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Relevance of laboratory wear experiments for the evaluation of in-service performance of materials

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Total **energy consumption** of global mining activities is **over 6%** of the total global energy consumption

www.metso.com

Energy spent to overcome friction and to manufacture and replace worn out parts cause over **200 000 M€ costs** annually

Holmberg K, Kivikytö-Reponen P, Härkisaari P, Valtonen K, Erdemir A. Global energy consumption due to friction and wear in the mining industry. Tribol Int 2017;115:116–39.

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Challenges in tribological scaling

\+ Increased realism of testing
Good utilizability of results

\+ Decreased cost
Increased control
Statistical significance

\- Expensive, complex, poor repeatibility

\- Realism?

Field test

Lokotrack LT140
Jaw width 1400 mm, rock size < 900 mm

Pilot test plant

Metso C80 jaw crusher
Jaw width 800 mm

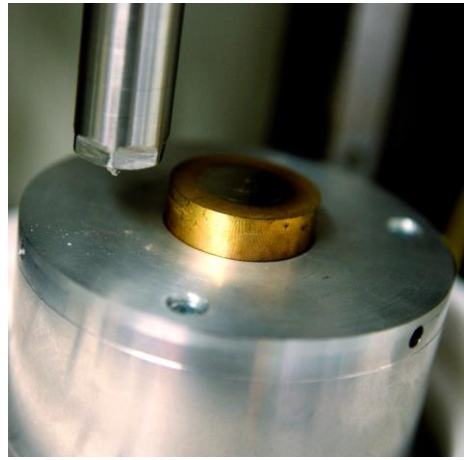
Miniature test

Laboratory crusher C7
Jaw width 70 mm

Crushing contact test

Dual pivoted jaw crusher
Jaw width 25 mm

Sliding contact test



Pin-on-disc
Rock tip size < 2 mm

Wear is not a material property it is a system property

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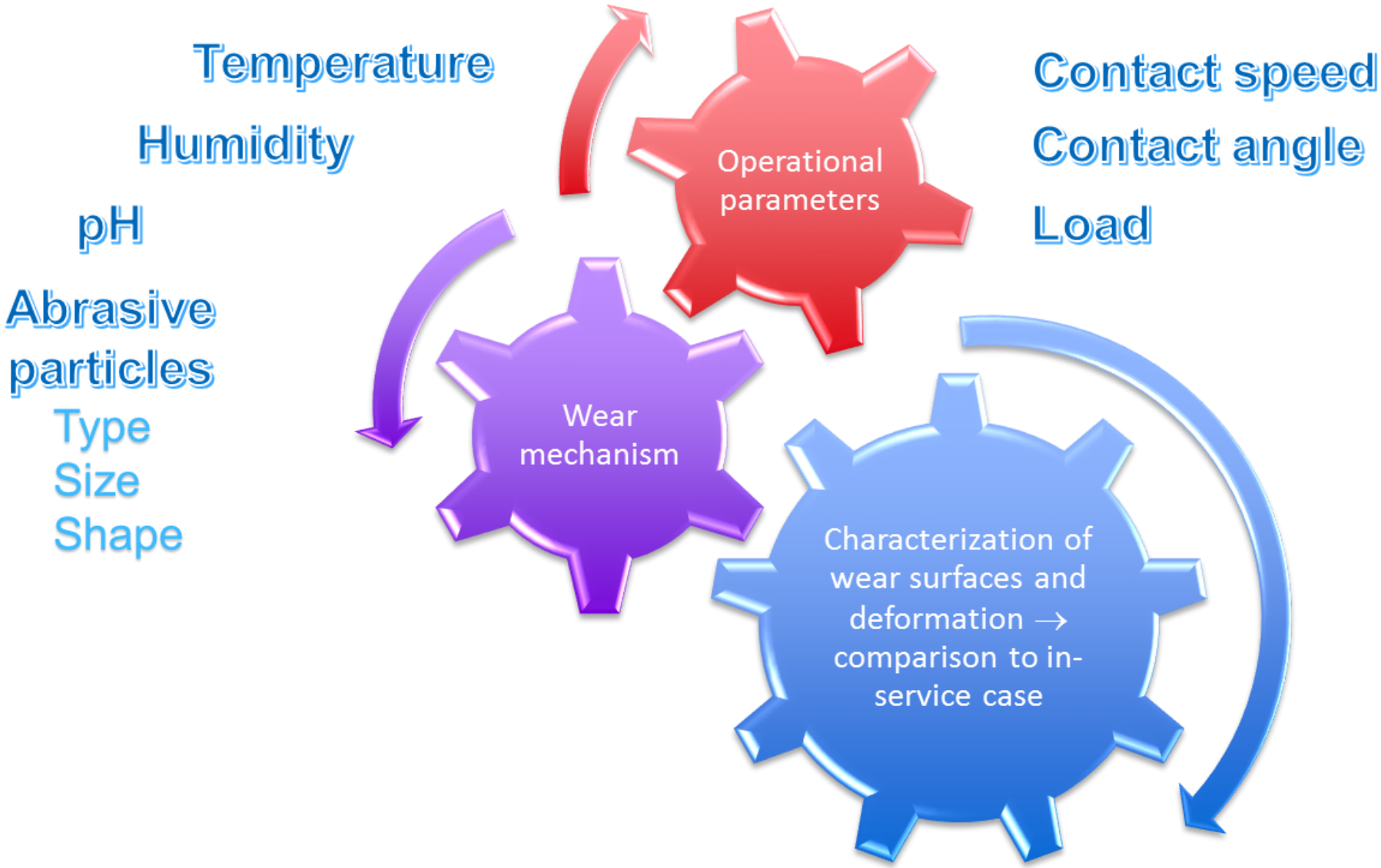
Planning of application oriented wear tests



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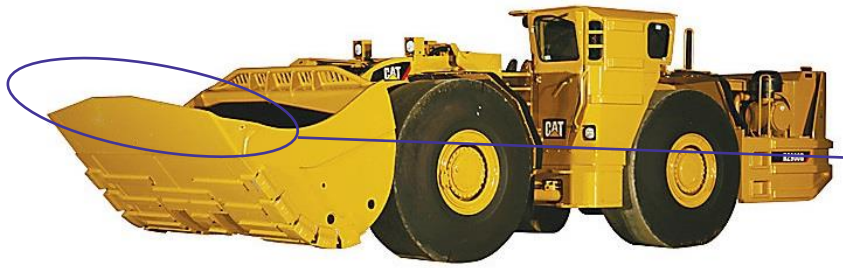
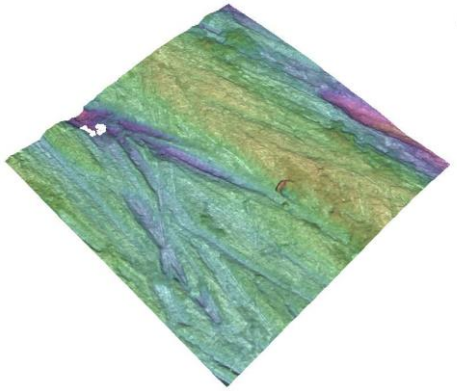
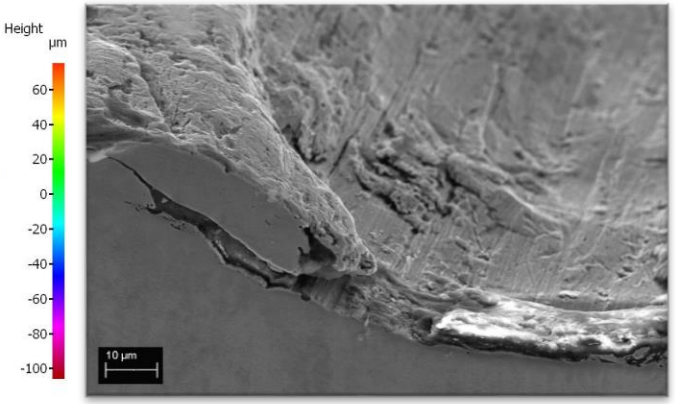
Characterization process

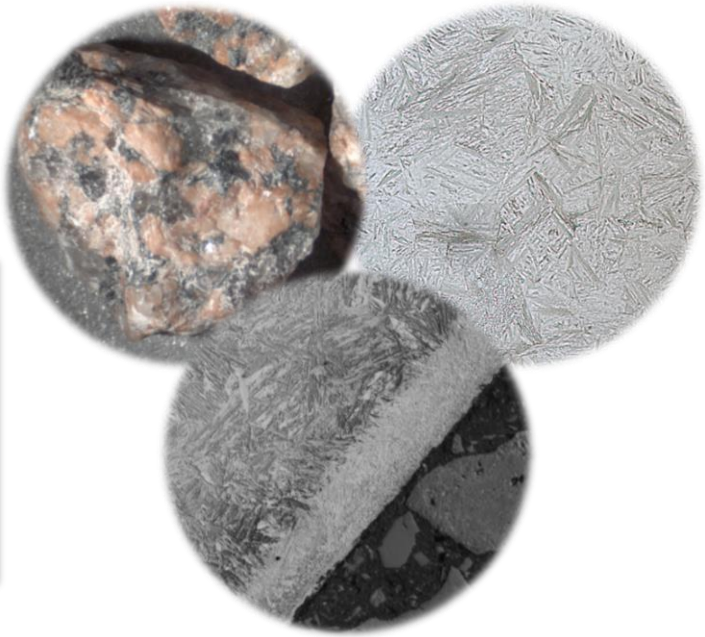


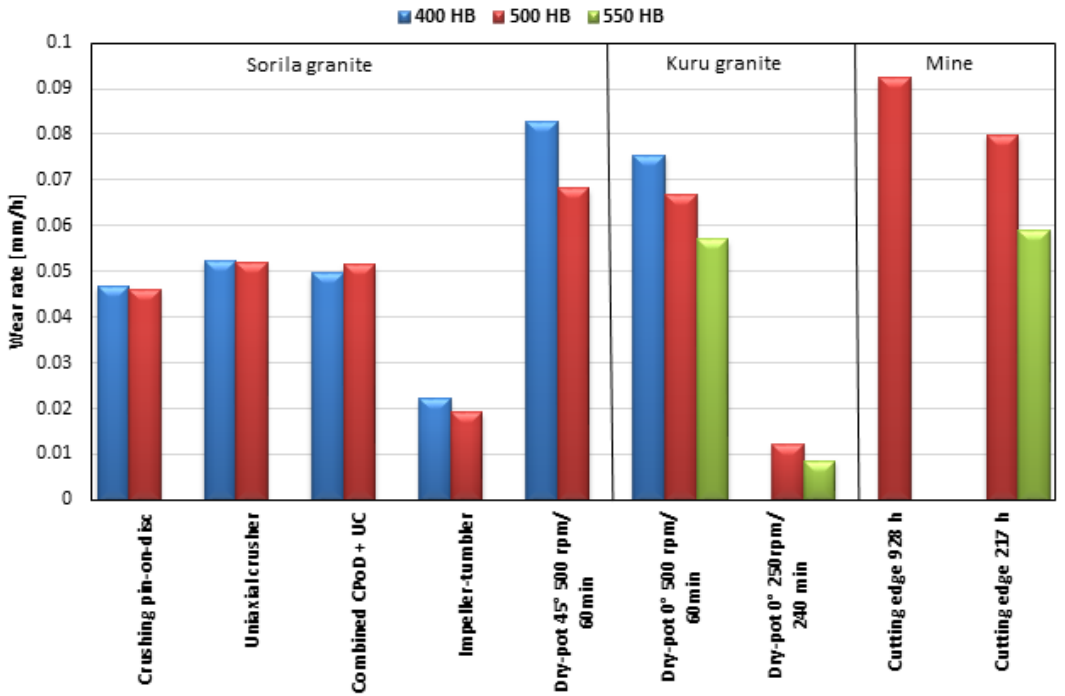




In-service

Laboratory





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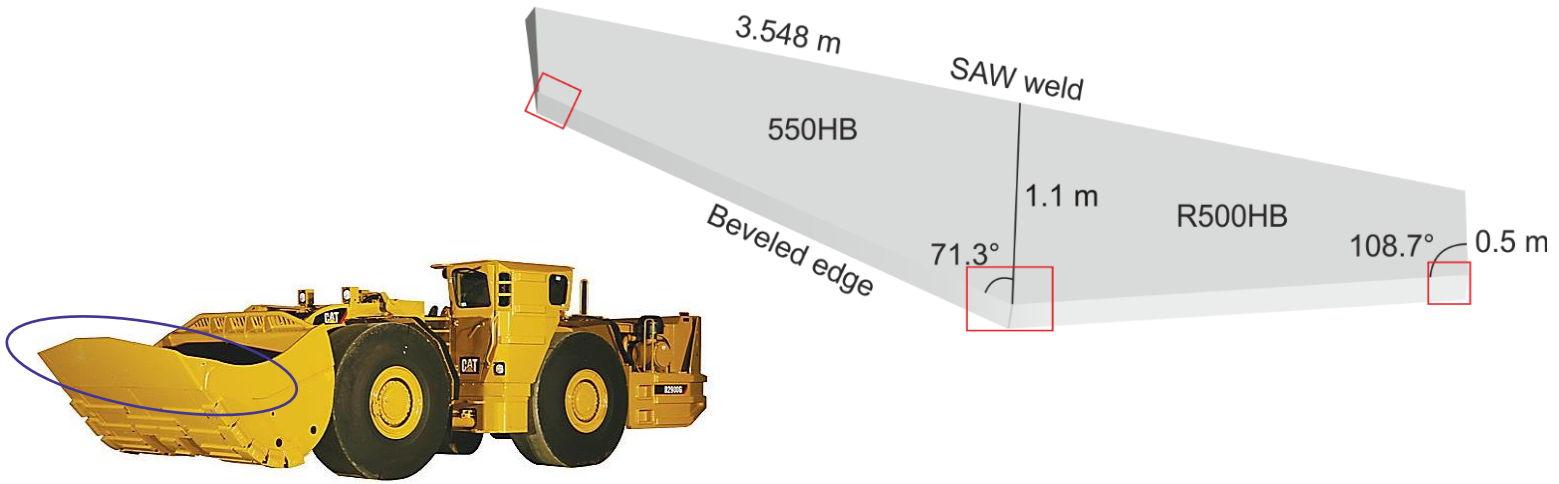
Case studies

- Wear plate of dumper truck body
  - 400 HB grade wear resistant steel
  - Use history not known
- Cutting edges of loader buckets
  - 500 HB and 550 HB grade wear resistant steels tested in the in-service use in a chromite mine 217 h



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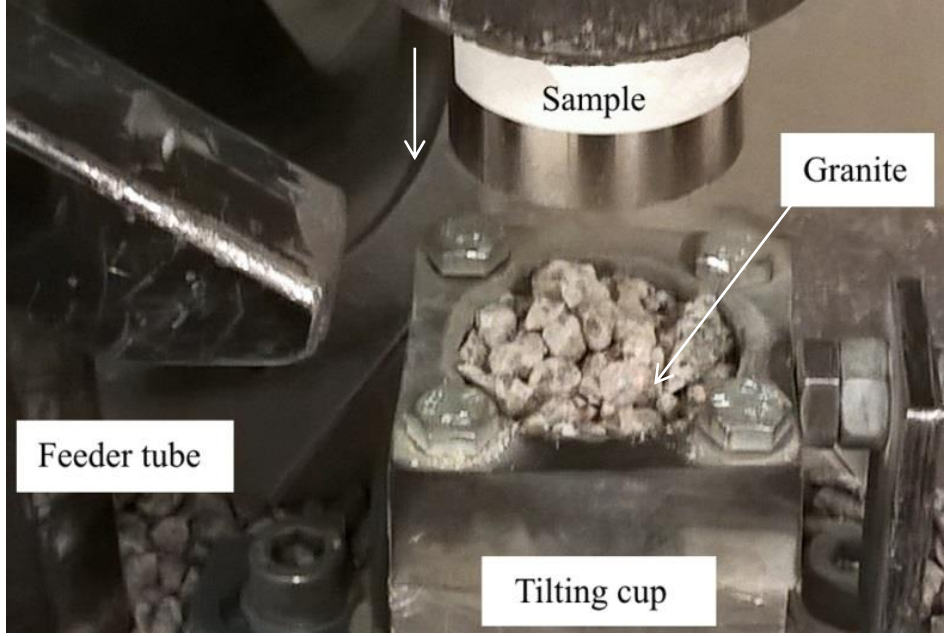
Truck

30 min test
(20 min contact)
1000 mm^2 area
Cyclic loading
200 N force
2-10 mm granite

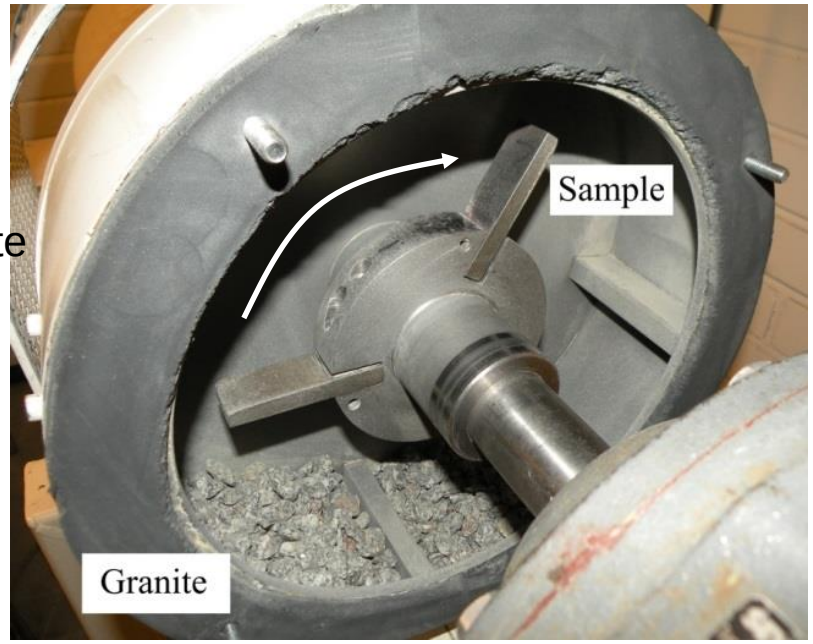
Crushing pin-on-disc (CPoD)



900 cycles
1000 mm^2 area
53 kN force
4-6.3 mm granite

Uniaxial crusher (UC)

60 min test
(= 4 x 15 min)
1200 mm^2 area
700 rpm
10-12.5 mm granite



Impeller-tumbler (IT)

Cutting edges of loader buckets

240 min test
250 rpm

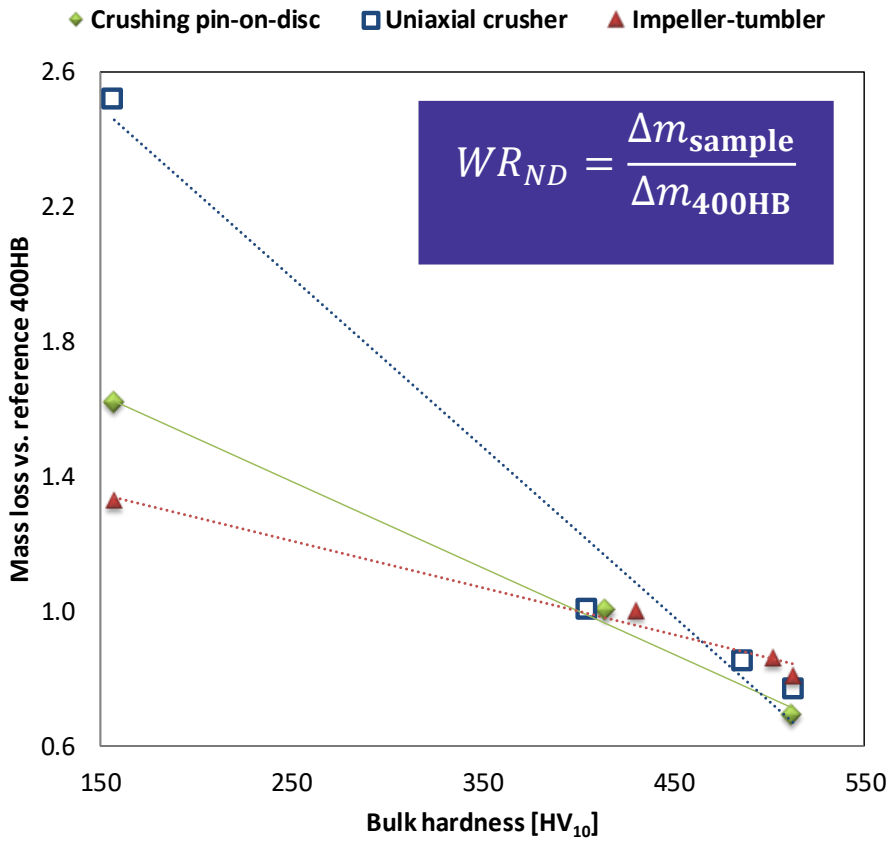
60 min test
(= 2 x 30 min)
500 rpm

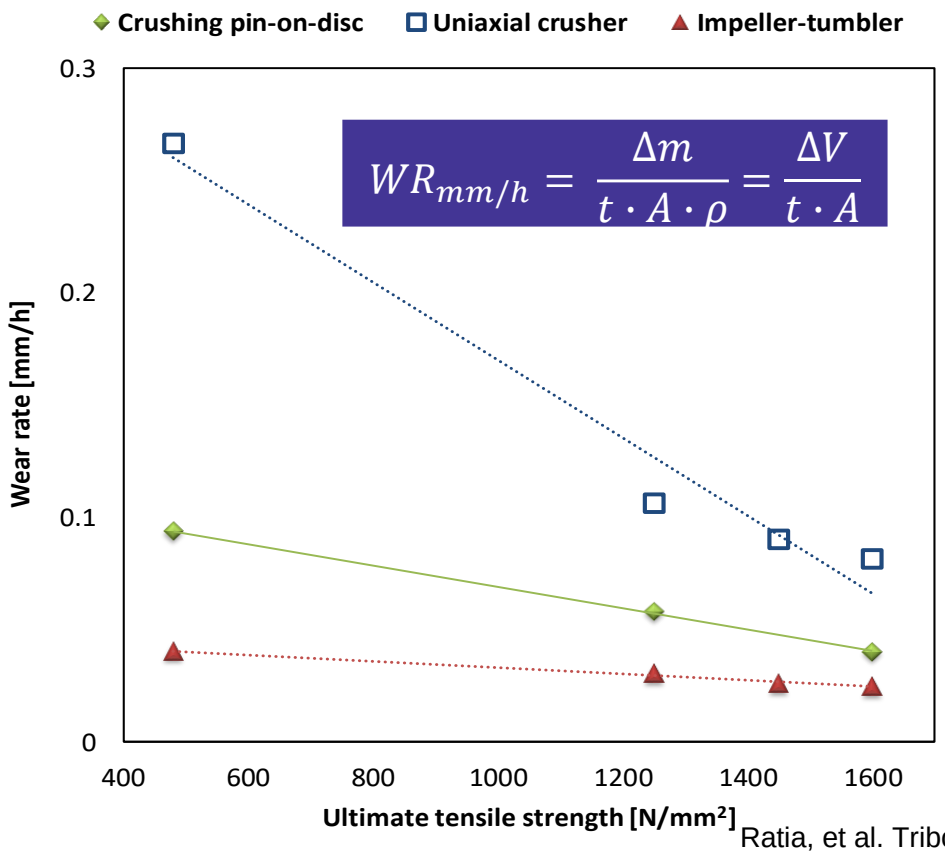
8-10 mm granite, chromite or quartzite

Slurry-pot with dry granite bed (Dry-pot)

Case 1: wear plate of dumper truck body

- Uniaxial crusher, crushing pin-on-disc, and impeller-tumbler wear test devices were used to study the wear behavior of four steel grades and to simulate the wear in a dumper truck body used to haul minerals in a mine.
- Normalization of the results by the corresponding data obtained for a reference material reveals the differences between the steels but not between the test methods.

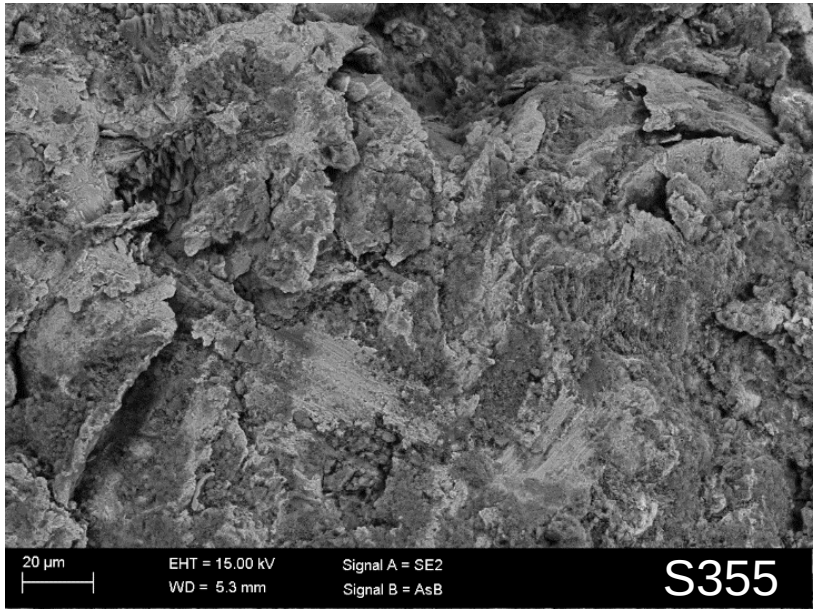


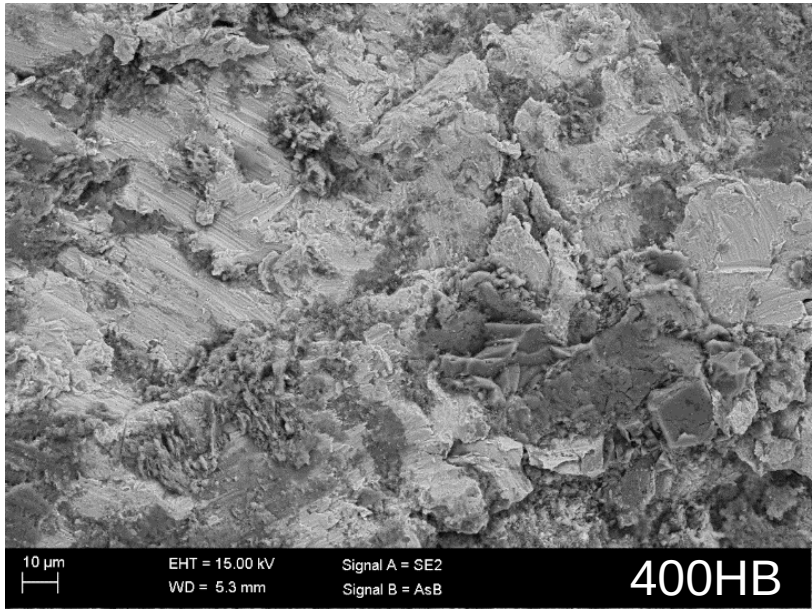


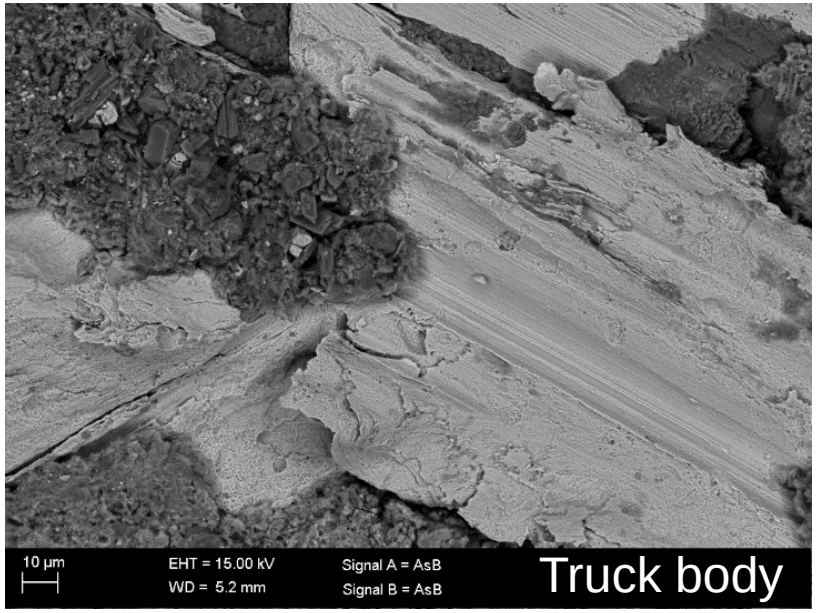
Ratia, et al. Tribol. Online 8 (2013) 152-161

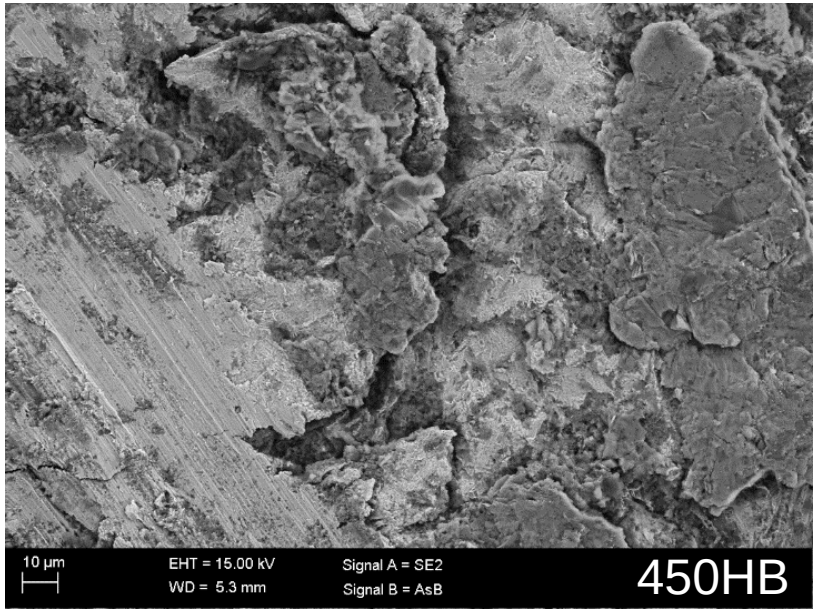
Comparison of impeller-tumbler tested samples

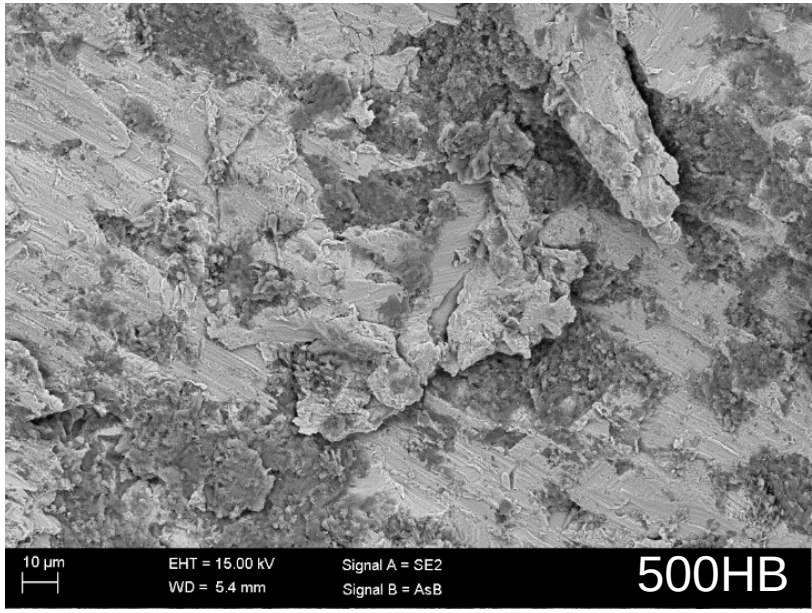
- Granite was mechanically mixed with the steel on the wear surfaces through impacts and sliding of the abrasive particles.
- Amount of sliding was much higher on the in-service case











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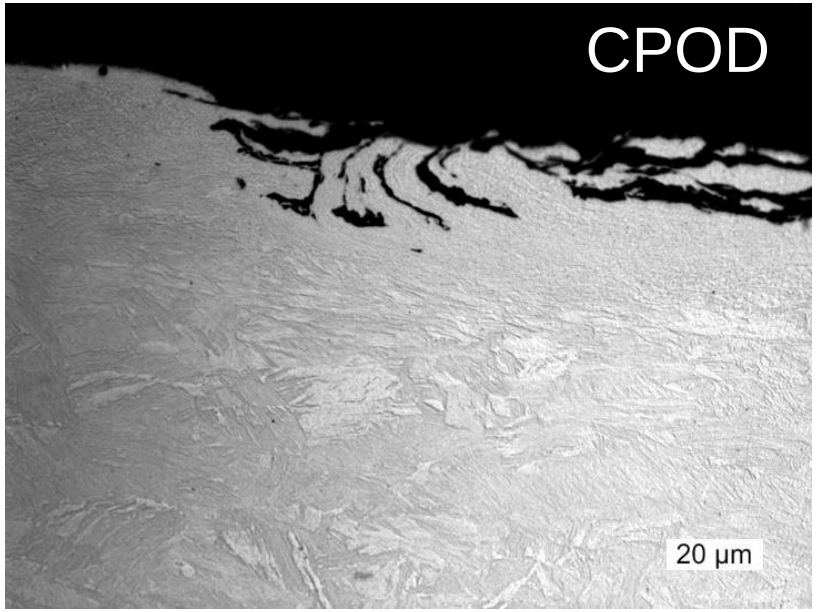
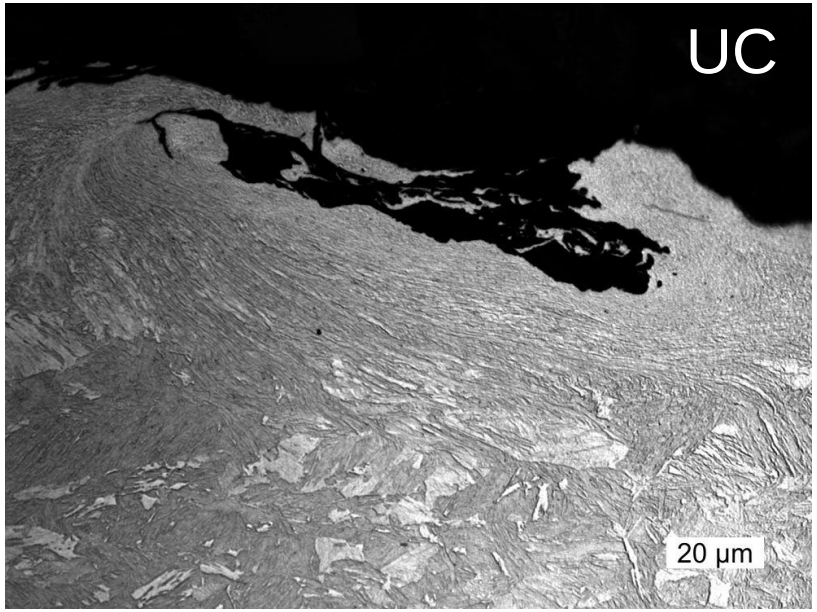
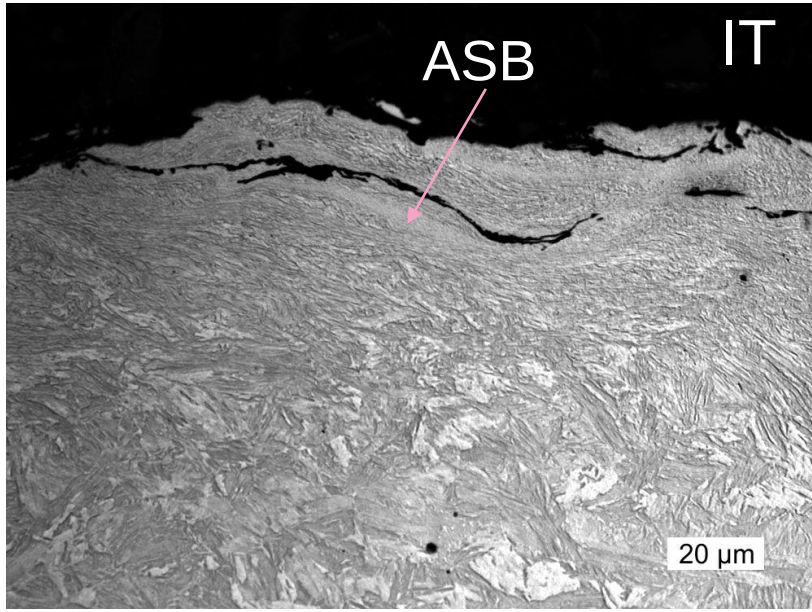
Wear testers vs. dumper truck body (400HB)

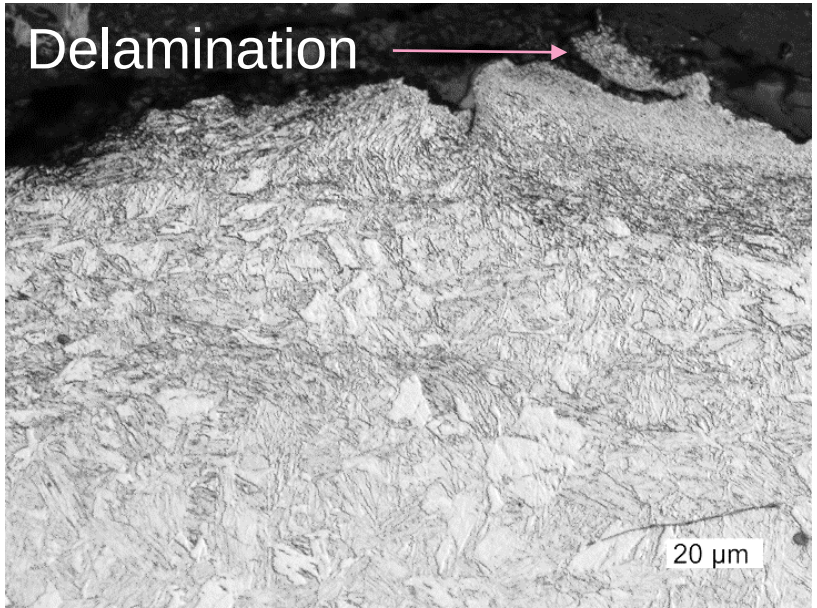
Wear testers

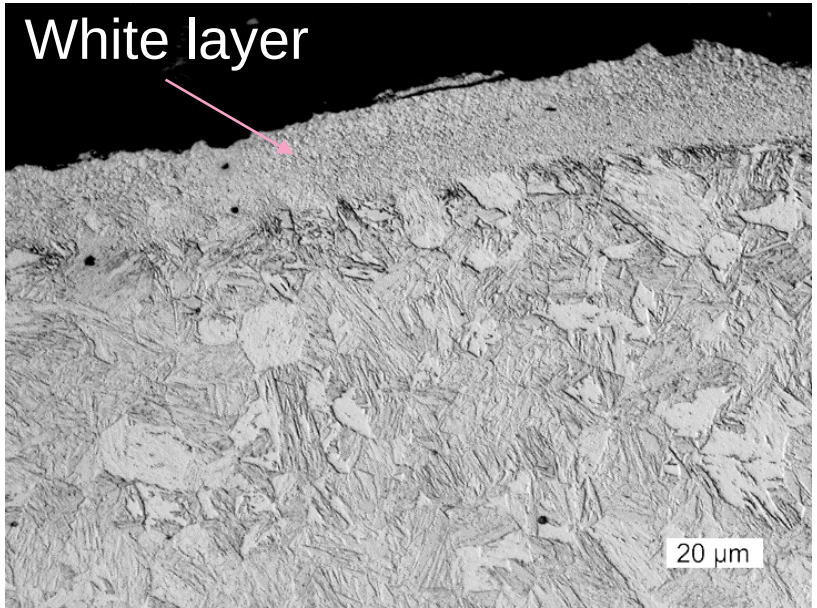


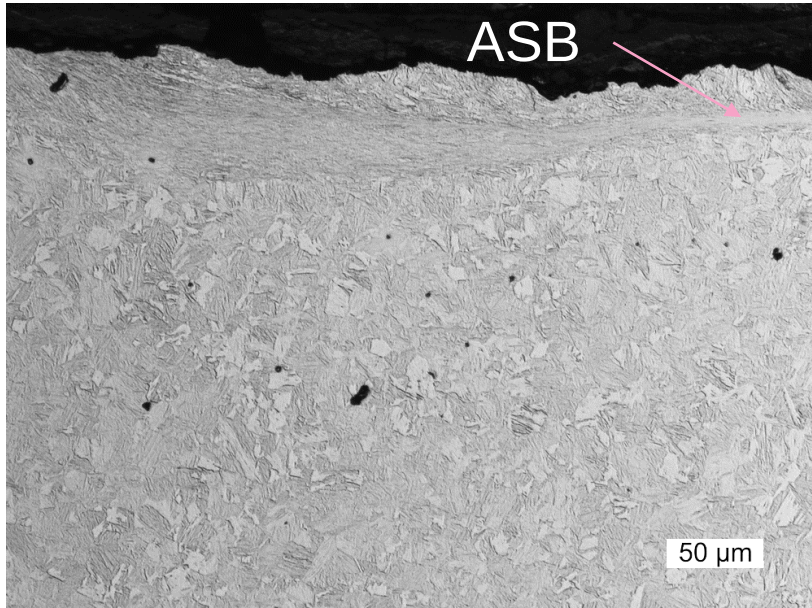




Dumper truck body



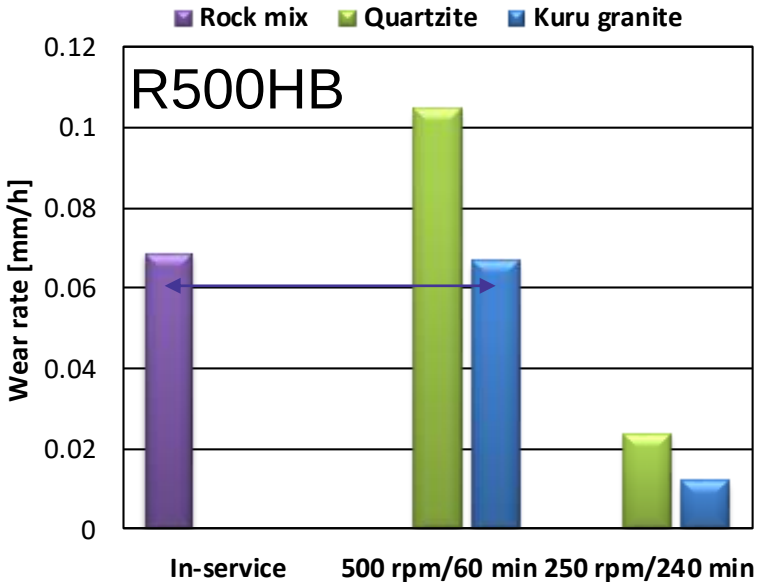


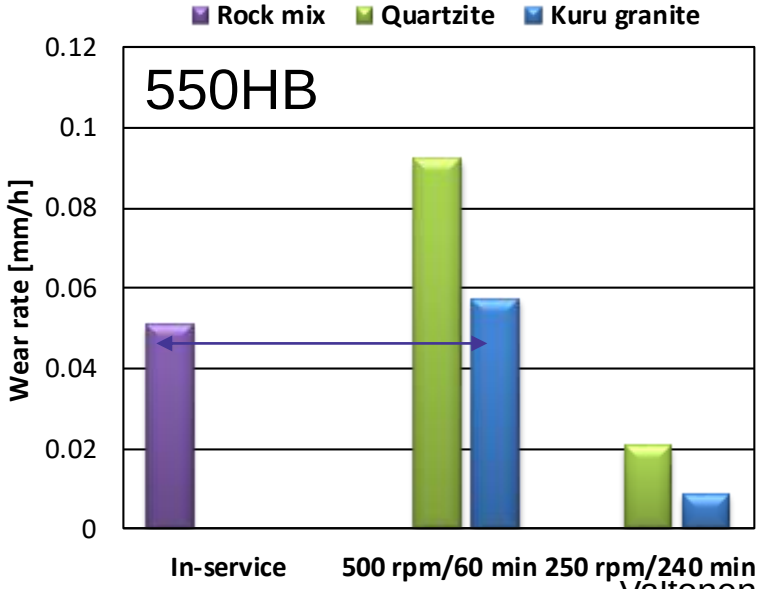


Case 2: High-stress abrasion of wear resistant steels in the cutting edges of loader buckets

- How to compare the in-service use to laboratory wear tests, when use history is known?
- Available data from the in-service use:
  - Mass loss of R500HB and 550HB steels
  - Size of the cutting edge
  - Total operation time (217 h)
  - Contact time estimated from the on-site loading videos (25% of operation time)

$$WR_{mm/h} = \frac{\Delta m}{t \cdot A \cdot \rho} = \frac{\Delta V}{t \cdot A}$$



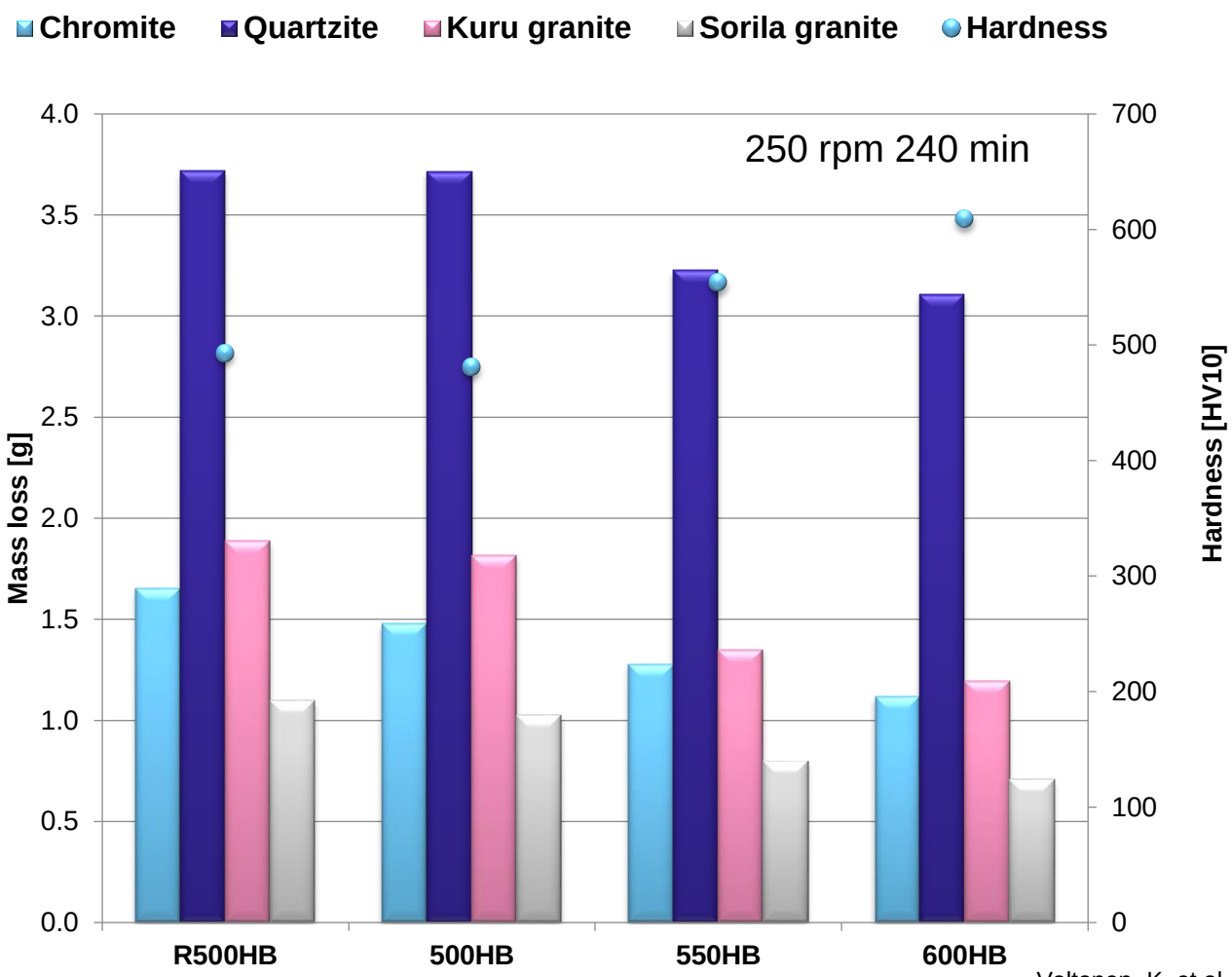


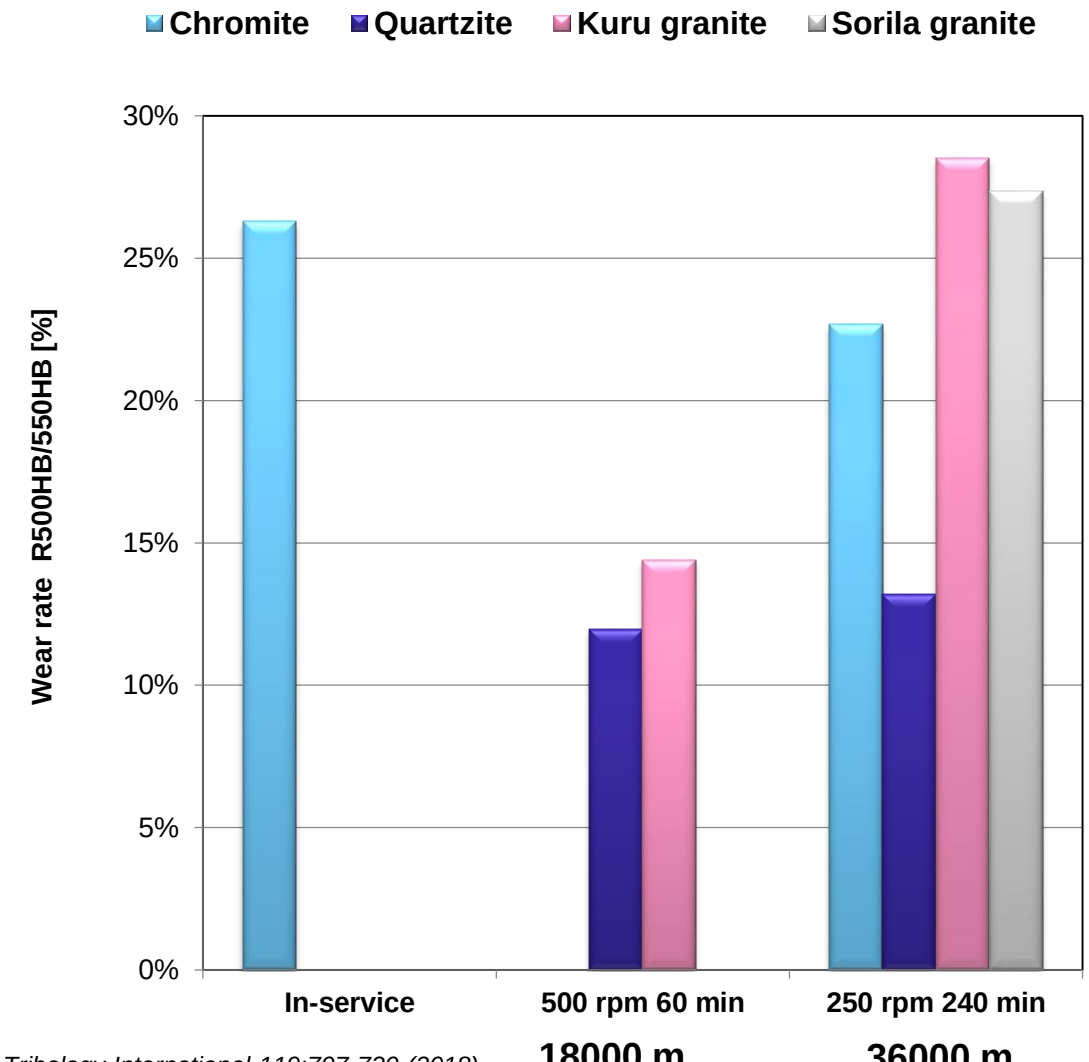
Valtonen, K. et al., *Tribology International 119:707-720 (2018).*

Effect of abrasives

	Quartzite	Chromite	Kuru granite	Sorila granite
Crushability [%]	35	79	38	38
Abrasiveness	1940	460	1380	1500

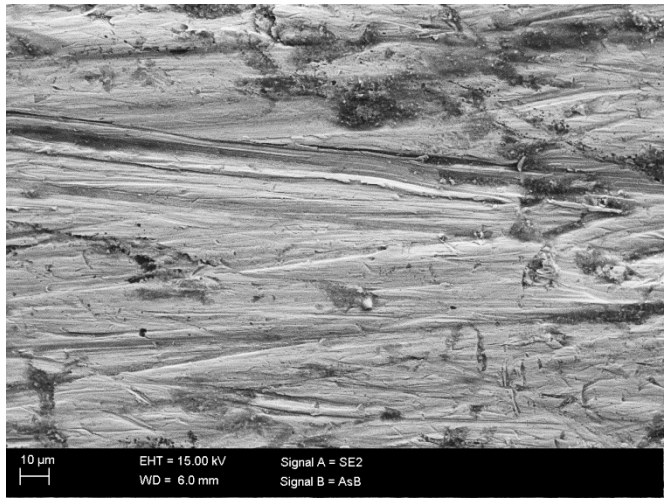
$$WR_{N\%} = \frac{\Delta m_{R500HB} - \Delta m_{550HB}}{\Delta m_{R500HB}} \cdot 100\%$$



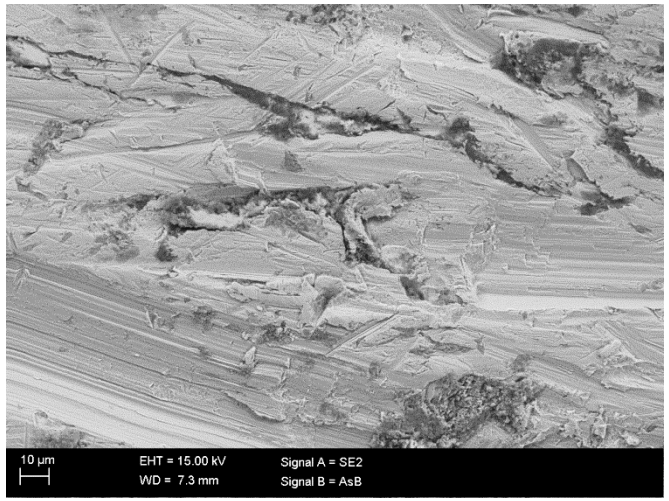


Valtonen, K. et al., *Tribology International 119:707-720 (2018).*

Wear surfaces of the in-service R500HB

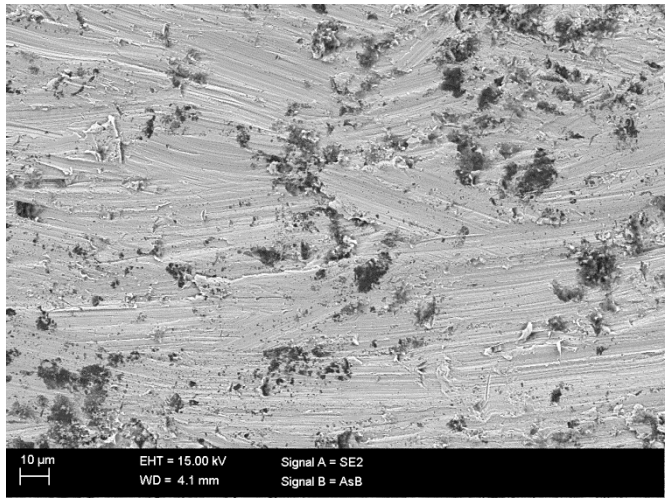


Underside

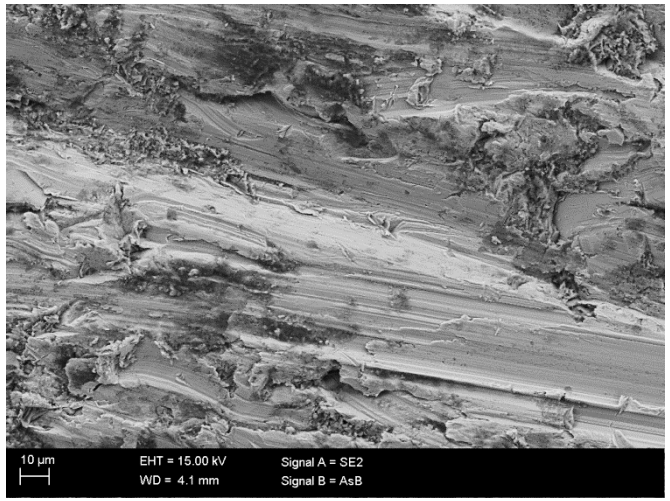


Upperside

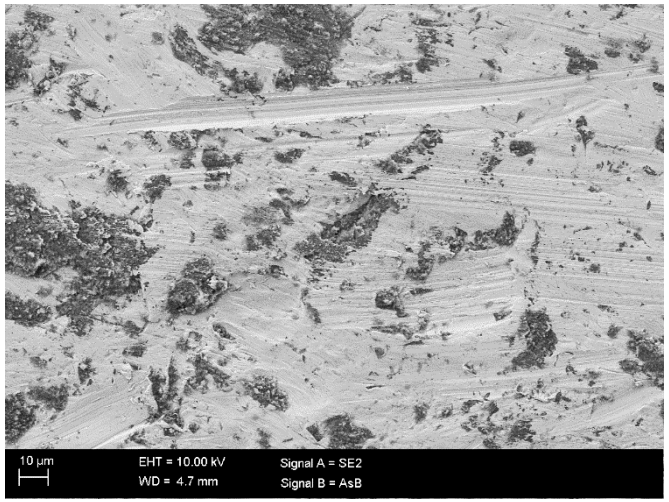
Wear surfaces of R500HB after 240 min dry-pot tests with 250 rpm



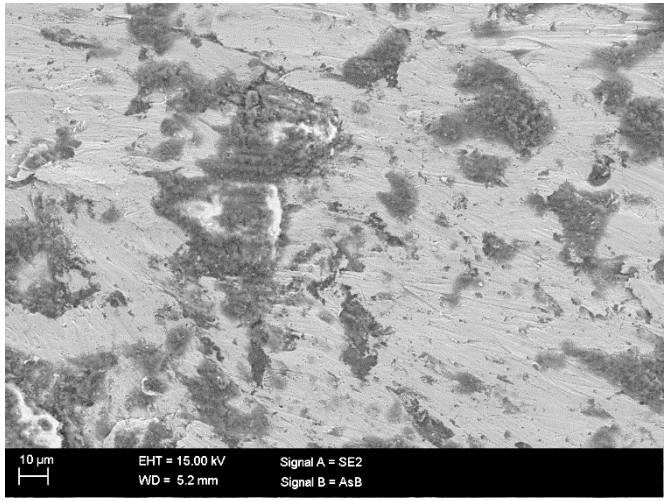
Quartzite



Chromite



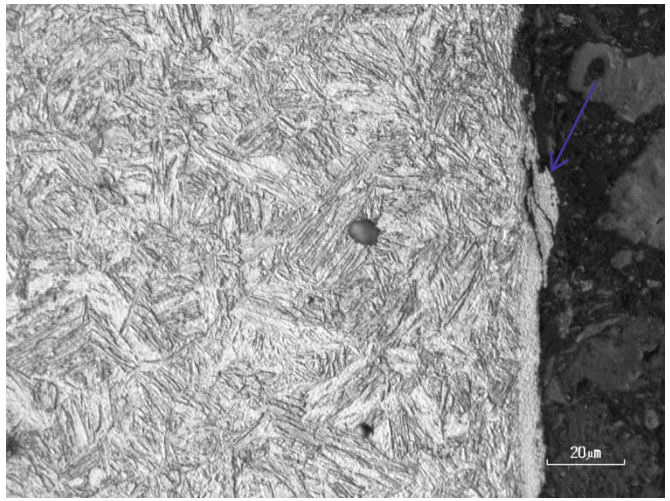
Kuru



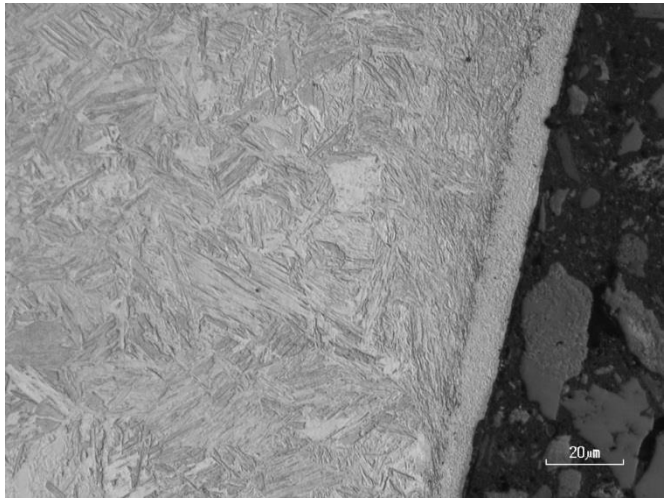
Sorila

Valtonen, K. et al., *Tribology International 119:707-720 (2018).*

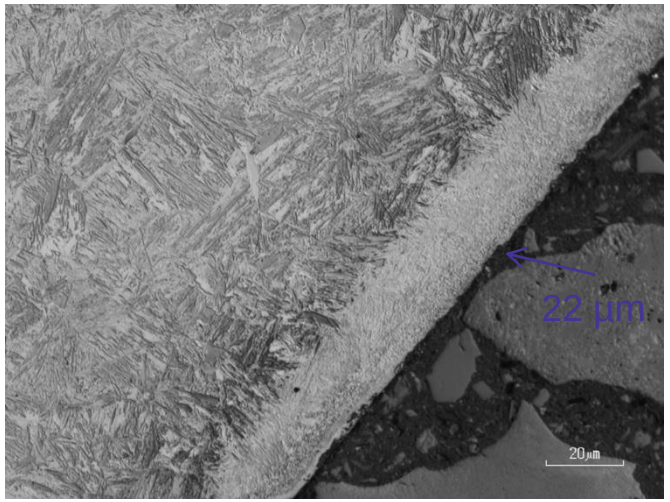
Thicker white layers were formed in the long 240 min 250 rpm tests than in the 60 min 500 rpm tests



450HB 500 rpm

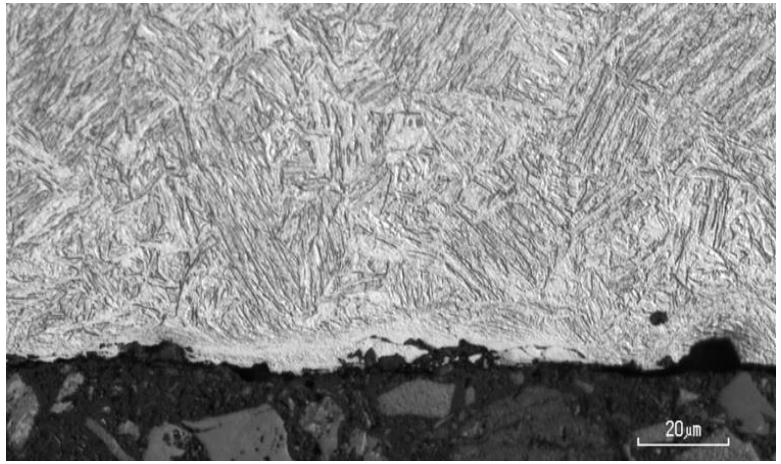


500HB 250 rpm

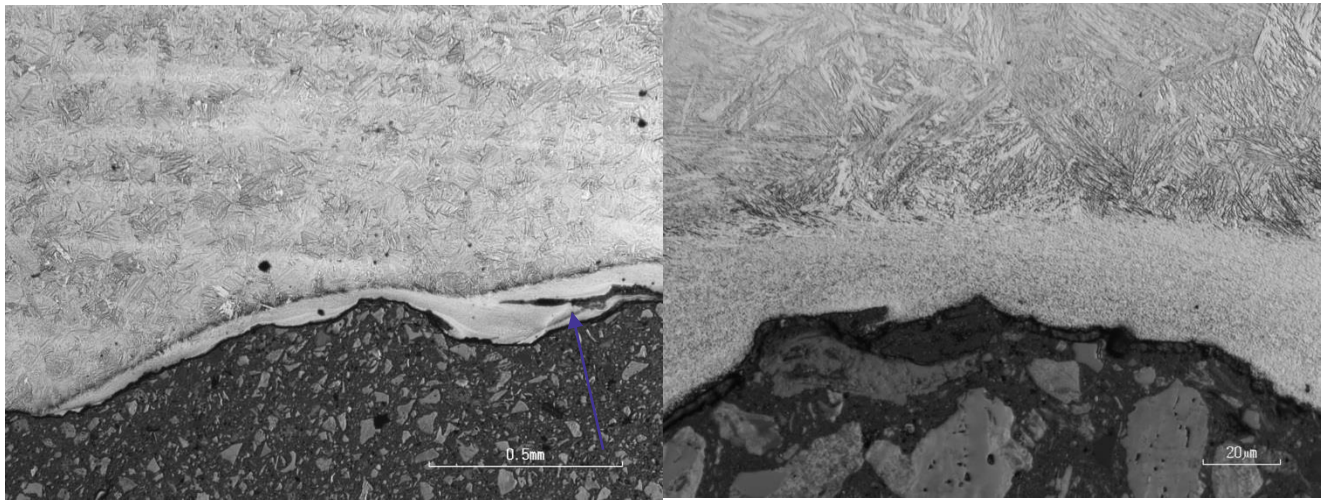


600HB 250 rpm

Thickest white layers in quartzite tests



500HB 500 rpm



Underside of the in-service R500HB sample with very thick and cracked white layer

Valtonen, K. et al., *Tribology International 119:707-720 (2018).*

Summary

- Normalization of the test results using the mass loss of a reference sample proved to be a good methodology, when comparing the wear rates of different steels.
  - Even the small differences between the different test cycles were corrected in this way.
- When different test methods are compared to each other or to the in-service data, the normalization should also take account of the differences in the contact time and the contact area in different cases.
- Essential also to characterize and compare the wear mechanisms and deformation of materials during wear.
- Only by combing these two different types of results, the relevance of the used test method can be assessed and confirmed.

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References (open access links)

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New insights into tribology and advances in electron microscopy

11th TWC International Wear Seminar, October 31st 2019
Vapriikki Museum Centre, Tampere

https://research.tuni.fi/twc/seminar/