Macro-segregations and their role in distortions in case-hardened ring gears

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Macro-segregations and their role in distortions in case-hardened ring gears

Projektinfo

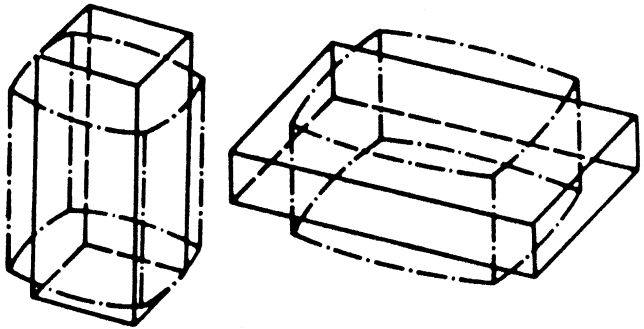
- Project leader: Emil Stålnacke, Swerim
- Contact: emil.stalnacke@swerim.se
- Project support: Rachel Petterson, Jernkontoret
- Time: 2020-10-28 to 2023-10-31
- Anders Olofsson — Scania
- Andreas Rindeskär — Ovako
- Johan Wendel — Rise

A project financed and supported by Metalliska Material in association with Sweden's Innovation Agency (Vinnova)

Macro-segregations and their role in distortions in case-hardened ring gears

What is a distorsion

- Dimension change + Shape change



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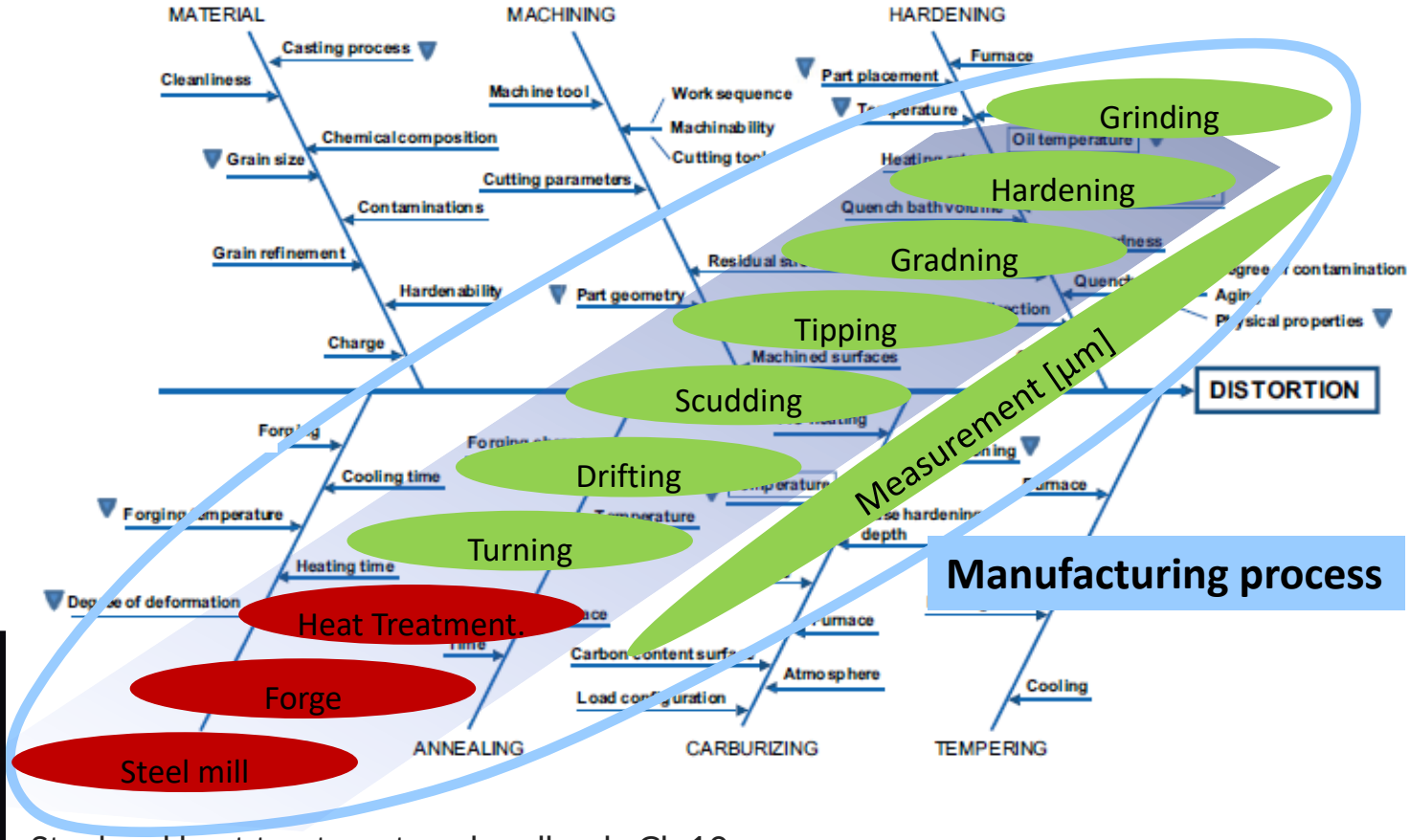
Mechanisms behind distorsions



Steel and heat treatment – a handbook, Ch 10

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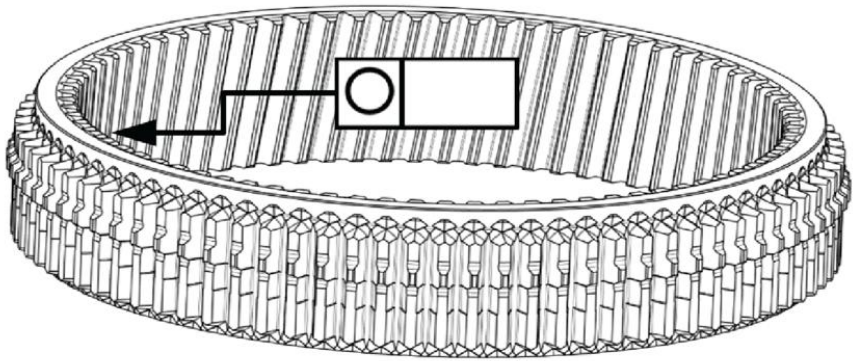
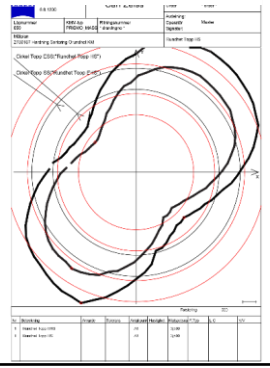
Hardening-induced distorions

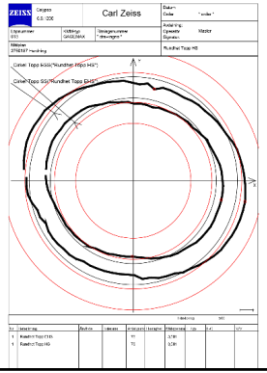
Project component

- Ring gear
- 20NiCrMoS2-2
- 4 kg
- Outer diameter : 270 mm
- Inner diameter: 226 mm
- Height 49 mm

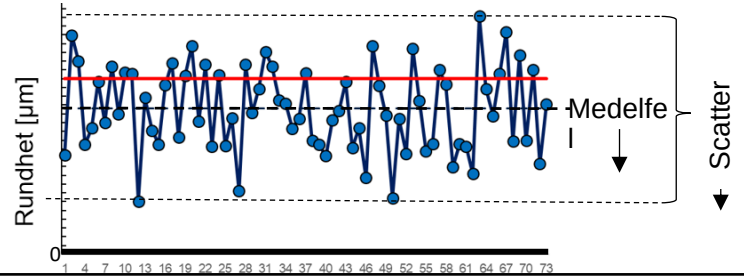


Visualzation





Challenge



Macro segregations

Casting process

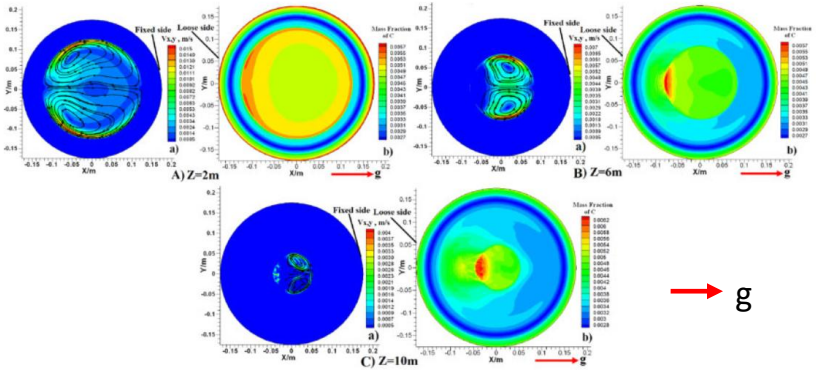
- Differential chemical composition between core and periphery of materail – macro-segregation

Foto: Pia & Hans Nordlander-Bildn

https://www.metalliskamaterial.se/sv/fakta/eurofer-goda-utsikter-for-europa-under-2018/

Excentric macro-segregations

- What is the influence of this



4 *a* melt flow patterns and *b* mass fraction distributions of solute element C at strand cross-sections with different distances from meniscus

H. Sun & L. Li (2015) Formation and control of macrosegregation for round bloom continuous casting, Ironmaking & Steelmaking, 42:9, 683-688, DOI: 10.1179/1743281215Y.0000000018

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Project goals

For the project:

- To quantify the influence of excentric macro-segregations on distorsions in ring gears
- To investigate how starting position of macro-segregations influence their final position in the ring gear

Long term:

- To attain knowledge to specify incomming material so distorsions become more predictable

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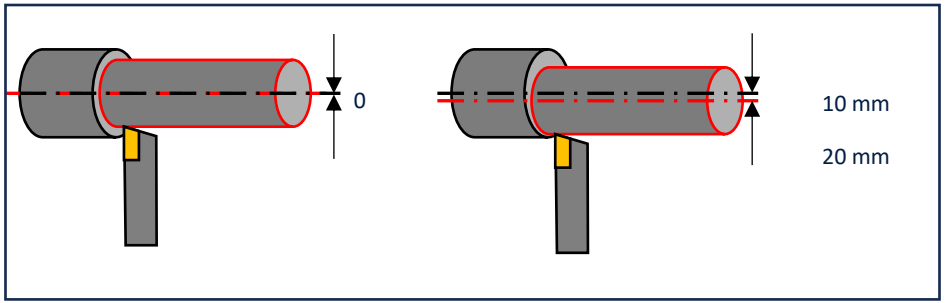
Material for distorsions

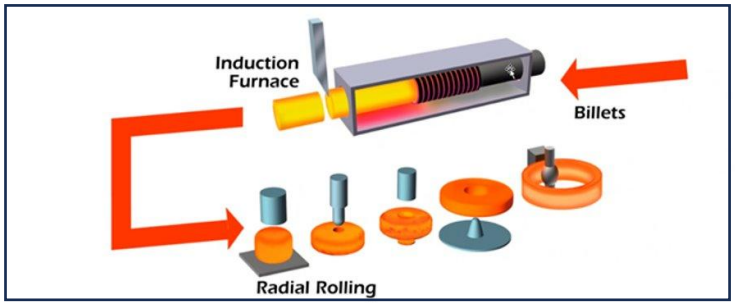
	C	Si	Mn	P	S	Cr	Ni	Mo
Comp.	0.22	0.26	0.86	0.007	0.011	0.58	0.45	0.18
Min	0.19	0.2	0.7	-	0.008	0.4	0.4	0.15
Max	0.23	0.35	0.9	0.015	0.015	0.6	0.7	0.25

Ingot casting

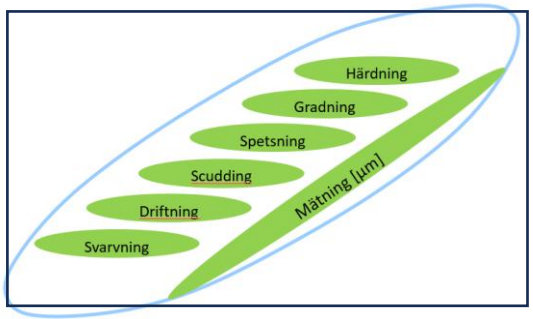
Bar rolling and machining smaller bars



Forging / Hot rolling



Gear soft machining and heat



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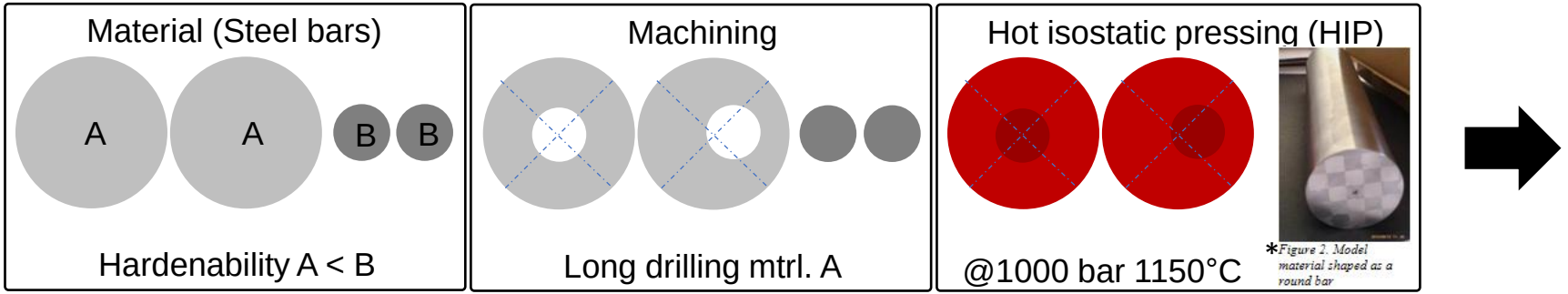
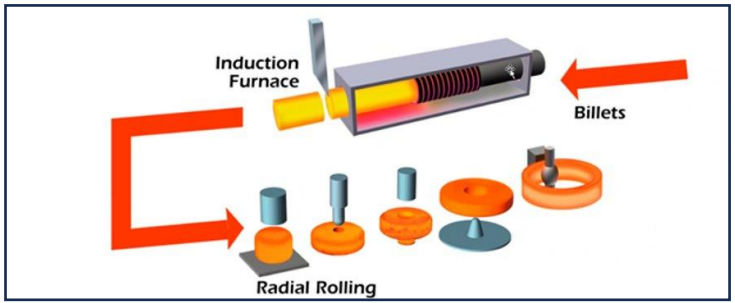
Material for verifying simulations

”Artificial” macro-segregation



Forging / Hot rolling



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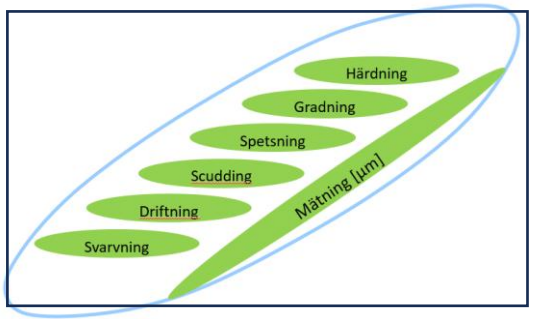

*T. Hansen & M. Werke (2012) Modelling and model validation of the deformation of macro inclusions during hot deformation, 8th International Conference on Clean Steel

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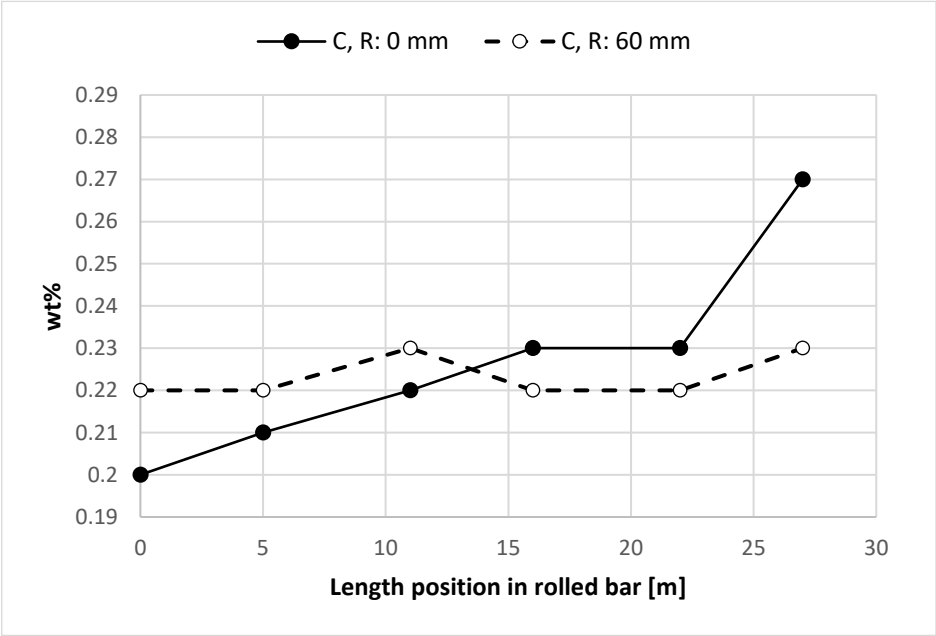
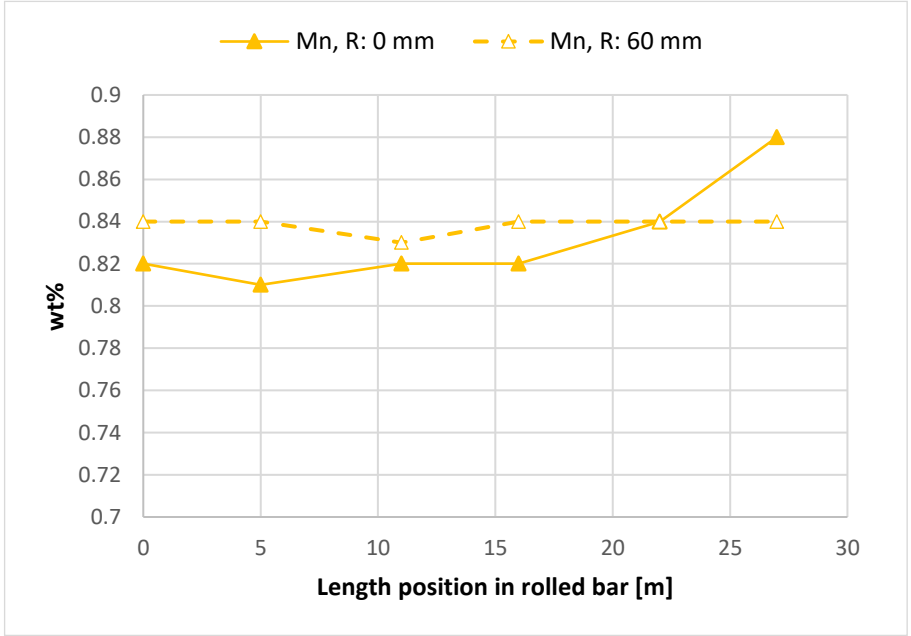
Material for distorsions





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Material for distorsions

Location	Composition (vikts%)						Ms
	C	Mn	Ni	Cr	Mo	Si	Andrews Linear
R:60; L:0	0.22	0.85	0.48	0.57	0.18	0.27	403
R:0; L:27	0.27	0.87	0.48	0.57	0.18	0.27	382
R:0; L:0	0.18	0.82	0.48	0.57	0.18	0.27	421

Not a large difference in Ms!

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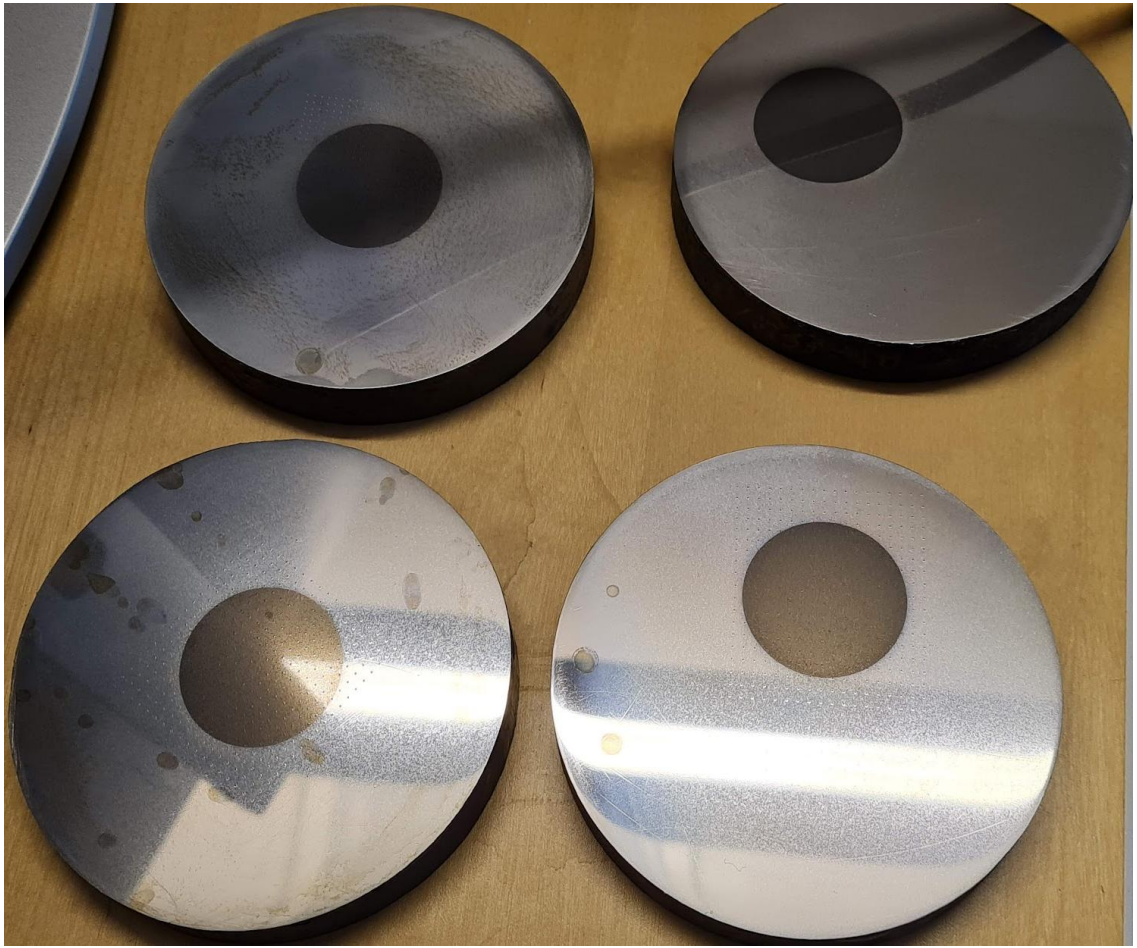
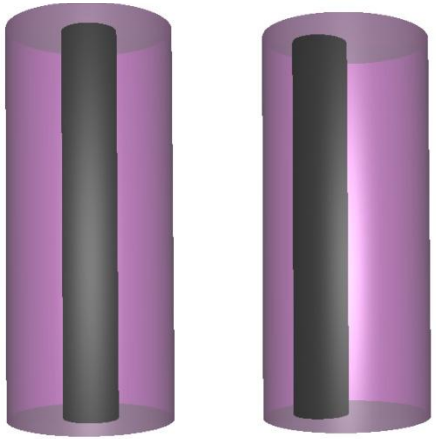
Material for simulations



After HIP

Simulation settup

Starting material



Center

Excentric

15 mm offset

Large Steel bar: Ø120 mm

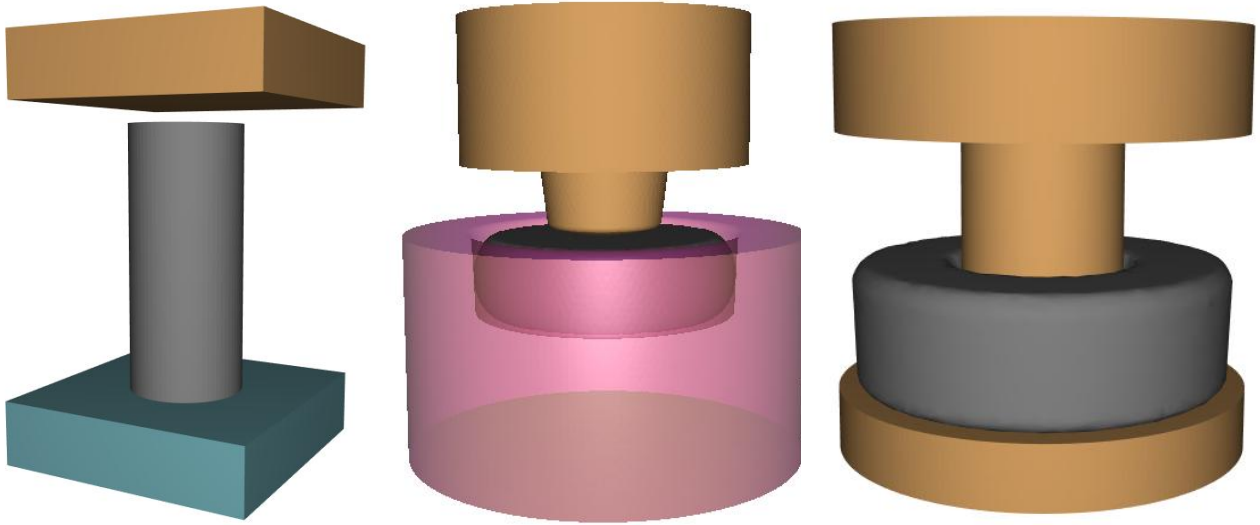
Small bar: Ø30 mm

Forging simulation

Hot pressing

Hollowing

Ring rolling

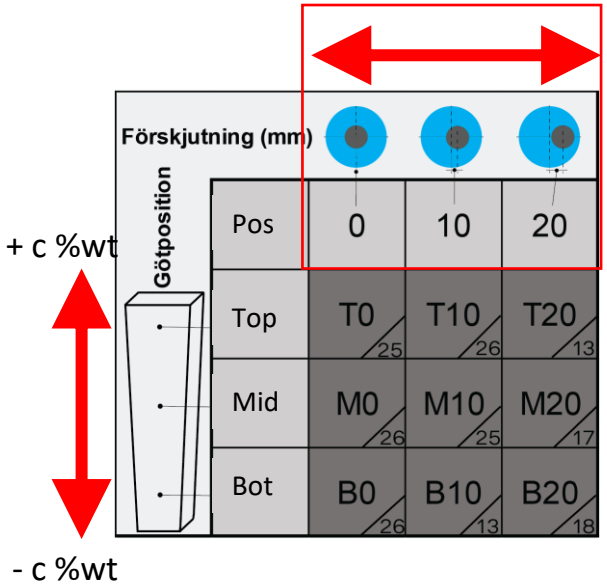


- Simulation software: FORGE NxT 4.0
- Material database: 100Cr6, with Hans-Spittel Material Model

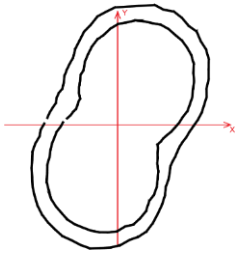
(Tool geometries from CAD-files)

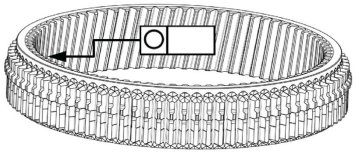
Results

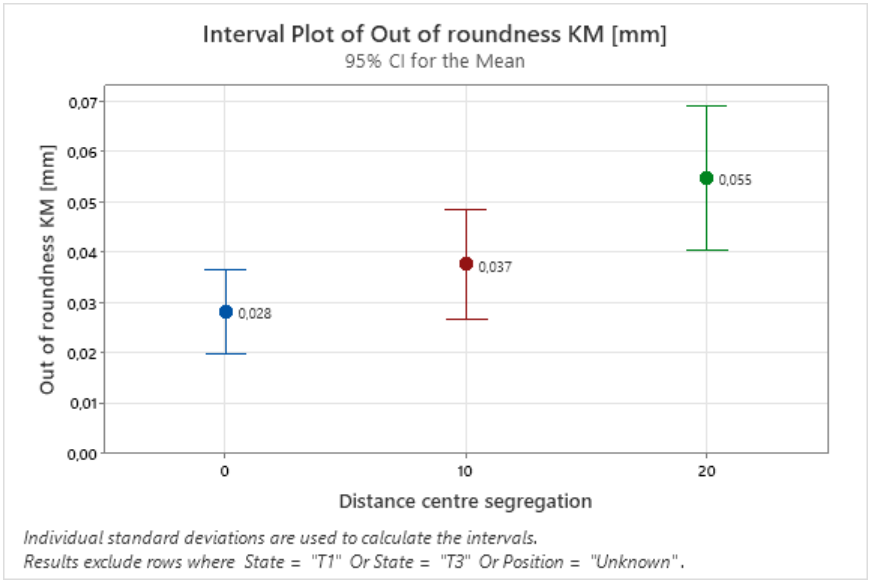
Out of roundness analysis



Out of roundness







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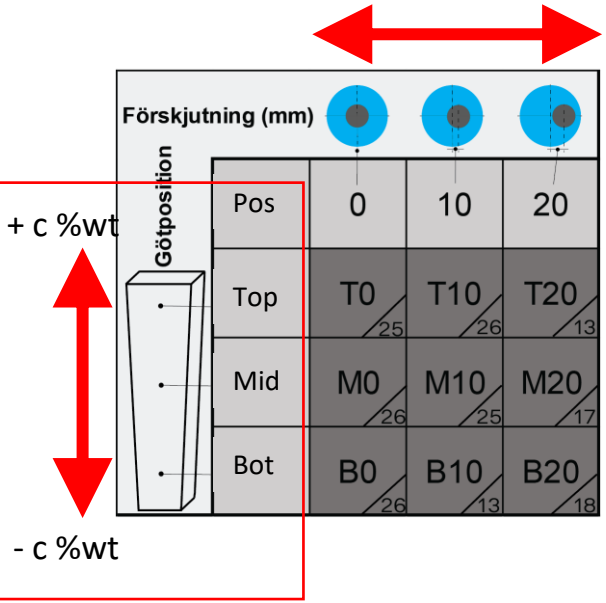
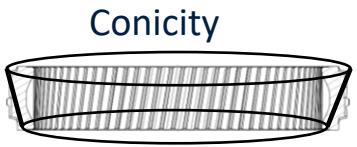
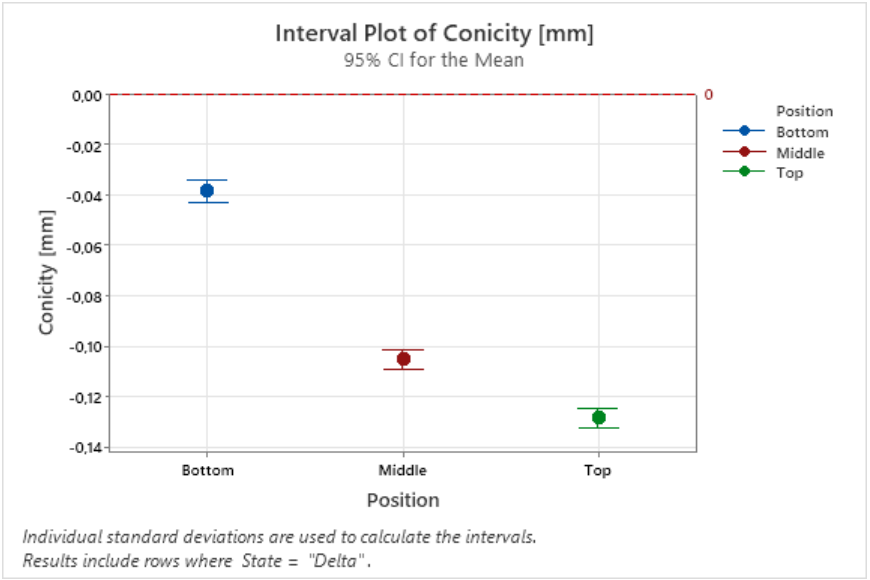
Conicity







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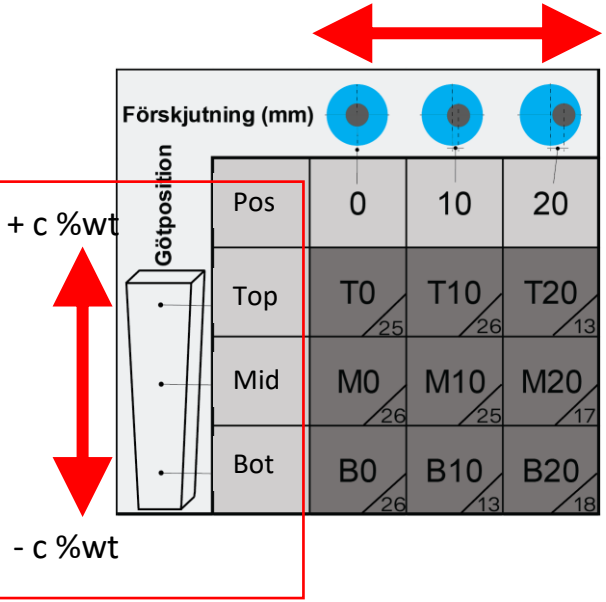
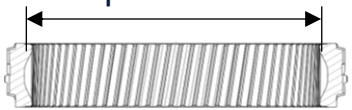
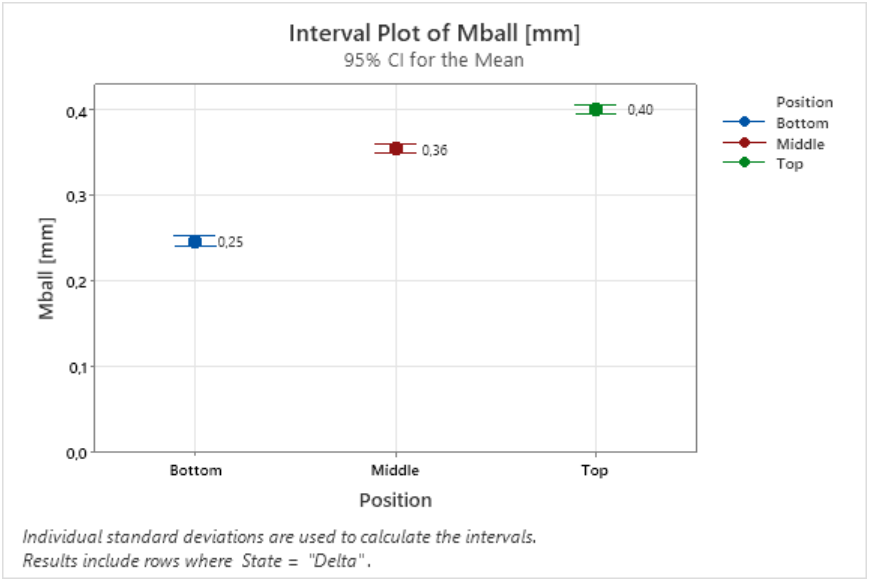
Diameter



Diameter exp





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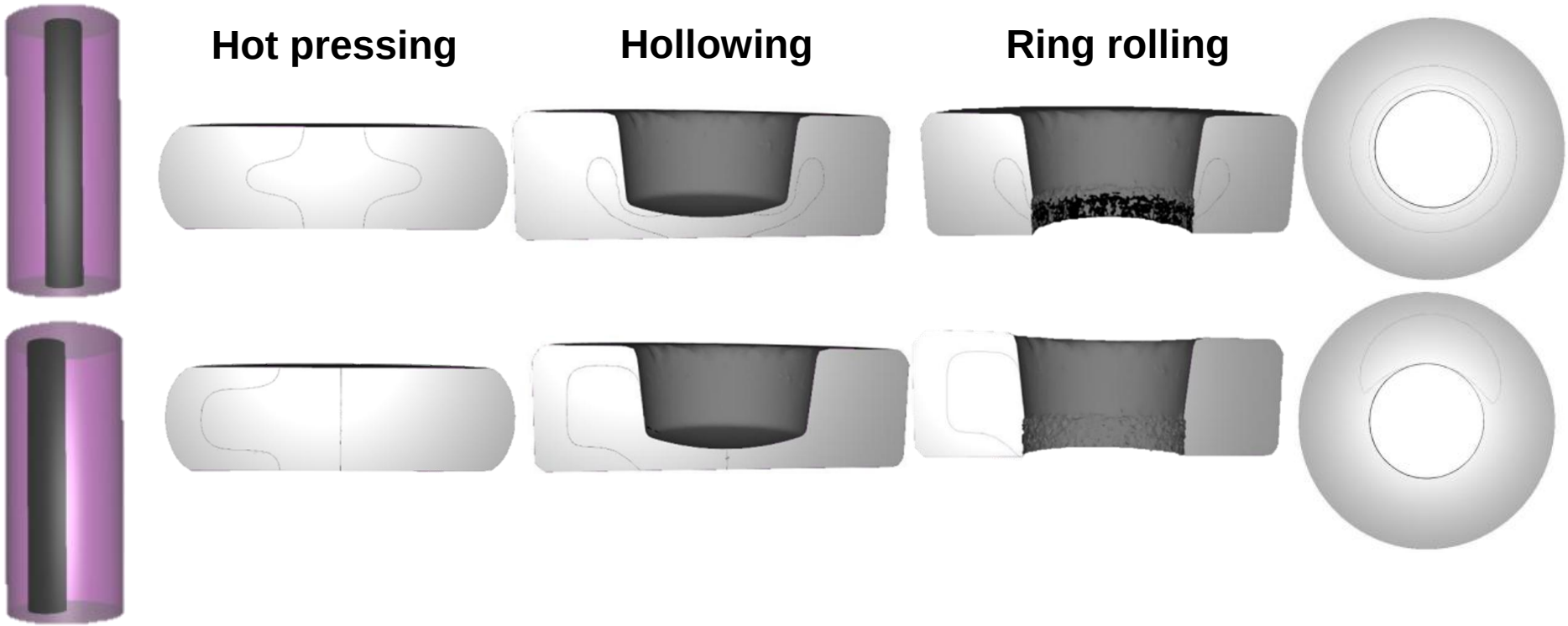
Simulation prediction



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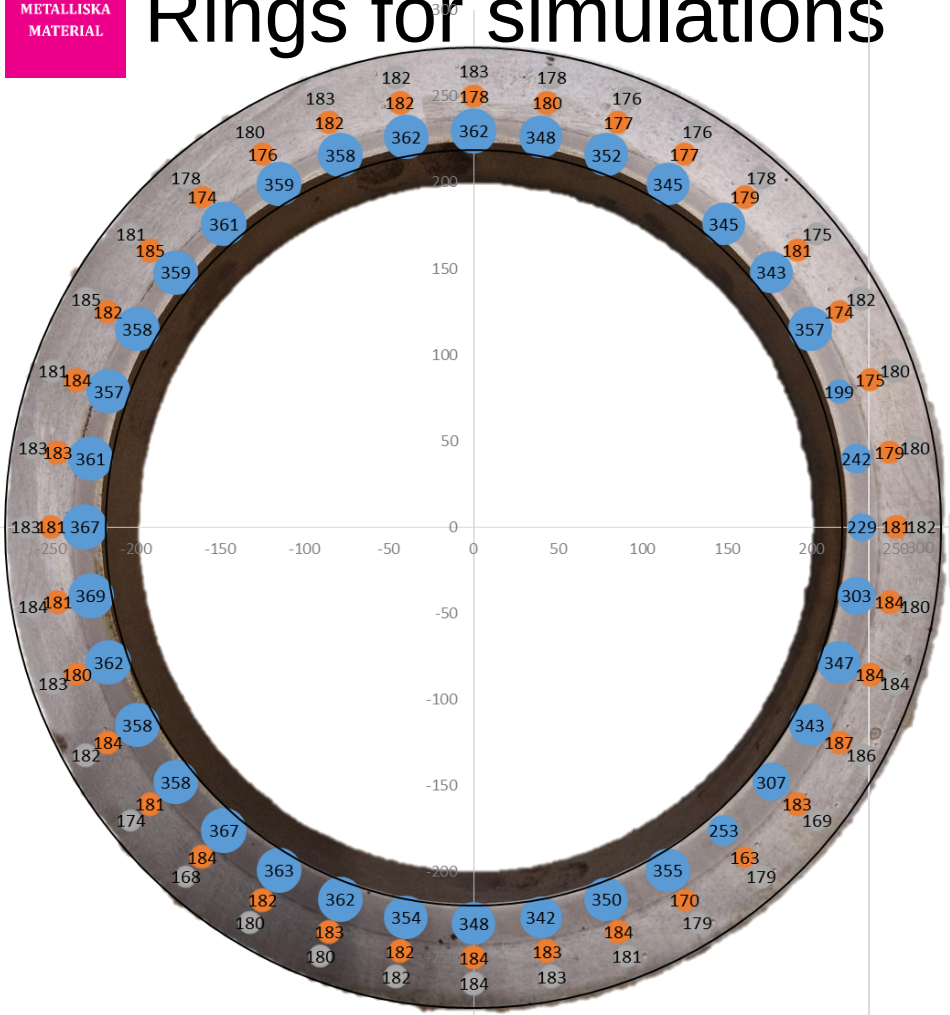
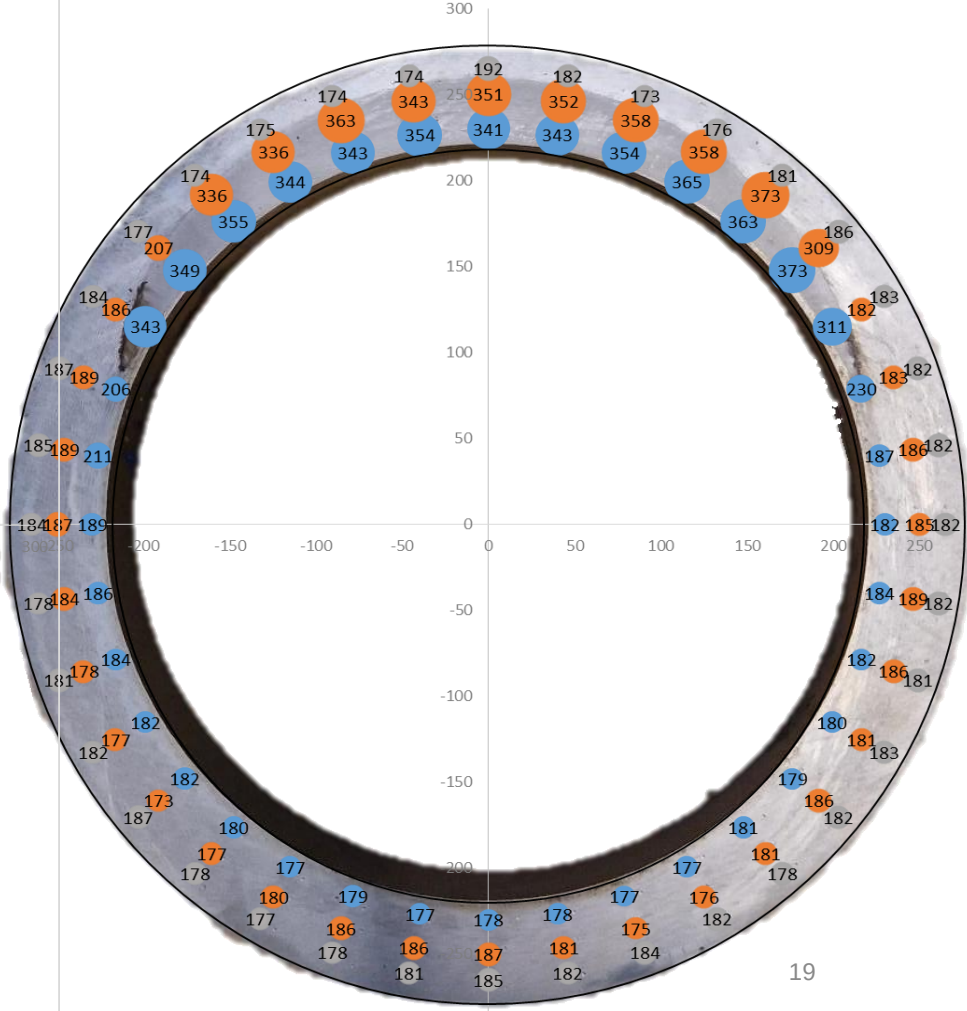
Rings for simulations





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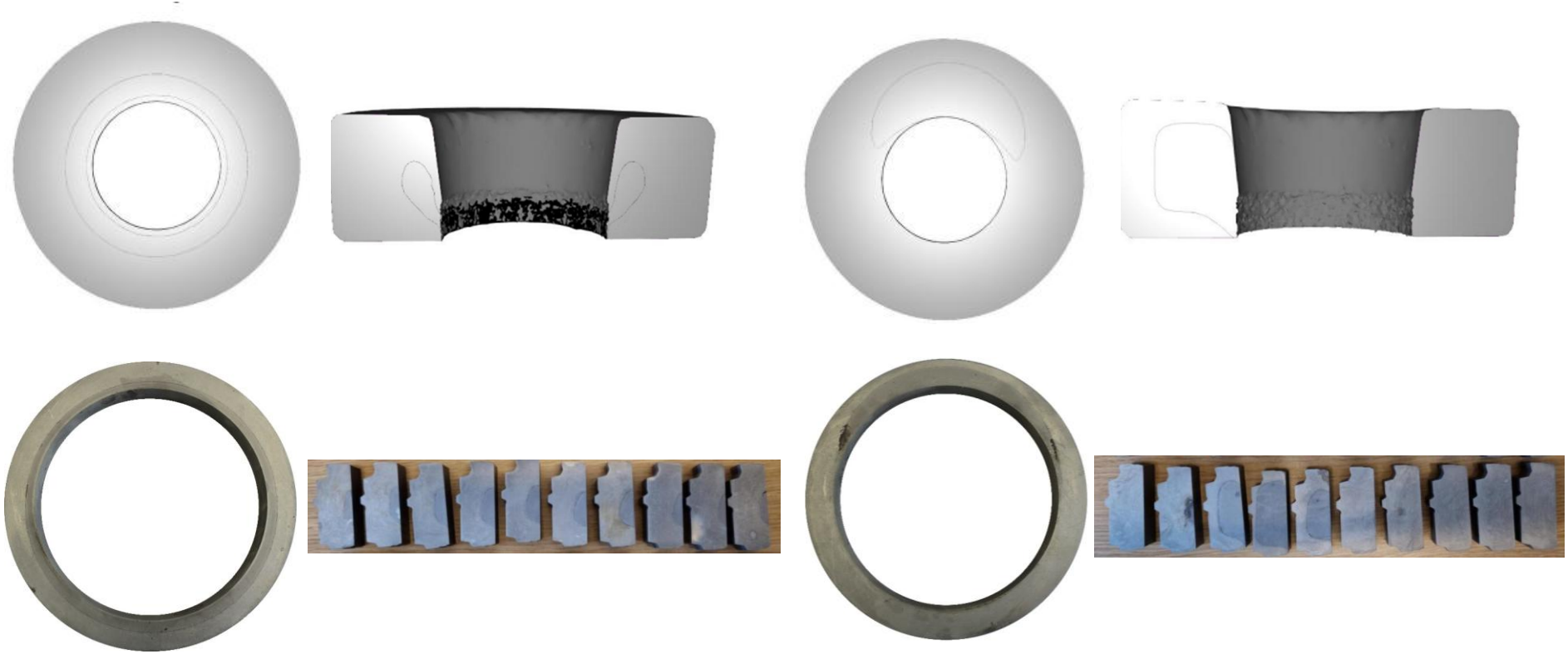
Experiments and Simulation



Summary

- Correlation between excentric centrum and out-of-roundness.
- Correlation between pos/neg and conicity.

- However, macro-seg. are very small (only 20°C Ms difference), not a likely explanation.

- The simulation tools can accurately predict the movement different material sections during ring-rolling.

Contact: emil.stalnacke@swerim.se