MPa

1120 MPa



Deformation in mm



Best practice copper extrusion tooling - summary

- Kind&Co
  - Expertise along the entire tool steel value chain
  - Global service network for extrusion tooling
- Best practice copper extrusion containers
  - A premium container is of high relevance for saftey, stability, and quality
  - Container = USN/1.2343, Internmediate Liner = HTR, Inner liner = SA718
  - Heating and cooling are very important (also temperature management during process), and need to be designed to reduce local stress maxima (e.g., Air Portect system)
- Best practice relining process
  - In order to understand your process and tooling better, all inspections have to be executed and documented during relining (e.g., boroscope, hardness in the bore)
- Premium stems for copper extrusion
  - Depending on extrusion pressure at stem, the corresponding tool steel has to be selected
  - The higher the pressure, the more likely is ESR/premium vs. Standard
  - Near net shape forging and stress simulation helps

Contact details

Thank you very much for your attention

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