CONTACT FATIGUE IN CARBONITRIDED STEELS AND THE INFLUENCE OF RETAINED AUSTENITE

CONTRA

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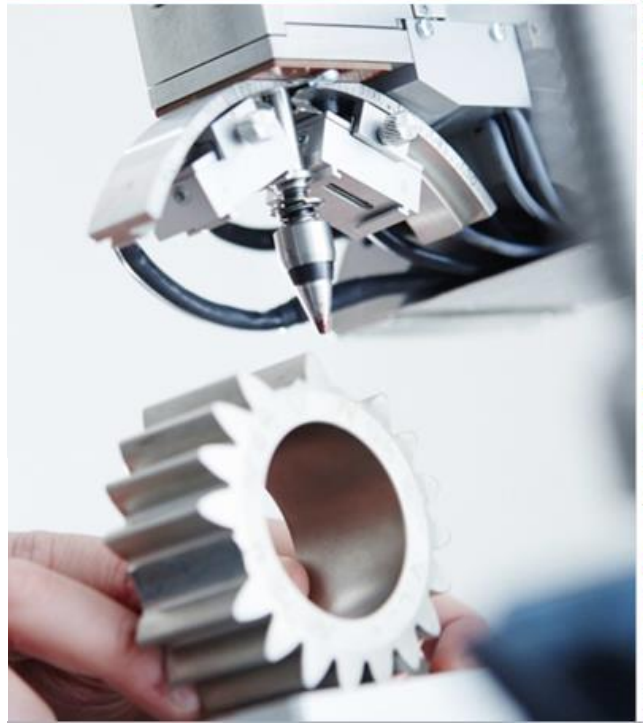
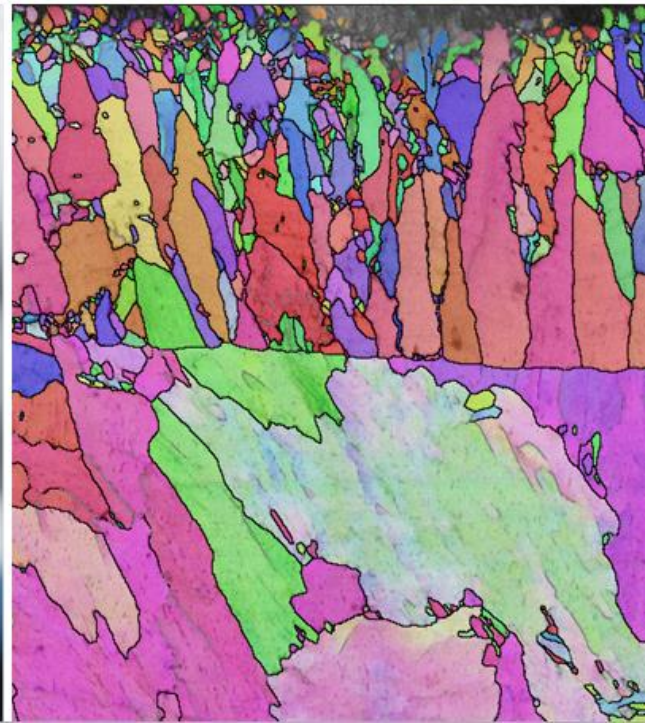
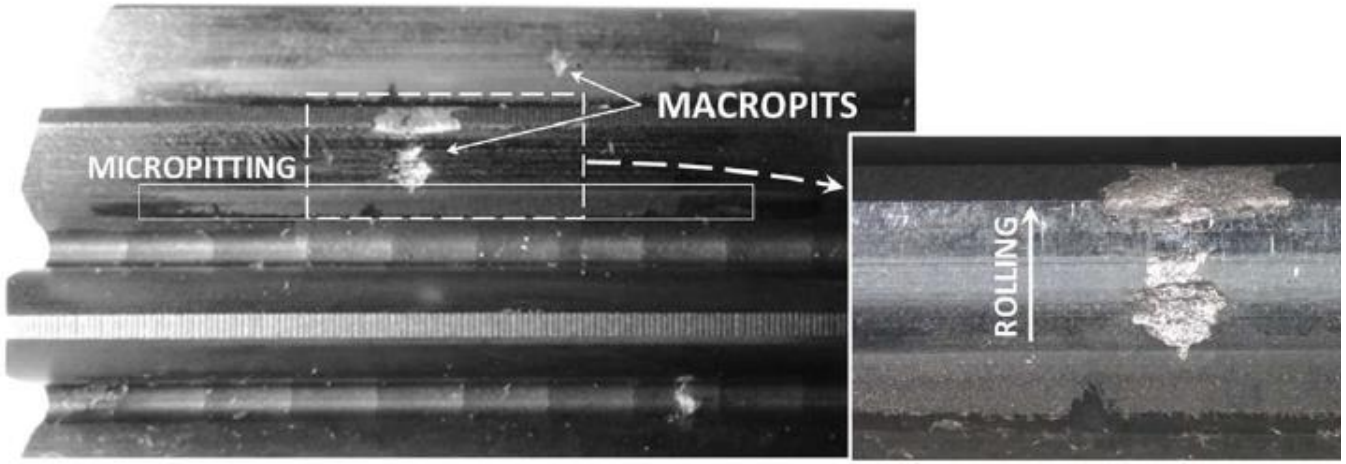


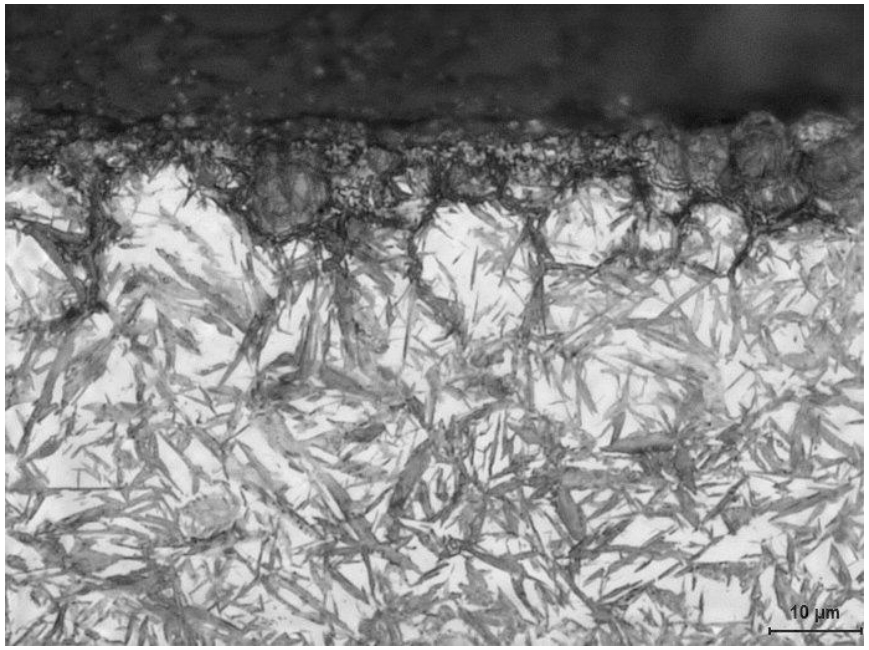


Why?



A. Terrin, G. Meneghetti, A comparison of rolling contact fatigue behaviour of 17NiCrMo6-4 case-hardened disc specimens and gears

- Contact fatigue can limit component life

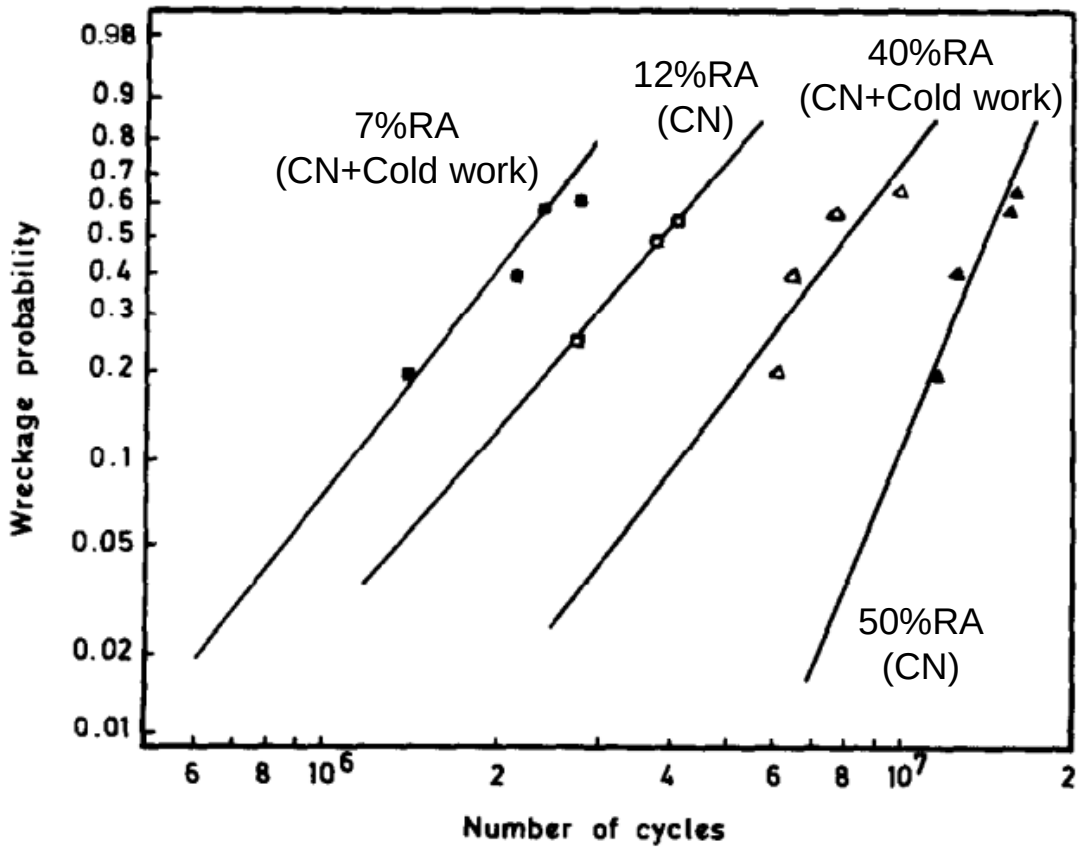


Carbonitriding

- Can further increase cont. fat. strength
- Correlated with higher retained austenite

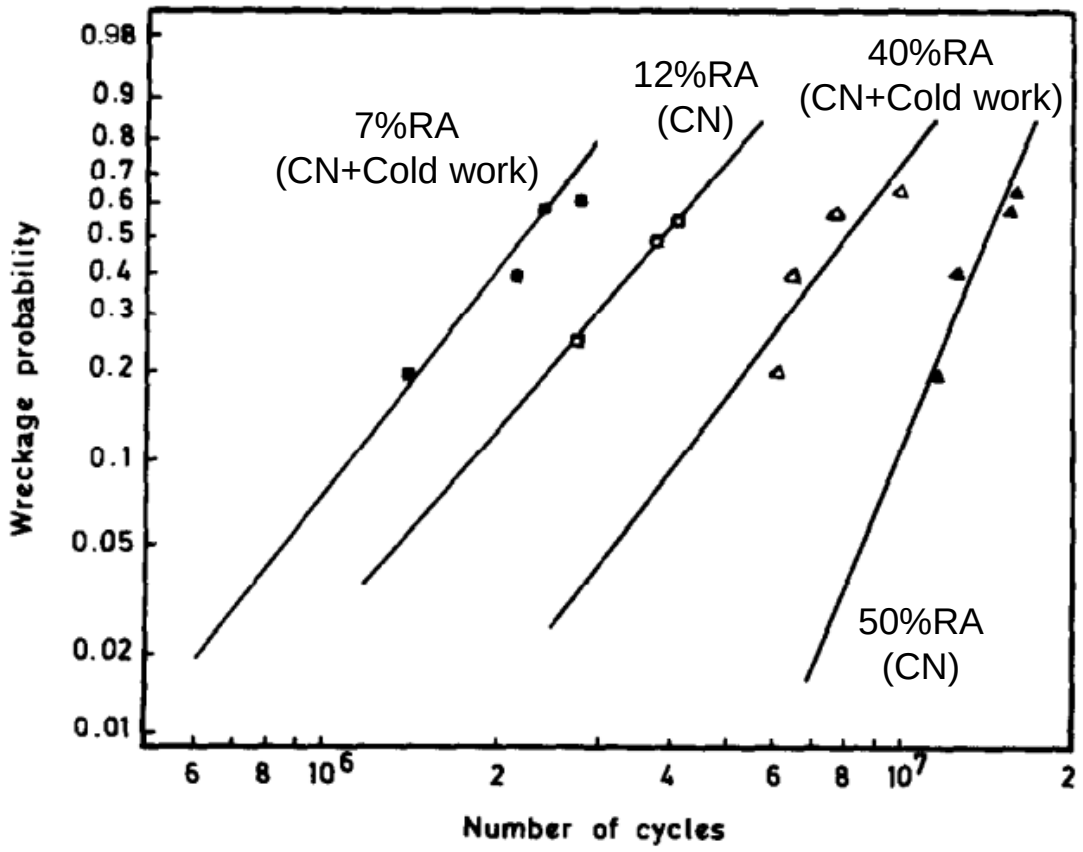
F. Hoffmann, P. Saddei and Steinbacher,
Carbonitriding: a new process-management for highly stressed parts,

Dong et al (1985) Effect of RA on rolling element fatigue



18Cr2Ni4WA
(0.18% C, 1.50% Cr, 4.25% Ni and 1.0% W)

Dong et al (1985) Effect of RA on rolling element fatigue



Retained austenite
→ deformation induced martensite

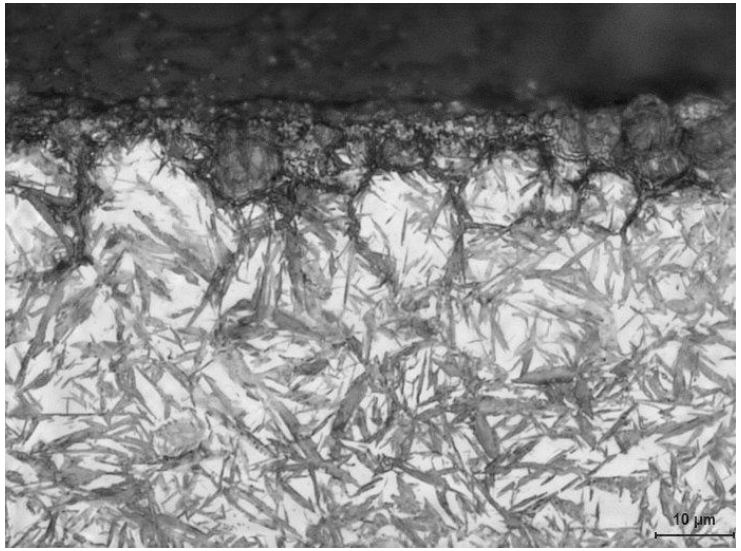
Precipitation hardening

18Cr2Ni4WA
(0.18% C, 1.50% Cr, 4.25% Ni and 1.0% W)

What?

Project impact goal:
Increase contact fatigue strength for carbonitridied steels

Project goal:
Confirm/Deny that high RA-content has a positive impact on contact fatigue strength.



Gnutti Carlo

Linde

Scania

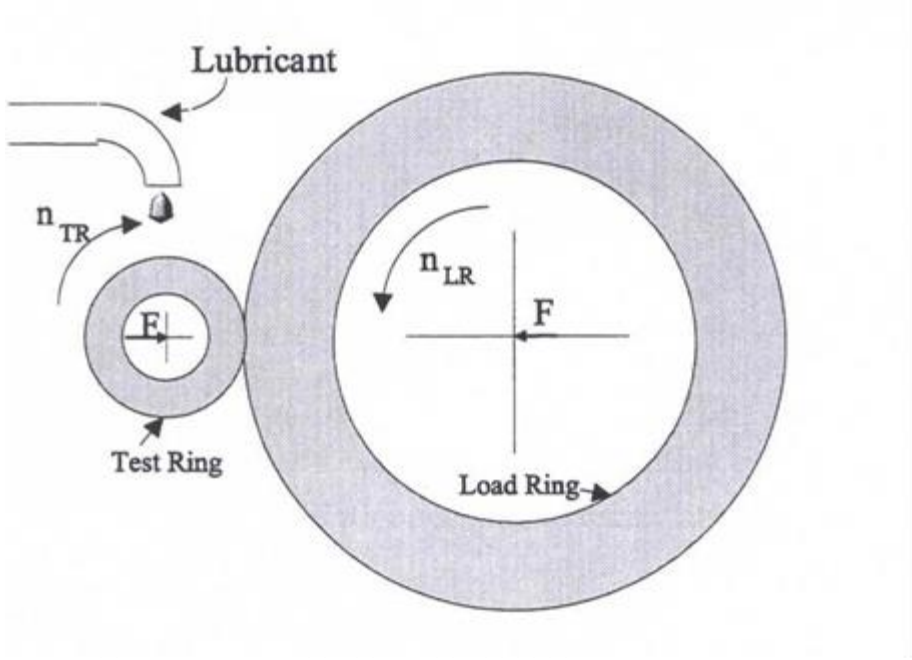
GKN Automotive

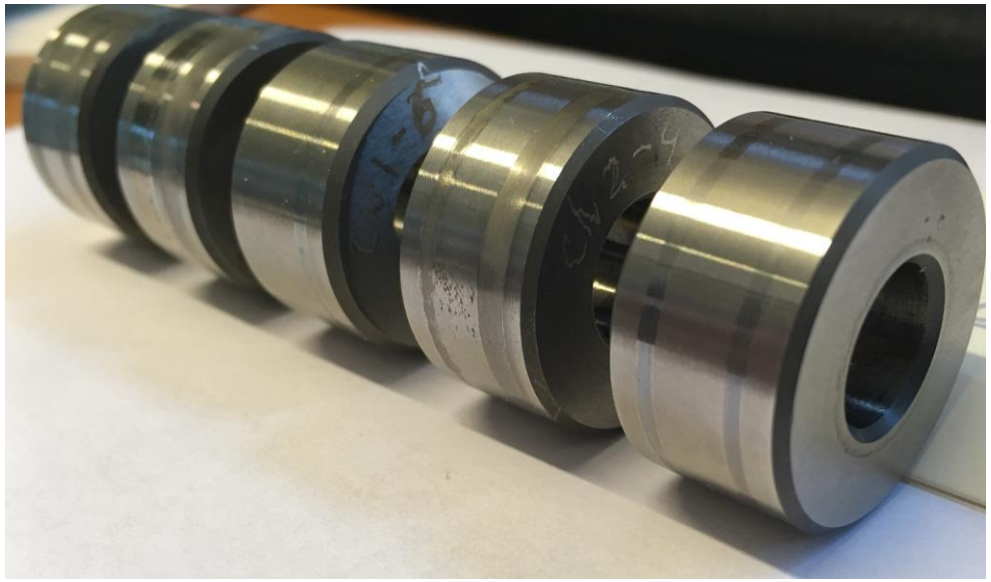
Ovako

Other members: Bodycote,

How?

- 18CrNiMo 7-6
- Rolling contact fatigue (up to 1.6 GPa)
- Examine
  - Fatigue
  - Hardness
  - Microstrucutre and XRD
- Heat treatment aim:
  1. Vary austenite content (preferably as high as possible with carbonitriding)
  2. Make an effort to minmize impact of other phases (e.g. nitrides, carbides)





Carburizing

Heat treatment

Gas carburizing 1	875	160	**0.85**	**-**	*Recieve high RA, no carbides*
Gas carburizing 2	875	160	**0.60**	**-**	*Recieve low RA (replicate process from KarboNit 2016)*

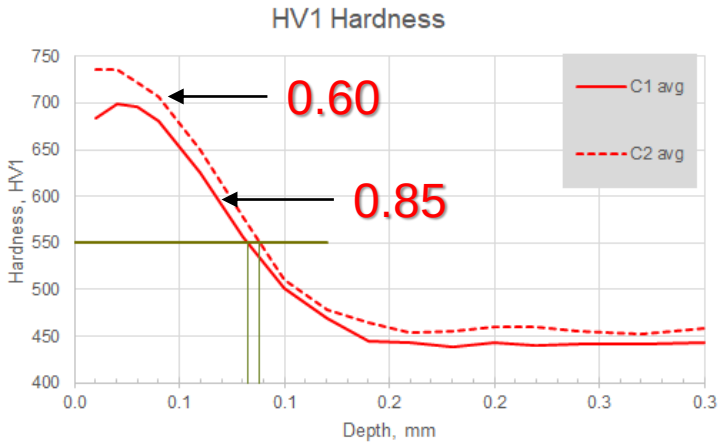
Heat treatment	Hardening temp [°C]	Tempering [°C]	**Cp**	**%NH3**	**Reasoning**

Aim: Case hardening depth 0.80 - 0.90mm

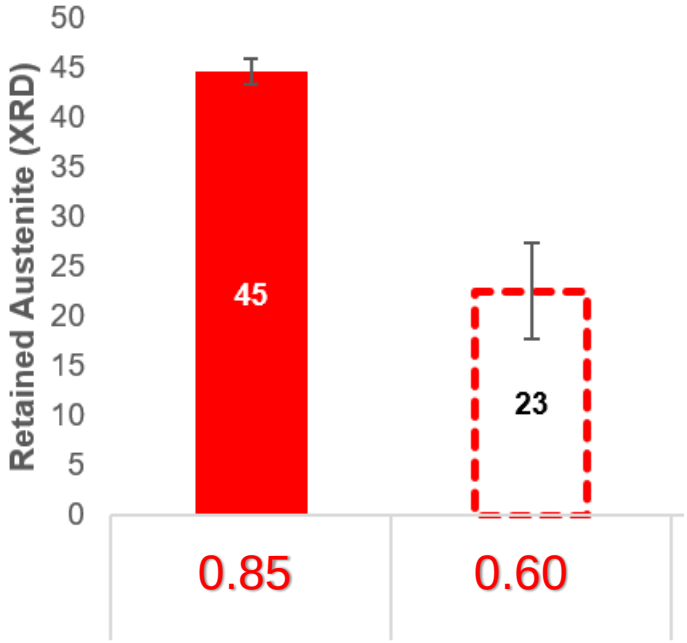
- After heat treatment samples 30 µm surface area was removed by grinding (to remove internal oxidation and HTTP)

Carburizing results

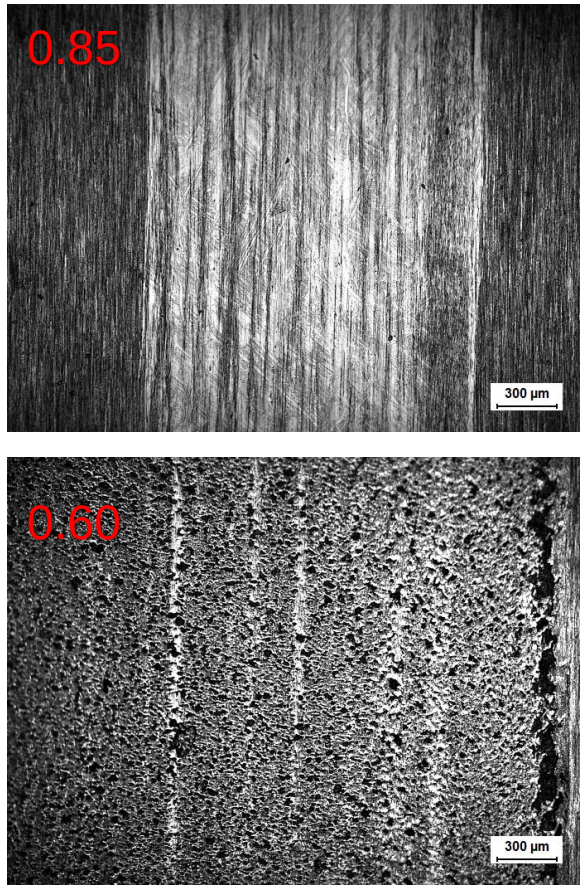
Hardness



XRD – Higher ret aust



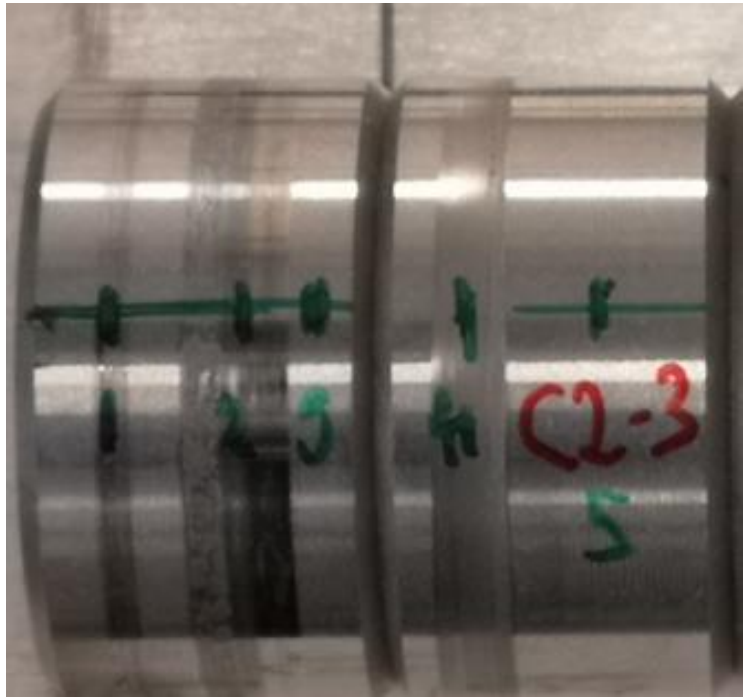
Rolling contact fatigue

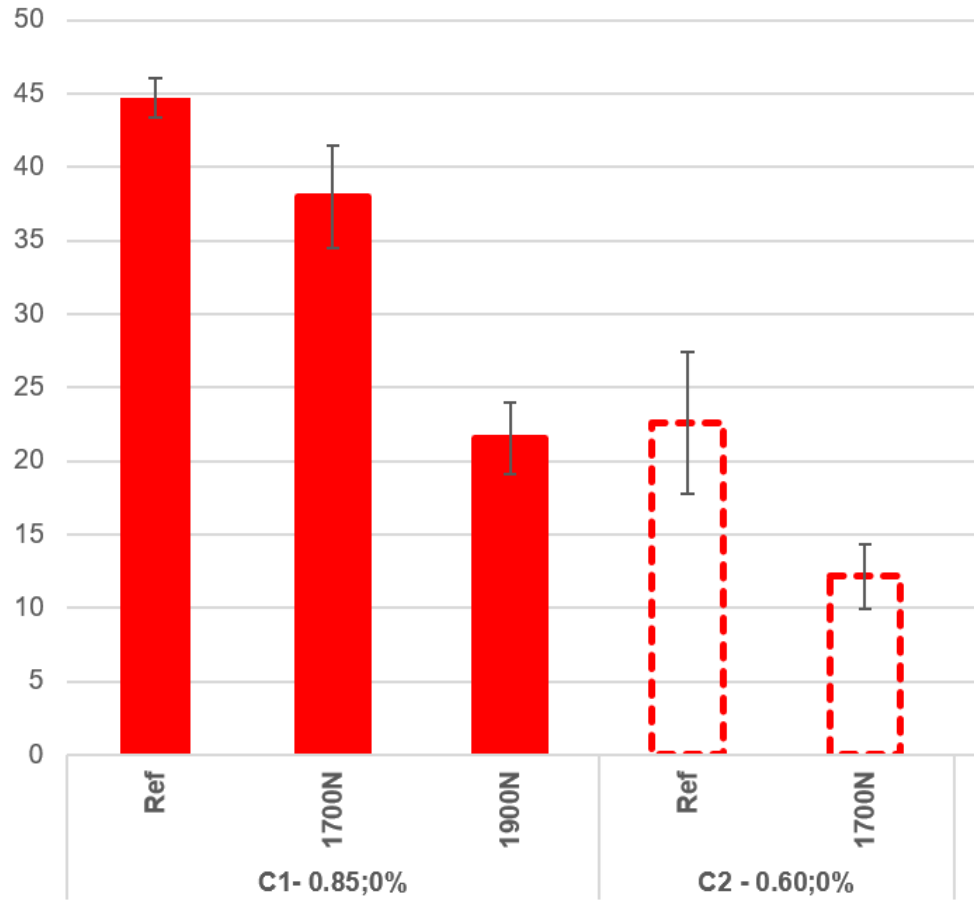


High RA – Better fat. Perf. – lower hardness

.’. Correlation between RA and perf

XRD after loading





Carbonitring

Heat treatment

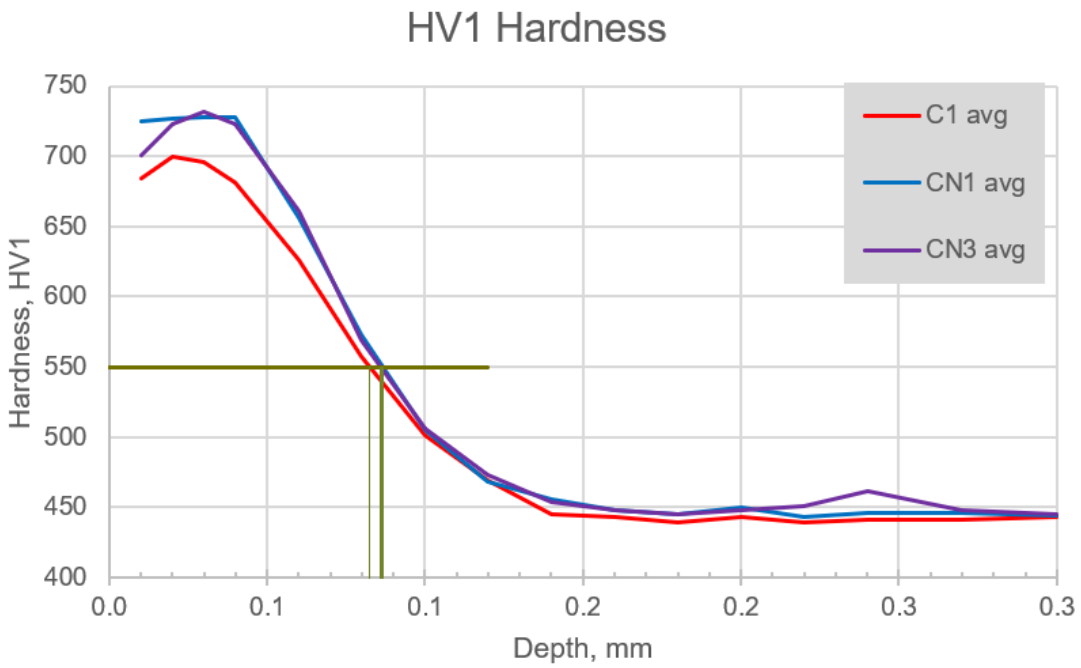
Heat treatment	Hardening temp [°C]	Tempering [°C]	Cp	%NH3	Reasoning
Carbonitriding 1	875	160	**0.85**	**5**	*Recieve high RA, further increased by by N (replicate process from KarboNit 2016)*
Carbonitriding 2	875	160	**0.60**	**5**	*Recieve lower RA but using same N (replicate process from KarboNit 2016)*
Carbonitriding 3	875	160	**0.85**	**3**	*Decided on site. Try to recieve high RA, try to avoid Cr-Nitrides to have "pure" RA-effect*

Aim: Case hardening depth 0.80 - 0.90mm

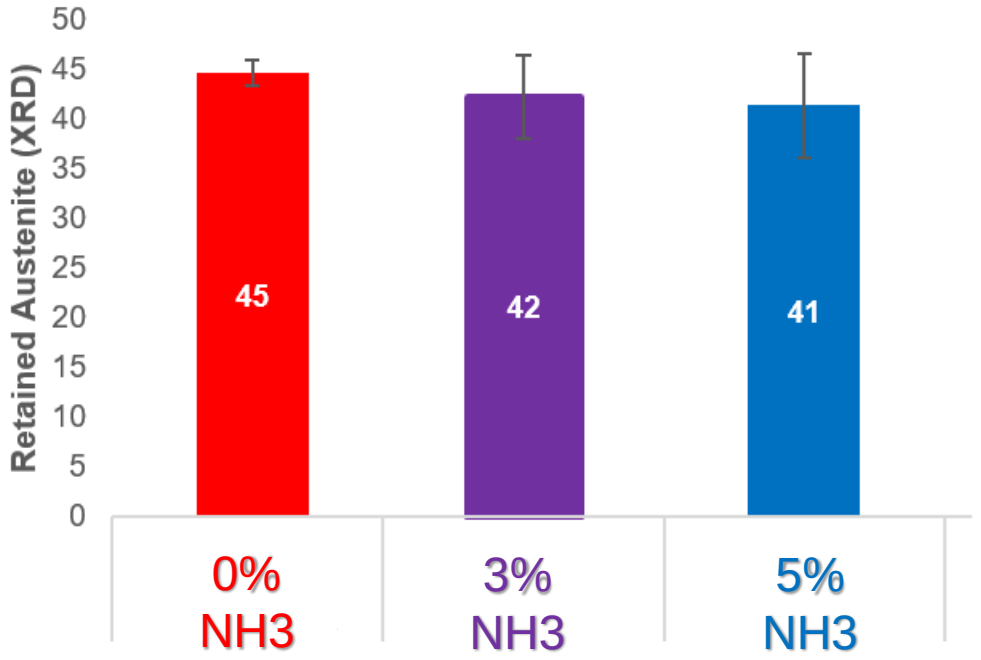
- After heat treatment samples 30 µm surface area was removed by grinding (to remove internal oxidation and HTTP)

Carbonitriding results

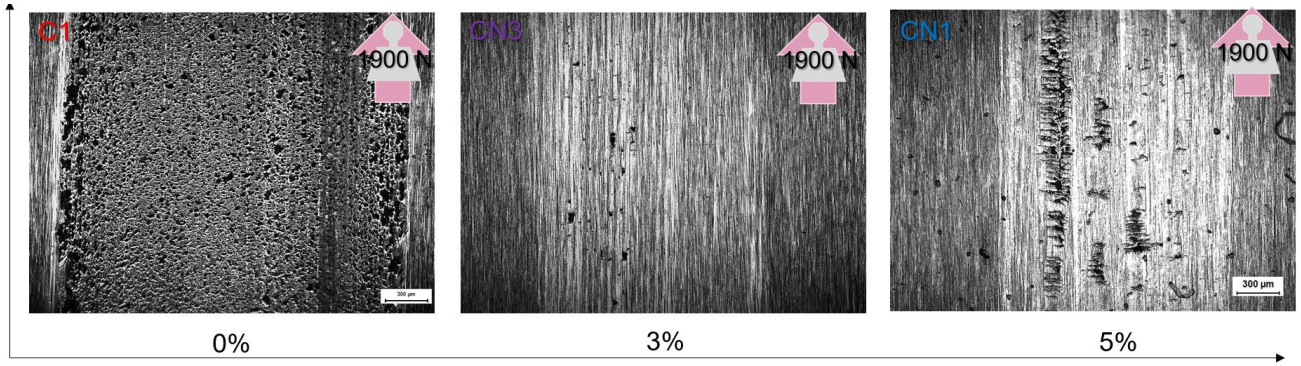
CN harder than C



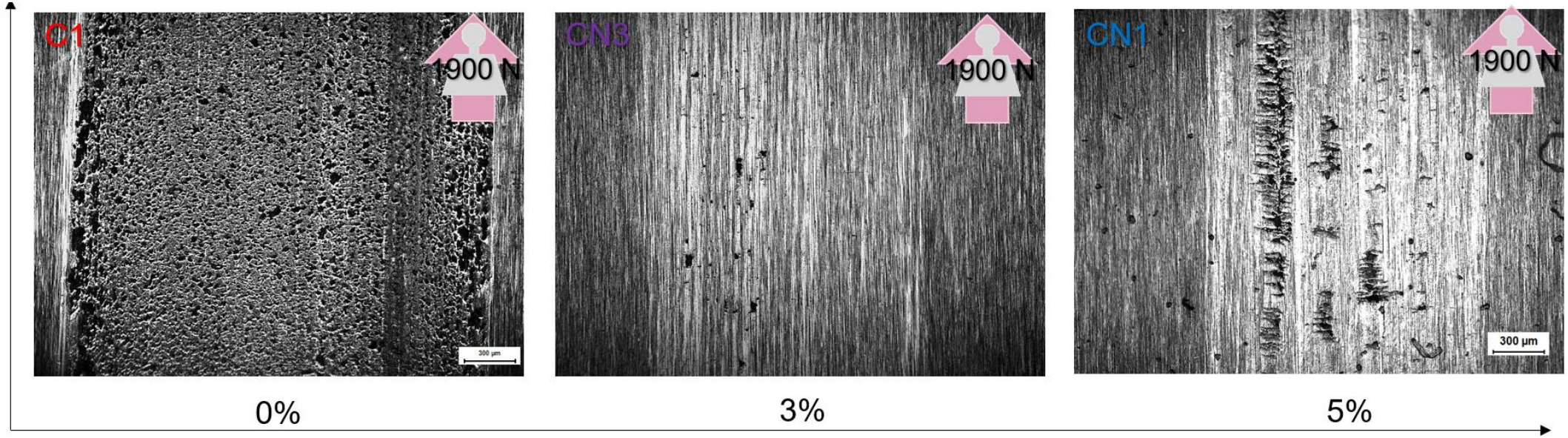
Same retained austenite

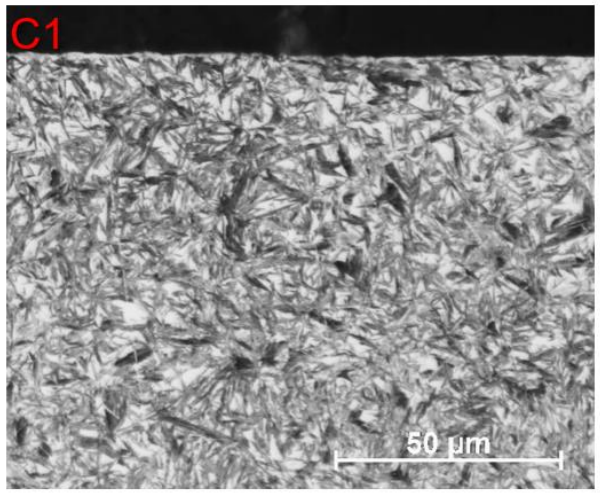


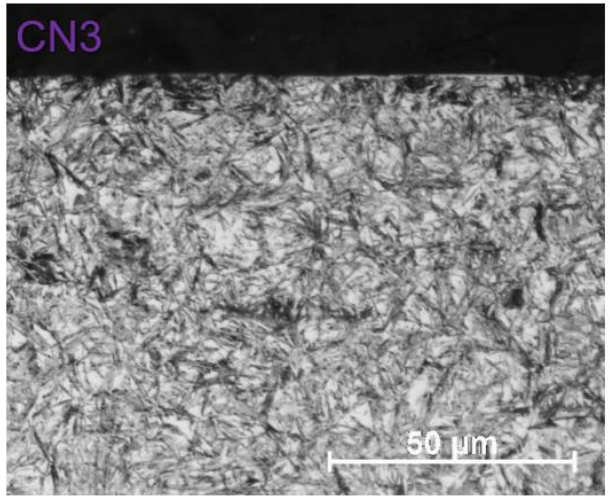
CN increase strength

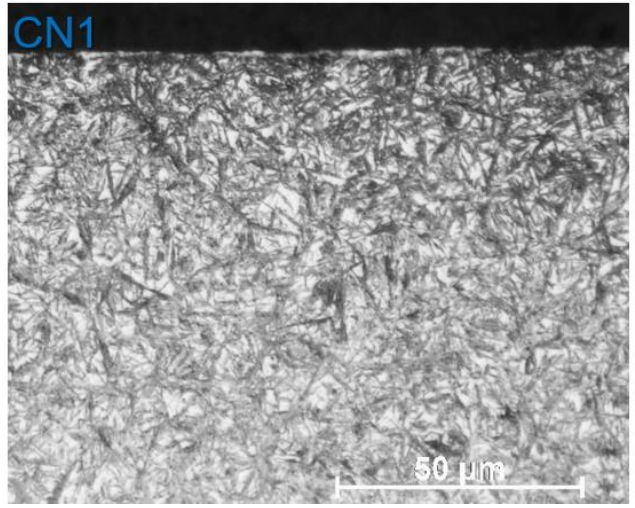


Similar microstructure



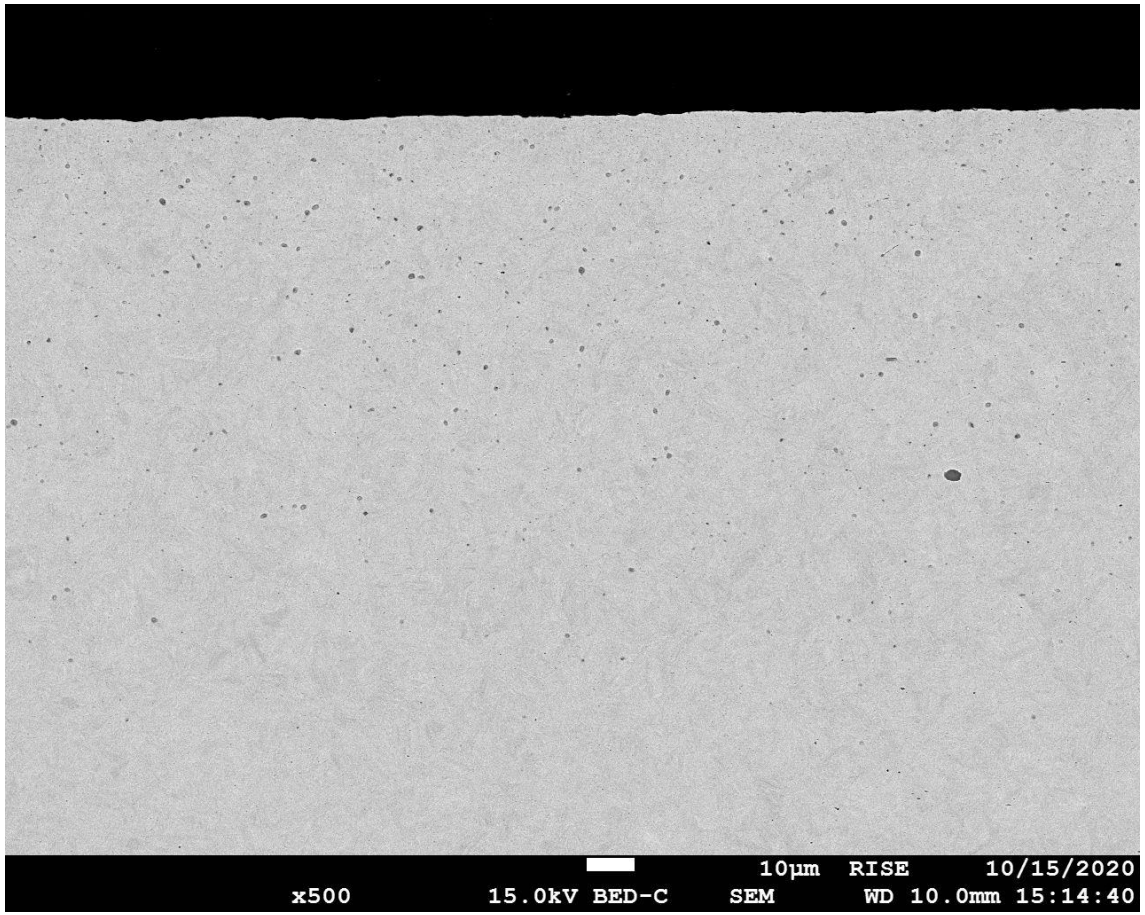




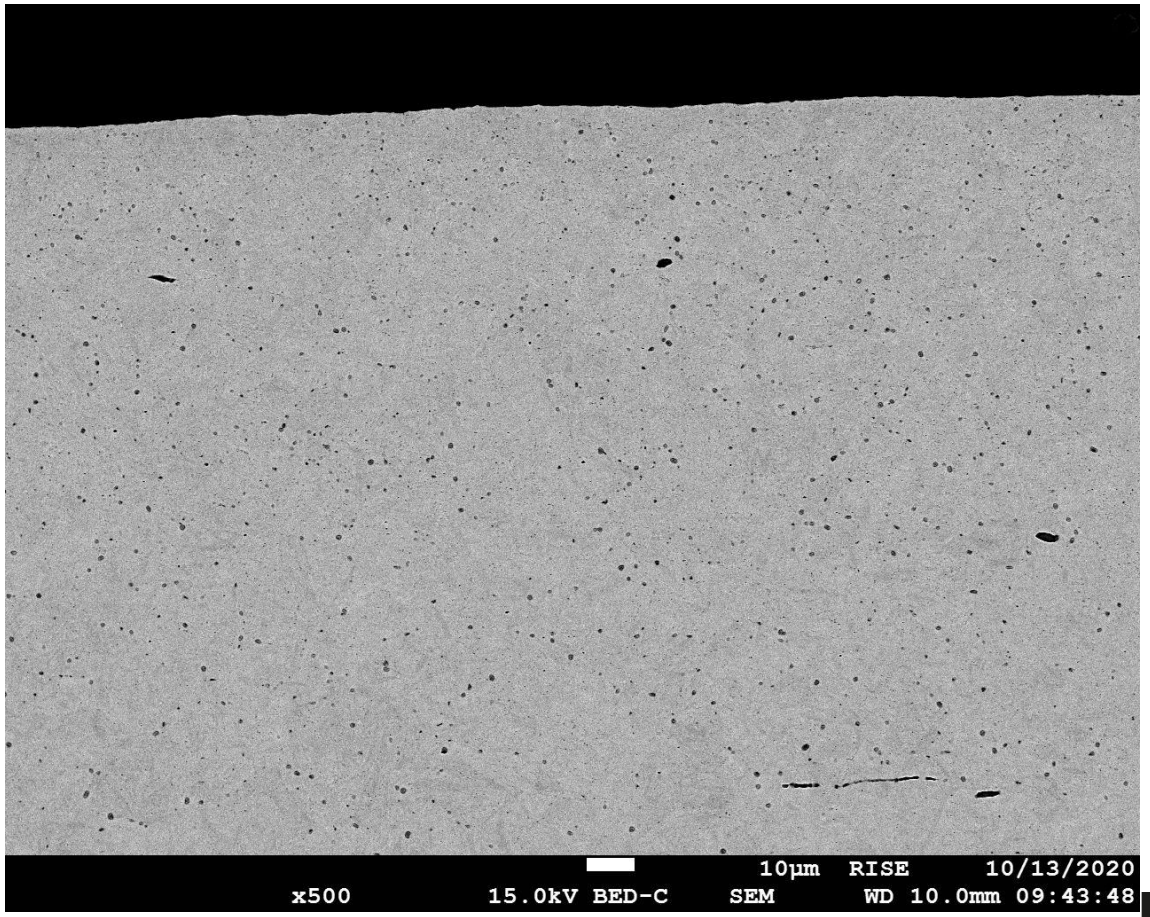


SEM – Precipitates

3% NH3

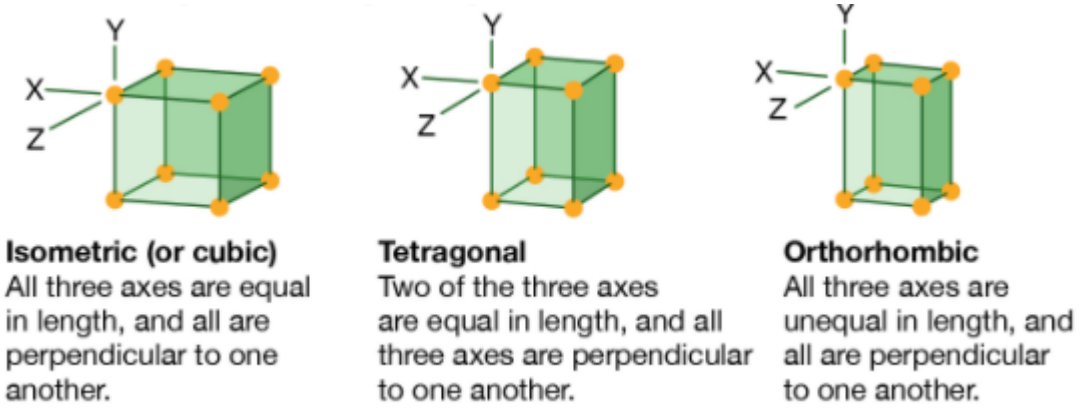


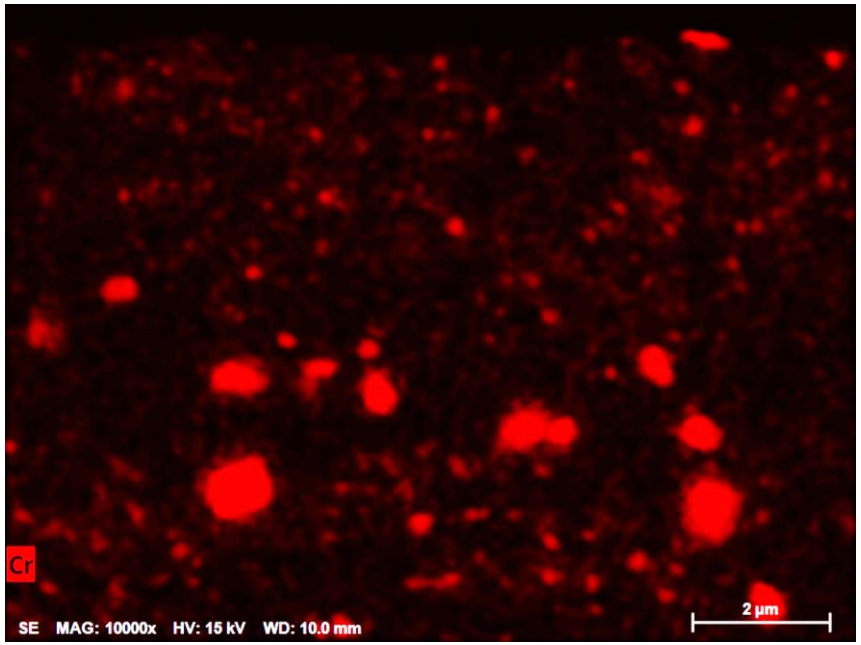
5% NH3



The precipiatets…

- Identified as **orthorhombic CrN**
  - Previously, we thought they were Cr(N,C). But further analysis showed that they contain less carbon than bulk





Precipitates and mechanical properties

- **Are they good for fatigue?**

  Size of precipiates is crucial to performance

  - When <10 nm (only TEM) → dispersion hardening
  - **When larger → increase risk of crack initiation**

The more SEM-visible particles, the worse the fatigue performance

H.-J. Kestenbach and J. Gallego, 2011, “on dispersion hardening of microalloyed hotstrip steels by carbonitride precipitation in austenite,” Scripta mater.,

W. Wang, H. Liu, C. Zhu, P. Wei and W. Wu, 2019, “Micromechanical analysis of gear fatigue-ratcheting damage considering the phase state and inclusion,”

Summarizing

All results

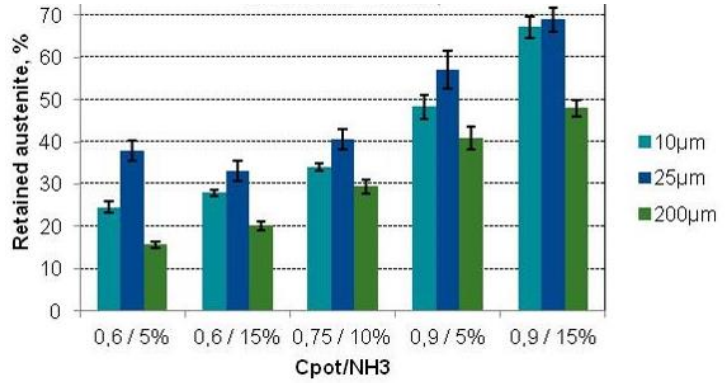
- High RA: better fat perf - lower hardn
  - RA decrease after mech loading
- Addition of NH3: unchanged RA - incr fat perf - incr hardness
  - Higher fat perf with lower NH3
- CrN found in both CN, but to varying size, volume fraction and depth

Conclusions

- **Confirmed that RA increase performance**, likely due to transformation into martensite
- Relatively small amount of NH3 can increase performance
- CrN-precipitates coarsen with increased ammonia content

Remember

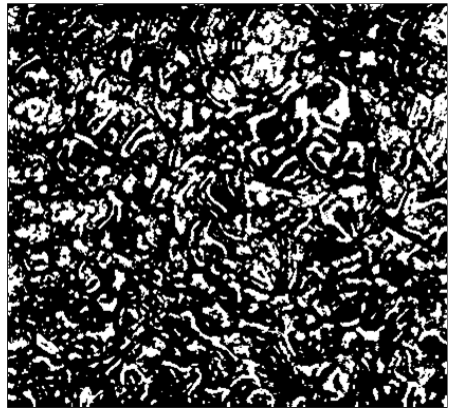
- Higher ammonia than used here can increase RA
  - Resulting performance?



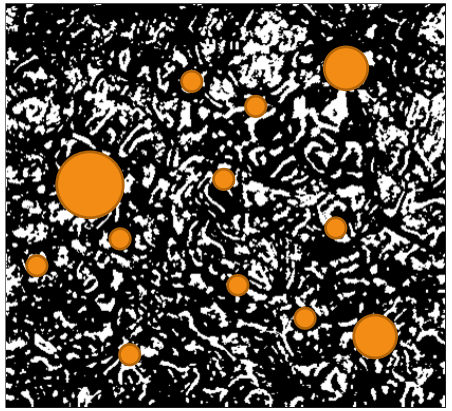
H. Kristoffersen, A. Stormvinter and S. Haglund, “VBC PF2016 Karbonit,” VBC,

Increasing NH3

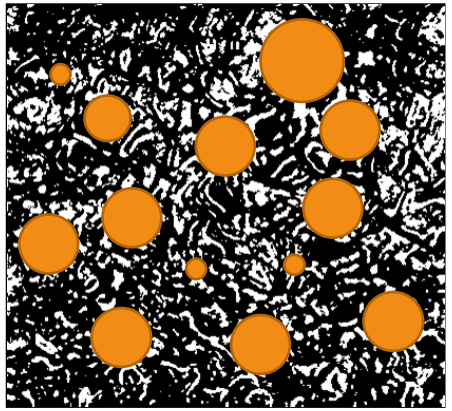
No CrN



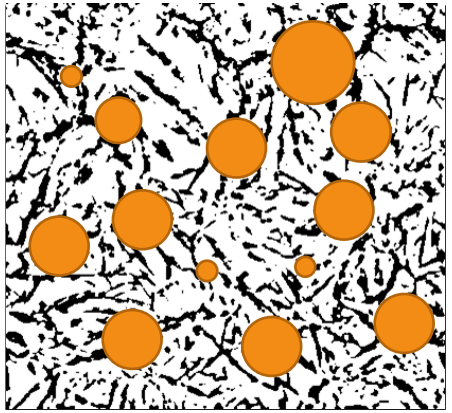
CrN, <10 nm
Strong



CrN, larger
Less strong



Large CrN + RA
??



Thank you for your attention!