SSAB

A stronger,
lighter and more
sustainable world

Why Hardox?

Juha Erkkilä

HARDOX®
WEAR PLATE

Aitik Mine – Sweden (-40°C)
20 mm Hardox 450
Lifetime: ~22 000 hours

50 mm
Hardox 450

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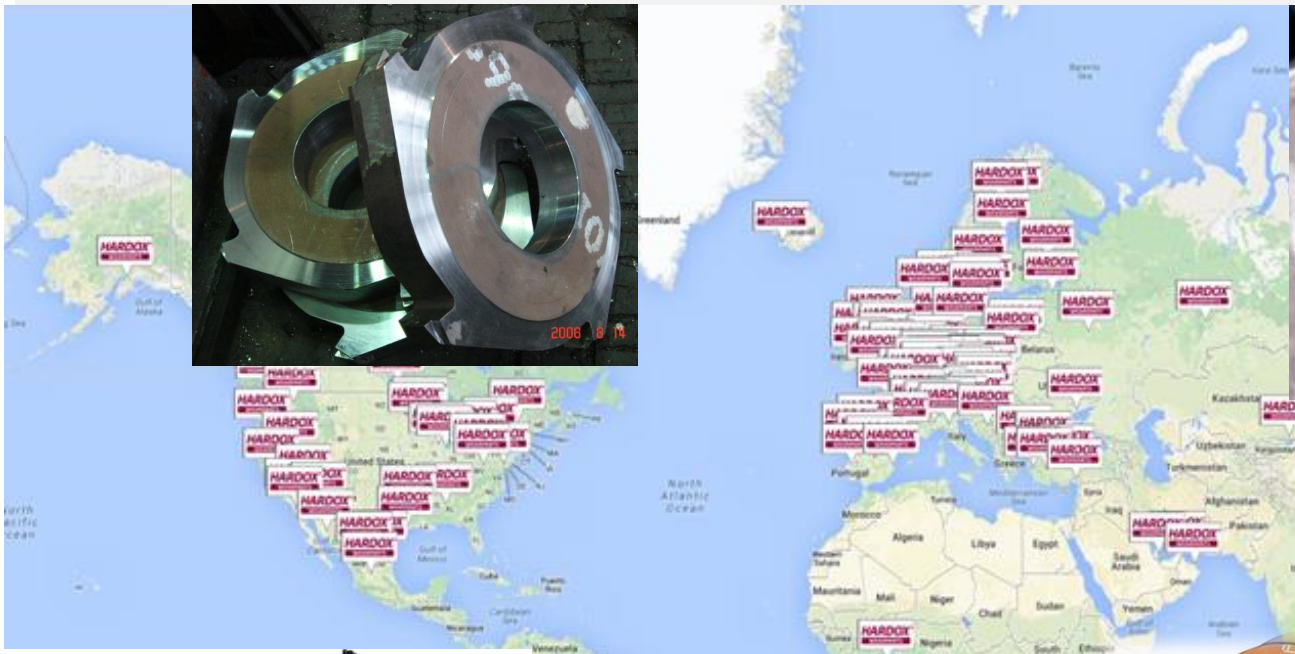
Hardox Wearparts



Hardox® Plate Product Program

Steel Grade	Hardness Nominal [HBW]	Impact toughness		Bending properties Transverse t<8 mm R/t	Rel. Service Life Interval[1]	CEV/CET[2] Typical (20 mm)	Thickness [mm]
		LCVN typical (20 mm)	TCVN minimum				
Hardox - Workshop friendly abrasion resistant wear plates for all purposes, enabling lighter, stronger and more durable applications.							
Hardox HiTuf	350	95 J –40° C[3]	40 J –40° C			0.55/0.36[3]	40–160[4]
Hardox 400	400	100 J –40° C		2.5	1	0.42/0.29	3–130
Hardox 450	450	50 J –40° C	27 J –20° C[7]	3.0	1.1–4.0	0.47/0.34	3–130[8]
Hardox 500	**500**	**37 J –40° C**	**27 J 0° C[9]**	**3.5**	**1.3–5.6**	**0.62/0.41**	**4– 103[10]**
Hardox 550	550	30 J –40° C			1.5–8.1	0.72/0.48	8–51
Hardox 600	600	20 J –40° C			1.8–12.3	0.73/0.55	8–51
Hardox Extreme	60 HRC	<15 J –40° C			2.4–17.9	0.84/0.59	8–19

All plates are produced with AccuRollTech™ precision guarantee or closer.
1. Max/min slideing wear by SSAB WearCalc (mild steel 0.2–0.8).
2. CEV=C+Mn/6+(Cr+Mo+V)/5+(Cu+Ni)/15; CET=C+(Mn+Mo)/10+(Cr+Cu)/20+Ni/40
3. 70mm
4. Thicknesses up to 170mm are under development.
5. Supplied with a cold rolled surface. Maximum width 1500mm.
6. Punch radius for a 90° bend in any direction.
7. Guaranteed CVN properties for Hardox 450 Tuf for 3 – 130 mm thicknesses
8. Thicknesses up to 160mm are under development.
9. Guaranteed CVN properties for Hardox 500 Tuf for 4 – 65 mm thicknesses
10. Thicknesses up to 120mm are under development.

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Hardox under development (AR)

- Datasheet not available on ssab.com
- Where special data sheet is avaliable it can be found at Marketspace: http://steelnet.ssab.com/Library/EMEA/MarketingSales/info_och_support/Info/information_and_news/projects_and_subjects/thick_plates/Pages/default.aspx

Grade	Thickness interval	Special data sheet
AR 350	160.1-170	Available
AR 400	130.1-160	Available
AR 450	130.1-160	Available
AR 500	103.1-120	Available
AR 550	51.1-80	Available
AR 600	51.1-65	Available
AR 650	19.1-30	Available

Wear Strip dimensions

From Borlänge	Thickness range mm
Hardox 400	3 – 8
Hardox 450	2.5 – 6**
Hardox 450 CR	0.7 – 2.1

From Raahe*	Thickness range mm
Raex 300	2 - 8
Raex 400	2 - 8
Raex 450	2.5 - 8
Raex 500	3 – 6.5

* Trial orders ongoing under Hardox name

** Trial orders up to 8 mm

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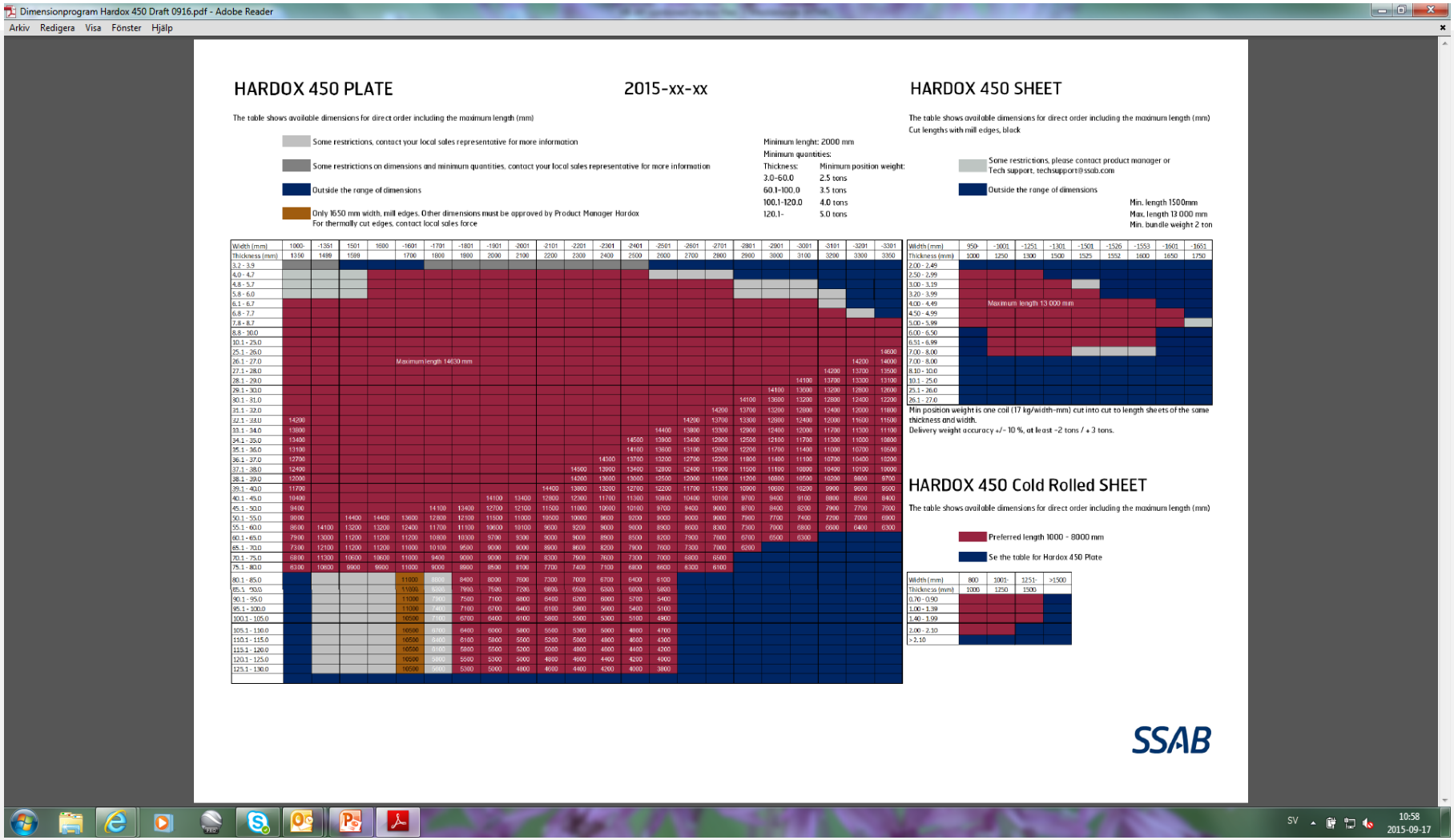
New dimensional program overview



Dimensionprogram Hardox 450 Draft 0916.pdf - Adobe Reader

Arkiv Redigera Visa Fönster Hjälp

HARDOX 450 PLATE

2015-xx-xx

The table shows available dimensions for direct order including the maximum length (mm)

Some restrictions, contact your local sales representative for more information

Some restrictions on dimensions and minimum quantities, contact your local sales representative for more information

Outside the range of dimensions

Only 1650 mm width, mill edges. Other dimensions must be approved by Product Manager Hardox
For thermally cut edges, contact local sales force

Minimum lenght: 2000 mm
Minimum quantities:

Thickness:	Minimum position weight:
3.0-60.0	2.5 tons
60.1-100.0	3.5 tons
100.1-120.0	4.0 tons
120.1-	5.0 tons

Width (mm)	1000-	-1351	1501	1600	-1601	-1701	-1801	-1901	-2001	-2101	-2201	-2301	-2401	-2501	-2601	-2701	-2801	-2901	-3001	-3101	-3201	-3301
Thickness (mm)	1350	1499	1599		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2900	2900	3000	3100	3200	3300	3350
3.2 - 3.9																						
4.0 - 4.7																						
4.8 - 5.7																						
5.8 - 6.0																						
6.1 - 6.7																						
6.8 - 7.7																						
7.8 - 8.7																						
8.8 - 10.0																						
10.1 - 25.0																						
25.1 - 26.0																						14600
26.1 - 27.0						Maximum length 14630 mm															14200	14000
27.1 - 28.0																				14200	13700	13500
28.1 - 29.0																			14100	13700	13300	13100
29.1 - 30.0																		14100	13600	13200	12800	12600
30.1 - 31.0																	14100	13600	13200	12800	12400	12200
31.1 - 32.0																14200	13700	13200	12900	12400	12000	11800
32.1 - 33.0	14200														14200	13700	13300	12800	12400	12000	11600	11500
33.1 - 34.0	13900													14400	13800	13300	12900	12400	12000	11700	11300	11100
34.1 - 35.0	13400												14500	13900	13400	12900	12500	12100	11700	11300	11000	10800
35.1 - 36.0	13100												14100	13600	13100	12600	12200	11700	11400	11000	10700	10500
36.1 - 37.0	12700											14500	13700	13200	12700	12200	11800	11400	11100	10700	10400	10200
37.1 - 38.0	12400										14500	13900	13400	12800	12400	11900	11500	11100	10800	10400	10100	10000
38.1 - 39.0	12000										14200	13600	13000	12500	12000	11600	11200	10800	10500	10200	9800	9700
39.1 - 40.0	11700									14400	13800	13200	12700	12200	11700	11300	10900	10600	10200	9900	9600	9500
40.1 - 45.0	10400							14100	13400	12800	12300	11700	11300	10800	10400	10100	9700	9400	9100	8800	8500	8400
45.1 - 50.0	9400					14100	13400	12700	12100	11500	11000	10600	10100	9700	9400	9000	8700	8400	8200	7900	7700	7600
50.1 - 55.0	9000		14400	14400	13600	12800	12100	11500	11000	10500	10000	9600	9200	9000	9000	9000	7900	7700	7400	7200	7000	6900
55.1 - 60.0	8600	14100	13200	13200	12400	11700	11100	10600	10100	9600	9200	9000	9000	8900	8600	8300	7300	7000	6800	6600	6400	6300
60.1 - 65.0	7900	13000	11200	11200	11200	10800	10300	9700	9300	9000	9000	8900	8500	8200	7900	7600	6700	6500	6300			
65.1 - 70.0	7300	12100	11200	11200	11000	10100	9590	9000	9000	8900	8600	8200	7900	7600	7300	7000	6200					
70.1 - 75.0	6800	11300	10600	10600	11000	9400	9000	9000	8700	8300	7900	7600	7300	7000	6800	6500						
75.1 - 80.0	6300	10600	9900	9900	11000	9000	8990	8500	8100	7700	7400	7100	6800	6600	6300	6100						
80.1 - 85.0					11000	8800	8400	8000	7690	7300	7000	6700	6400	6100								
85.1 - 90.0					11000	8300	7900	7500	7200	6800	6500	6300	6000	5800								
90.1 - 95.0					11000	7900	7500	7100	6800	6400	6200	6000	5700	5400								
95.1 - 100.0					11000	7400	7100	6700	6400	6100	5900	5600	5400	5100								
100.1 - 105.0					10500	7100	6700	6400	6100	5800	5500	5300	5100	4900								
105.1 - 110.0					10500	6700	6400	6000	5800	5500	5300	5000	4800	4700								
110.1 - 115.0					10500	6400	6100	5800	5500	5200	5000	4800	4600	4500								
115.1 - 120.0					10500	6100	5800	5500	5200	5000	4800	4600	4400	4200								
120.1 - 125.0					10500	5800	5500	5300	5000	4800	4600	4400	4200	4000								
125.1 - 130.0					10500	5600	5300	5000	4800	4600	4400	4200	4000	3800								

HARDOX 450 SHEET

The table shows available dimensions for direct order including the maximum length (mm)
Cut lengths with mill edges, black

Some restrictions, please contact product manager or Tech support, techsupport@ssab.com

Outside the range of dimensions

Min. length 1500mm
Max. length 13 000 mm
Min. bundle weight 2 ton

Width (mm)	950-	-1001	-1251	-1301	-1501	-1526	-1553	-1601	-1651
Thickness (mm)	1000	1250	1300	1500	1525	1552	1600	1650	1750
2.00 - 2.49									
2.50 - 2.99									
3.00 - 3.19									
3.20 - 3.99									
4.00 - 4.49			Maximum length 13 000 mm						
4.50 - 4.99									
5.00 - 5.99									
6.00 - 6.50									
6.51 - 6.99									
7.00 - 8.00									
7.00 - 8.00									
8.10 - 10.0									
10.1 - 25.0									
25.1 - 26.0									
26.1 - 27.0									

Min position weight is one coil (17 kg/width-mm) cut into cut to length sheets of the same thickness and width.
Delivery weight accuracy +/- 10 %, at least -2 tons / + 3 tons.

HARDOX 450 Cold Rolled SHEET

The table shows available dimensions for direct order including the maximum length (mm)

Preferred length 1000 - 8000 mm

Se the table for Hardox 450 Plate

Width (mm)	800	1001-	1251-	>1500
Thickness (mm)	1000	1250	1500	
0.70 - 0.90				
1.00 - 1.39				
1.40 - 1.99				
2.00 - 2.10				
> 2.10				

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Benefit of Hardox

A unique combination of hardness, toughness and good workshop properties

Bending

Drilling

Milling

Welding

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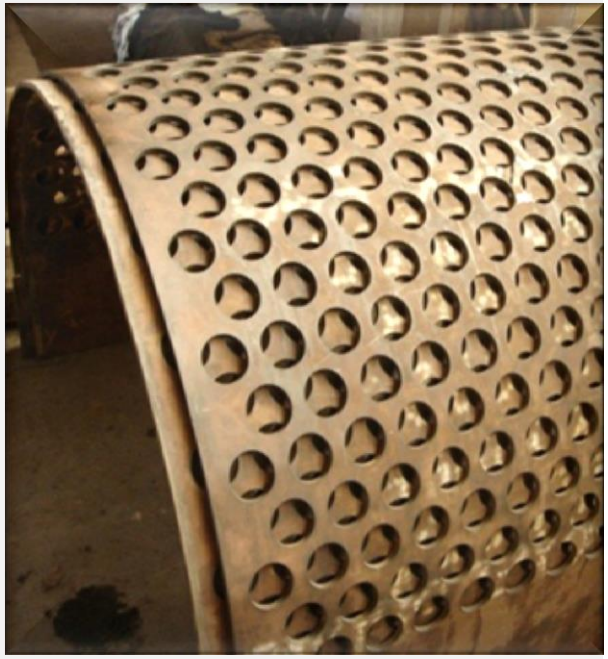
High Hardness and High Toughness with excellent workshop properties – Cost savings

- Excellent toughness
  - **Possible to use higher hardness!**
- Higher hardness, longer service life
  - **Life-cycle cost advantage!**
  - **Less down time!**
- Excellent workshop properties due to clean steel
  - **Lower manufacturing costs!**

HARDOX®
WEAR PLATE



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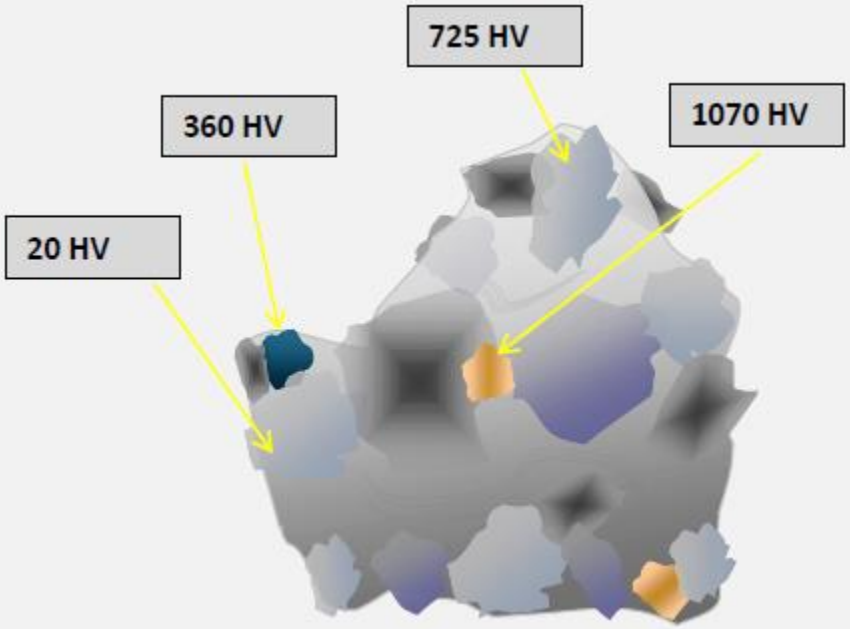
Increasing lifetime by managing wear

How to predict wear and increase service life

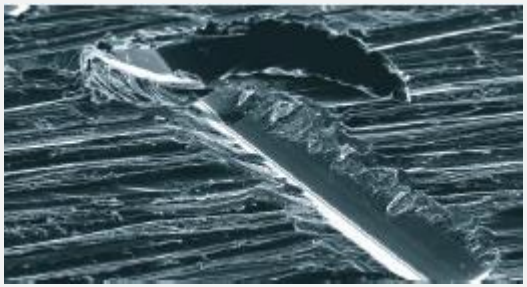


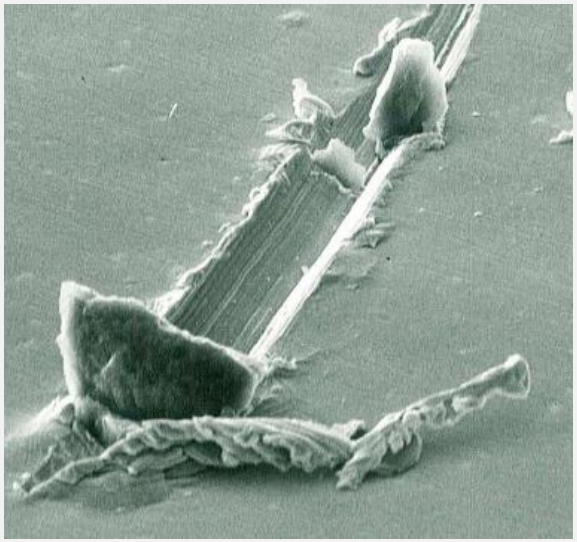
Relative hardness (H_r)

$$\frac{Rock\ hardness}{Plate\ hardness} = H_r$$

$H_r > 1.8$ *Micro cutting*

$H_r < 1.5$ *Micro ploughing*





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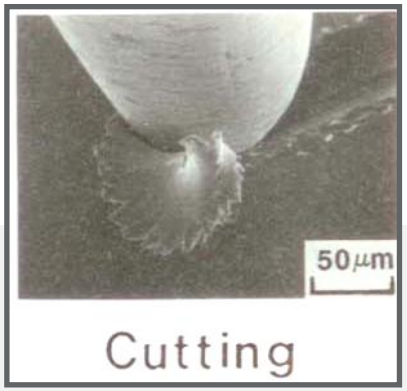
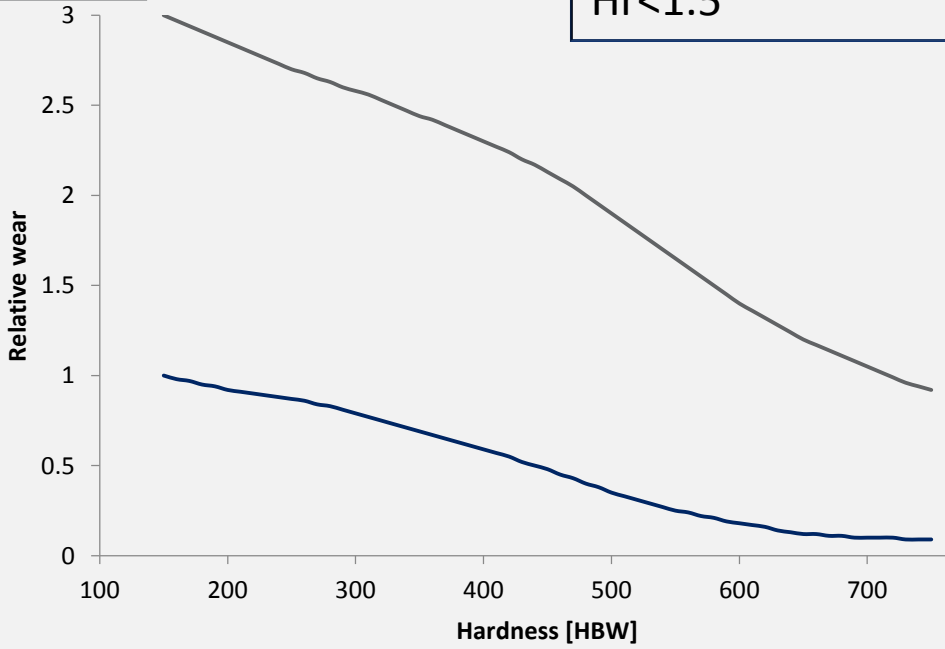
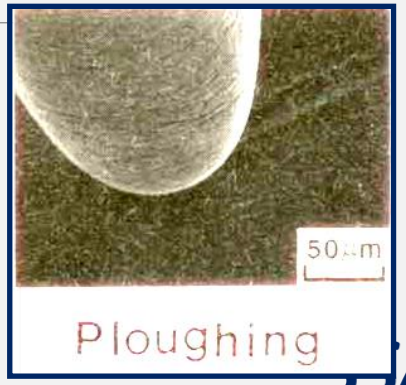


Hr>1.8	Cutting
1.8≥Hr ≥ 1.5	Transition
Hr<1.5	Plastic deformation

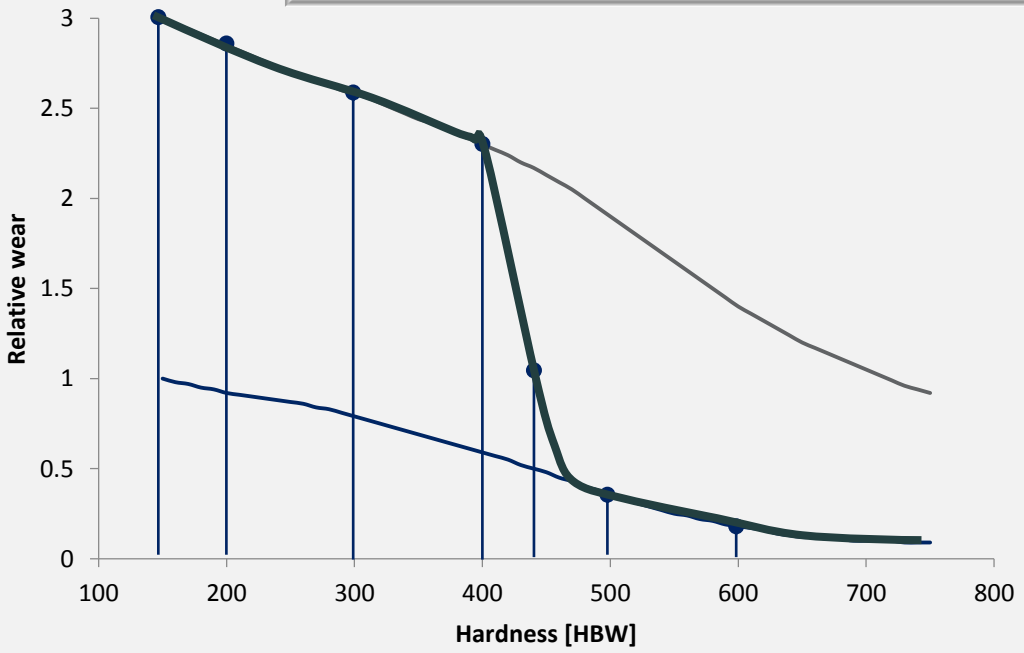




Hr>1.8	Cutting
1.8≥Hr ≥ 1.5	Transition
Hr<1.5	Plastic deformation

Assume Ha=725HV

If Hp=600
Hr=Ha/Hp=725/600
Hr=1.21
1.5>1.21 → Plastic deformation



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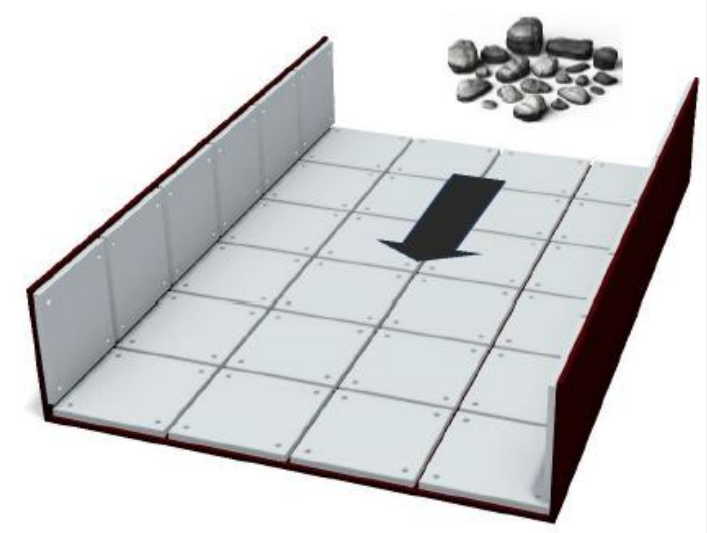
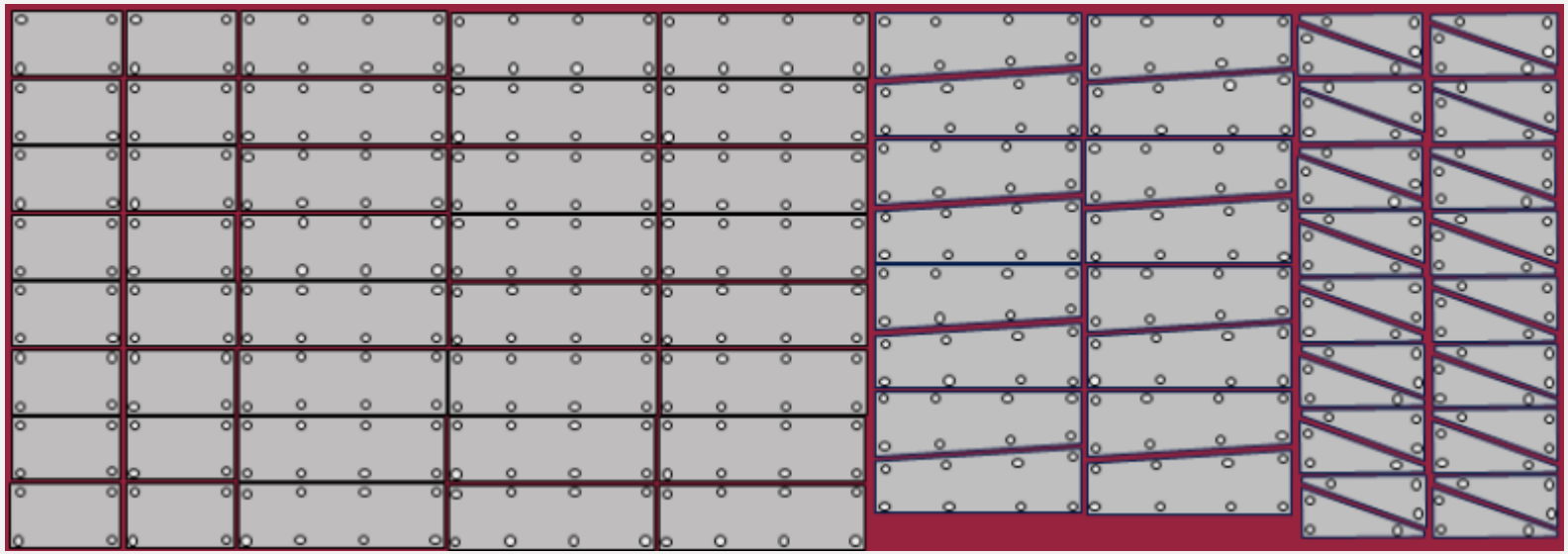
How to select material – an example

Quarry chute handling waste rock containing both hard and soft minerals – what material to use?

- 2500 x 6000 x 30 [mm]
- 88 liner plates
- 140 m flame cutting
- 480 counter sunk holes





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How to select material – an example

	Mild Steel	Hardox 400	Hardox 500	Hardox 600
Plate price	2 200	4 500	5 000	6 500
Drilling costs	1 600	2 000	2 400	2 900
Cutting cost	250	270	300	350
Transport cost	300	300	300	300
Attaching plates	1 100	1 100	1 100	1 100
Over head	500	500	500	500
Total cost to produce one set	**€ 5 950**	**€ 8 670**	**€ 9 300**	**€ 11 650**

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How to select material – an example

	Mild steel	Hardox 400	Hardox 500	Hardox 600
Manufacturing and attachment	5 950	8 670	9 300	11 650
Relative service life	1.0	2.1	4.5	6.3
Absolute service life (days)	100	210	450	630
Yearly maintenance cost (€)	21 710	15 070	7 540	6 750
Yearly Down time cost (€)*	28 970	23 800	8 730	3 910
Yearly total cost (€)	**50 680**	**38 870**	**16 270**	**10 660**

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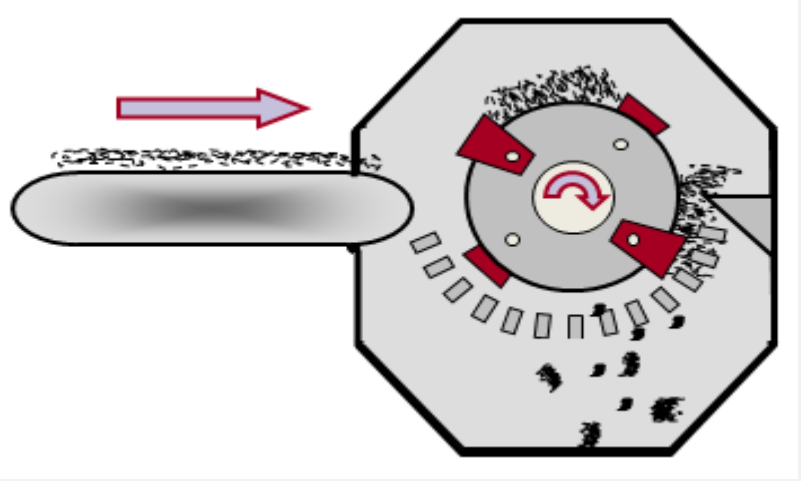
Metal scrap hammers

- The sandwich hammer made by Hardox 500 tested in scrap processing



Previous life time for hammers measured in scrap volumes:

- S690Ql – 1600 tons
- Hardox 400 – 2500 tons
- Original 12%Mn steel – 7000 tons
- New „adwance“ 12%Mn steel – 9700 tons
- Hardox 500 (sandwich) – 14500 tons

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Take the properties into use!

Screen of a shredder

Steelgrade: Hardox 500
Thickness range: 6-10 mm
Industry segment: Recycling
Description of the application
The screens are used in the shredder processing plastic waste. They work as last "cutter" as well. To utillize the material they are roller bending the screen after ca 800 hour to the opposite radius.
Previous material
400 HBW steel
Service life
1100 hours (800 + 300)
Competitive advantage
Service life
Manufacturing steps
Cutting method - Laser cutting;
Bending method - Roll bending

Status: Success

Reason for failure or success
500 HBW together with good toughness

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…and save money!

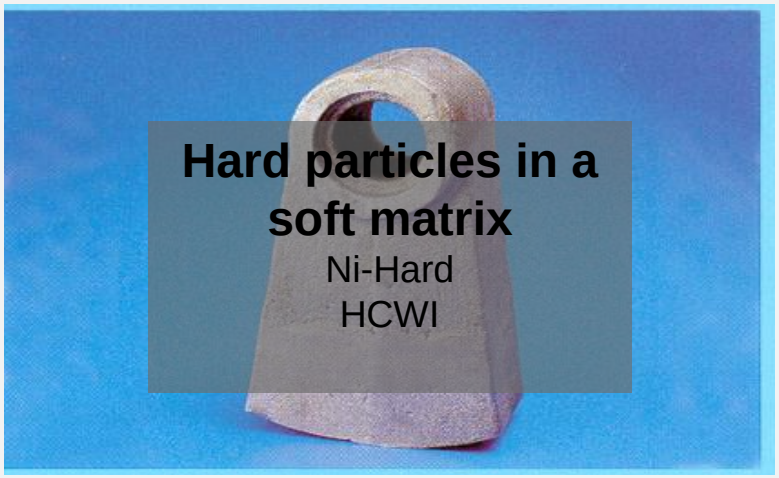
- Shears cutting the scrap at the scrap yard prior to use in steel mill

- Currently using OEM spare parts made out 52 HRC tool steel
  - Worn out in 10 days
  - Cost of the blades really high → 7000 USD/ton
  - Delivery time ~6 months

Different materials in recycling applications

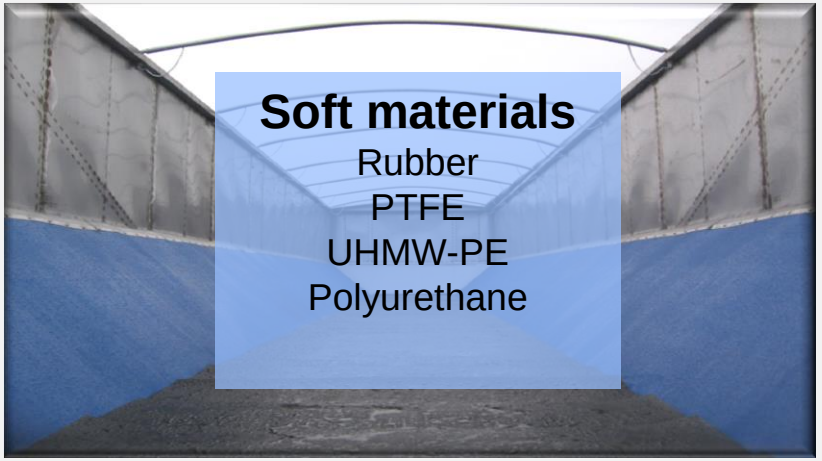
Wear resistant materials

Hard materials
QT-steel
Mn-Steel
Co-alloys
Case hardening
Tool steel



Hard particles in a soft matrix
Ni-Hard
HCWI

Very hard materials
Ceramics



Soft materials
Rubber
PTFE
UHMW-PE
Polyurethane

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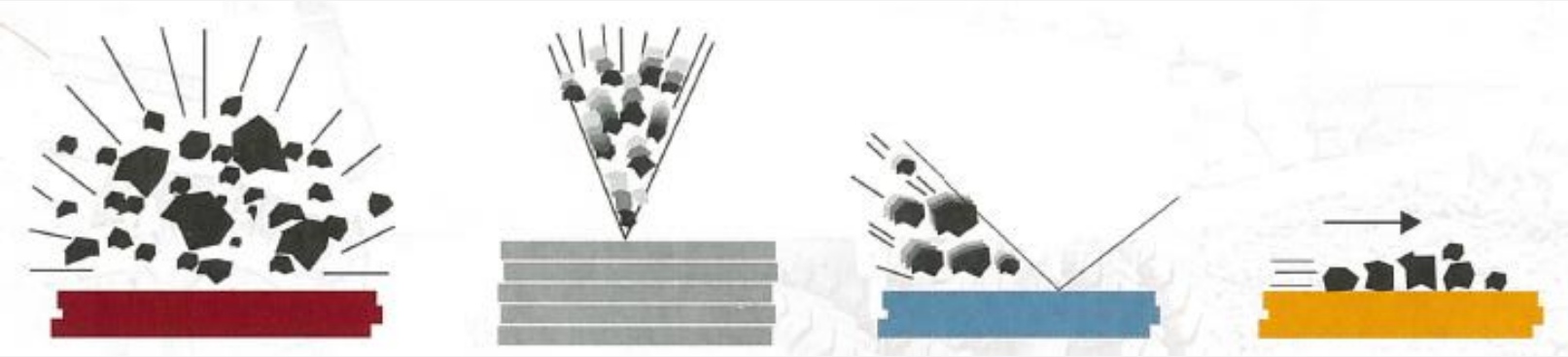
Wear resistant materials



Quenched and tempered steel plate

Soft wear materials

Hard particles in a soft matrix

Very hard materials

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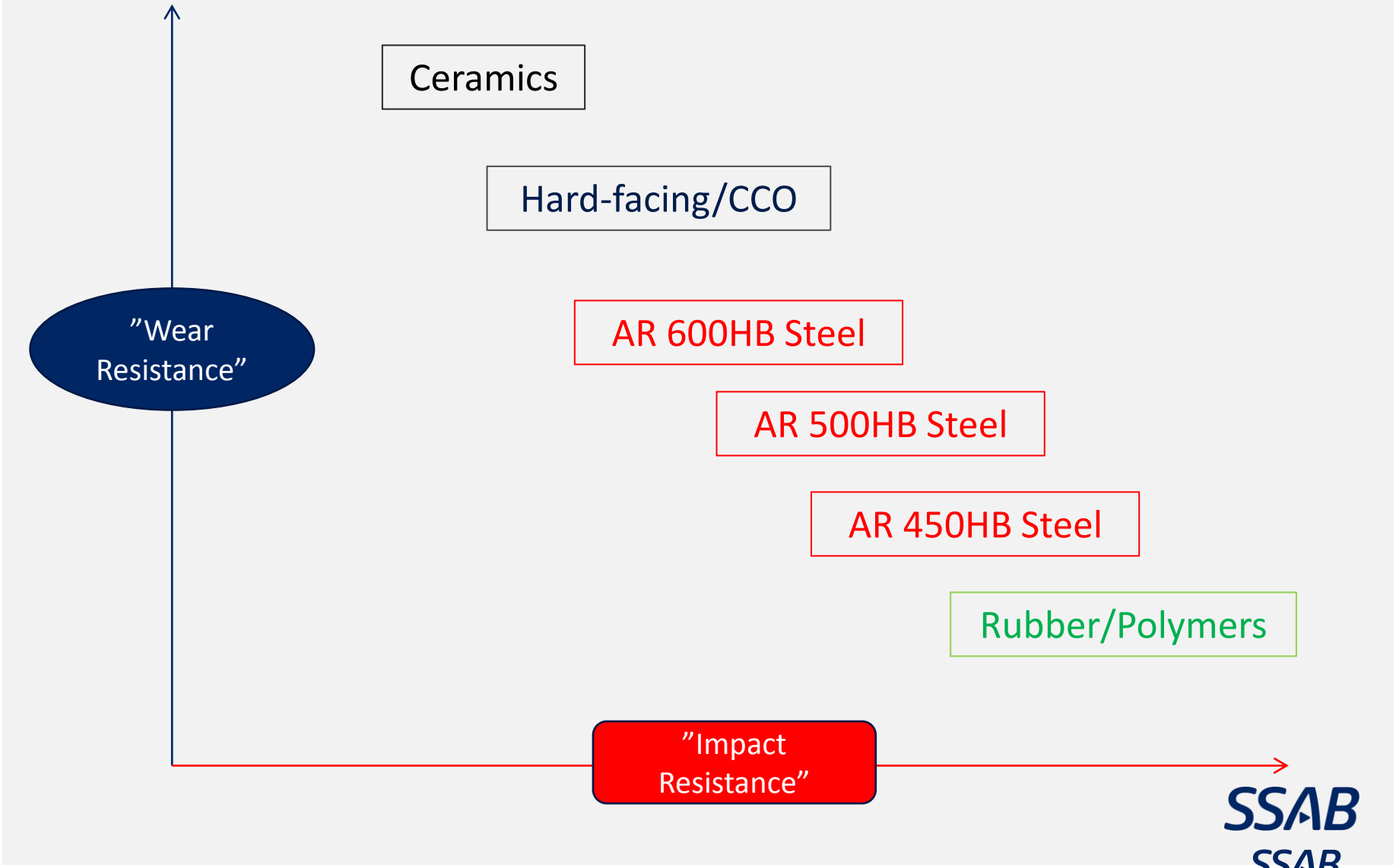
Wear resistant materials



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Wear resistant materials

Hard materials – QT steels

- Good wear resistance
- Reliable performance
- Good impact toughness
- Easy to weld
- Easy to machine

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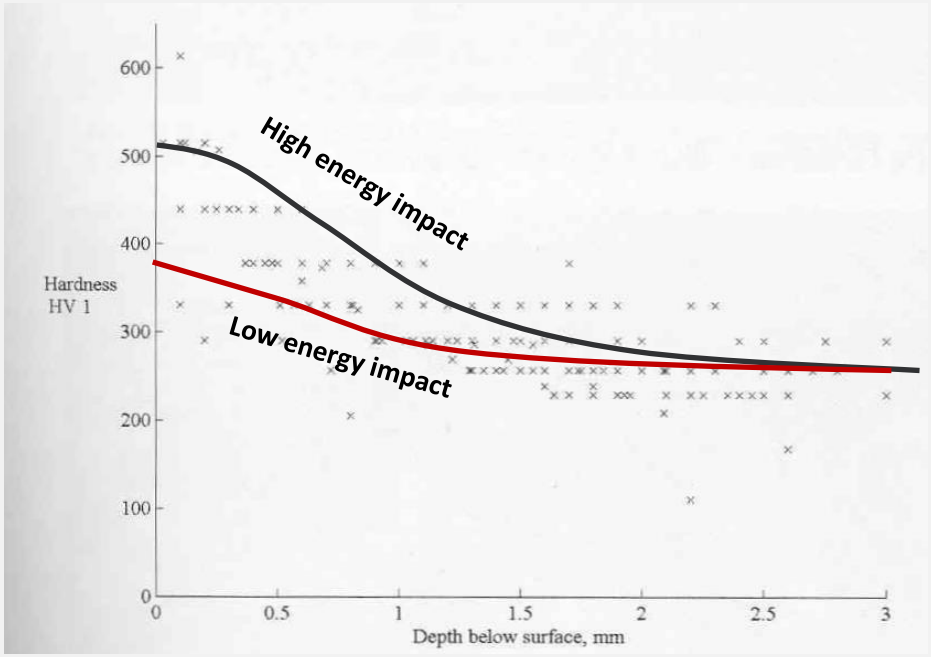
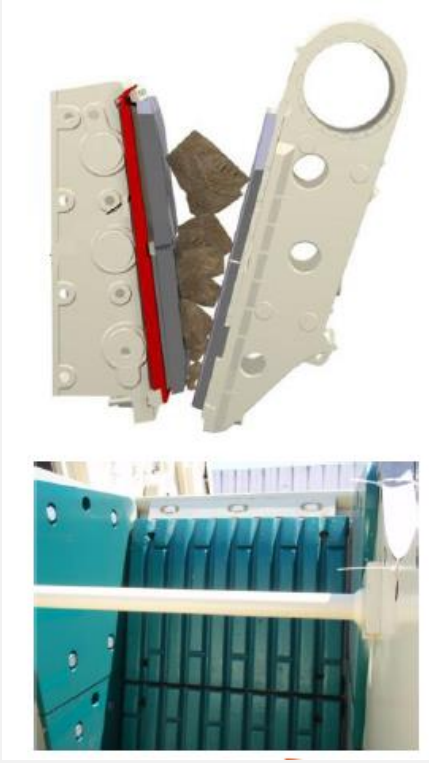
Wear resistant materials

Hard materials – Manganese steels

- Hardens during service (250HB → ~500HB)
- Good in ”active” components





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Wear resistant materials

Hard materials – Tool steels

- Good wear resistance
- High C-content
  - Weldability and toughness impaired
- High alloying content
- High cost
- Can withstand elevated temperatures
- Requires heat treatment

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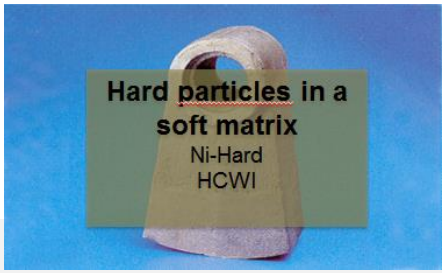
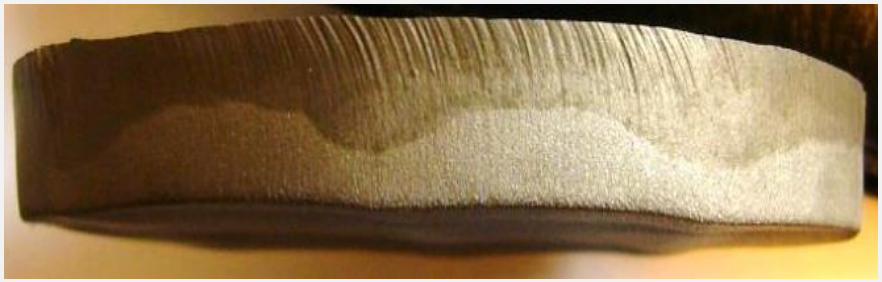
Wear resistant materials

Hard particles in a soft matrix – CCO (hardfacing)

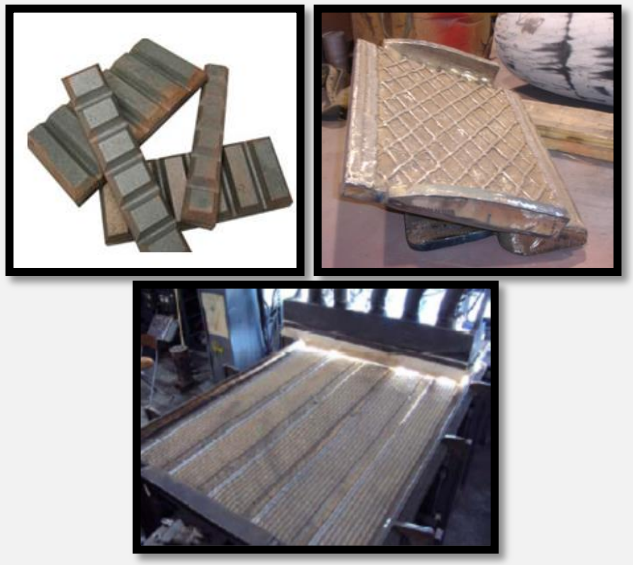


- High wear resistance
- Brittle

Hard chromium carbide layer



Soft mild steel layer



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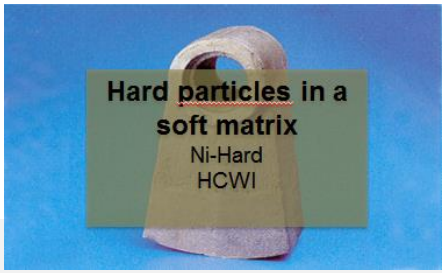
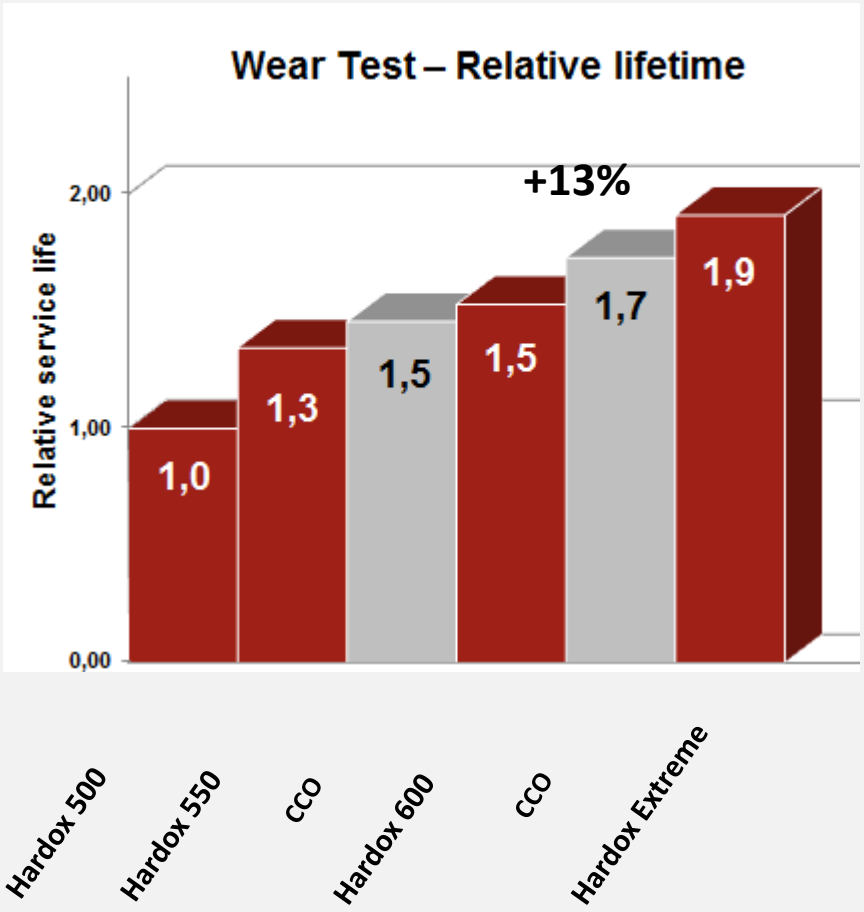
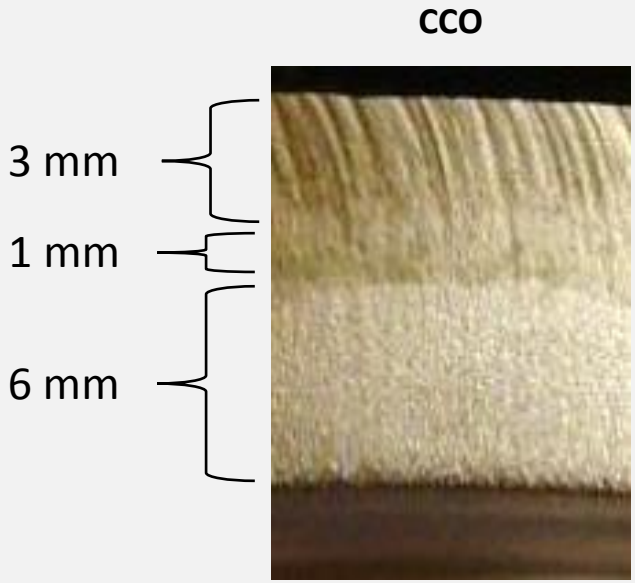
Wear resistant materials

Hard particles in a soft matrix – CCO (hardfacing)







Service life of liner plate

Hardox 600 (8mm)	- 80 days
CCO (4mm)	- 45 days
St.52 Mild steel (6mm)	- 8 days

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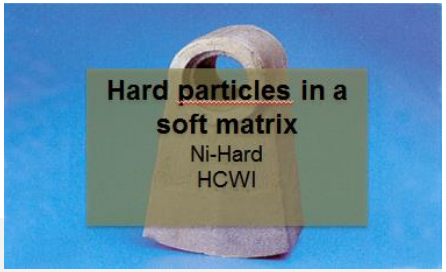
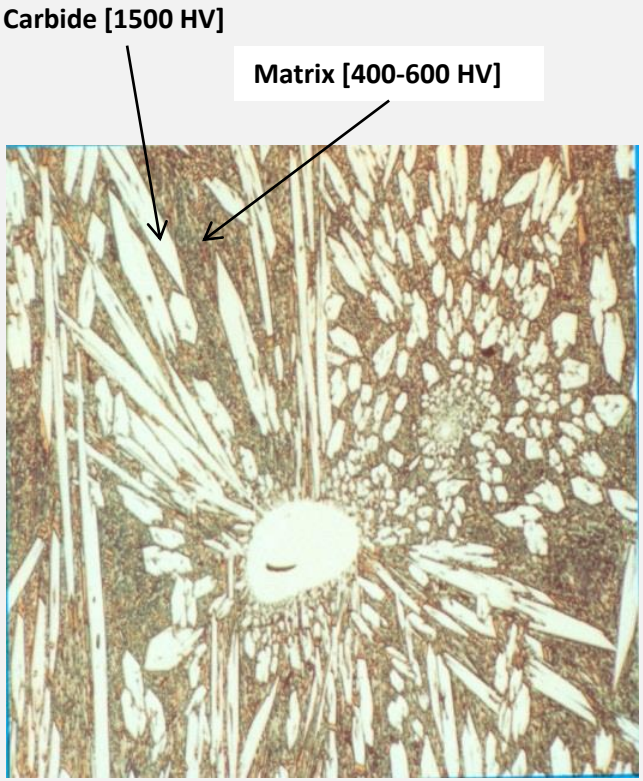
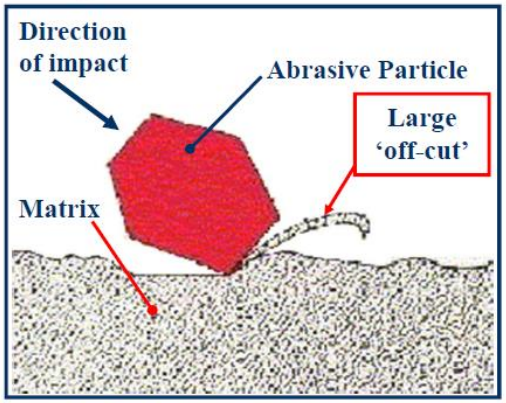
Wear resistant materials

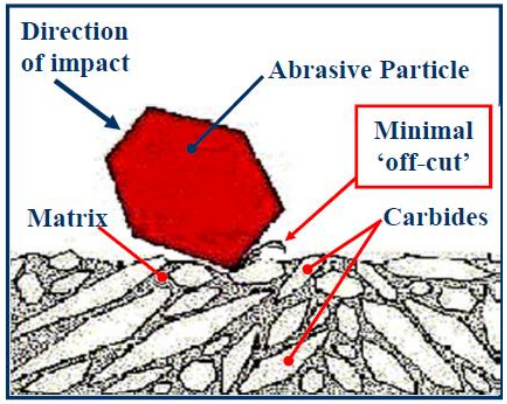
Hard particles in a soft matrix





Microstructure of CCO





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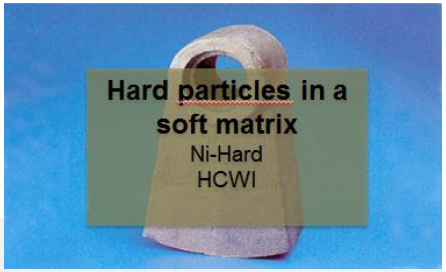
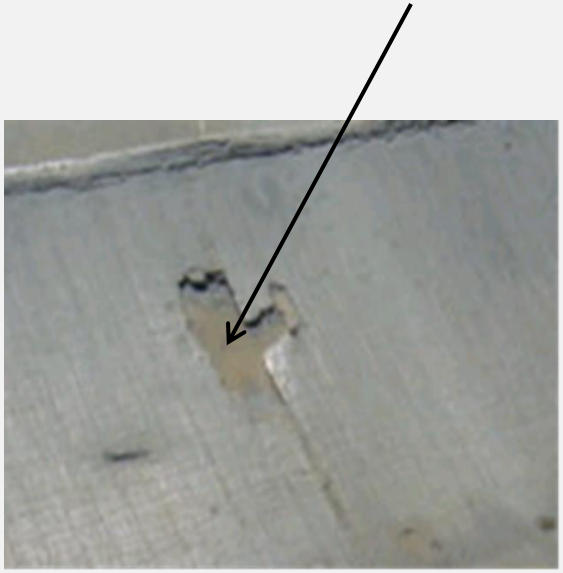
Wear resistant materials

Hard particles in a soft matrix



Chip-out of chromium carbide layer



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Wear resistant materials
Ceramics

- Very good wear resistance
- Best for small particles
- Low friction
- Not suitable for welding or impact wear

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Wear resistant materials
Rubber

- Good against some impact wear
- Low friction
- Low weight
- Low performance against dry sliding wear
  - *worn 3x faster than mild steel*

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Wear resistant materials

Overview

Material	Sliding wear	Impact wear	Toughness	Welding	Bending	Machining	Cutting
Qt-Steel	Very Good	Very Good	Very Good	Good	Good	Medium / Good	Good
Ceramics	Excellent	Poor	Poor	----	----	-----	----
Mn-Steel	Medium	Very Good	Excellent	Medium	Possible	Medium	Poor / Medium
HCWI	Excellent	Good/Medium	Poor	Casting - Poor Hardfacing – Good	Overlay-Medium	Not Possible	Poor/Medium
Ni-Hard	Very Good	Medium	Poor	Not Possible	Not Possible	Not Possible	Not Possible
Rubber	Poor	Good	----	Gluing	----	----	----

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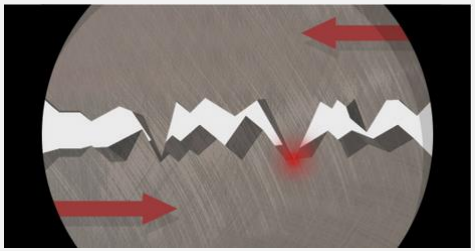
High temperature wear

- Elevated working temperature

- Friction heat



$$Q = F_N \, \mu \, v$$

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Decreasing weight for more efficiency

Example: recycling container, -1400 kg

Hardox 450 in cargoholds bluewater wessels

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The liners

- 235 Mpa
  - 1300MPa (Hx450)
- Thickness 15mm
  - 10mm
- Servicelife 8 years
  - New servicelife 36 years
- Linerplate weight 74 ton
  - New 51 ton
    - 23 ton lighter (payload)

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Why is Hardox different from others - or is it?

Hard and Tough – A difficult combination!

Impact Strength

- Cleaner Steel
- Finer structure
- Alloying
- In-house developed key processes

Heat treatment, alloying

Strength/Hardness

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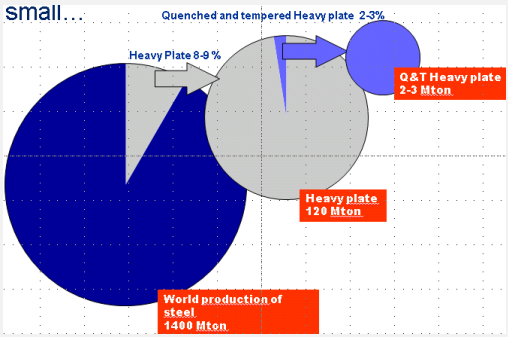
Why is SSAB ahead?

Niche focus

- Equipment and Control System
- Operators
- Process engineers



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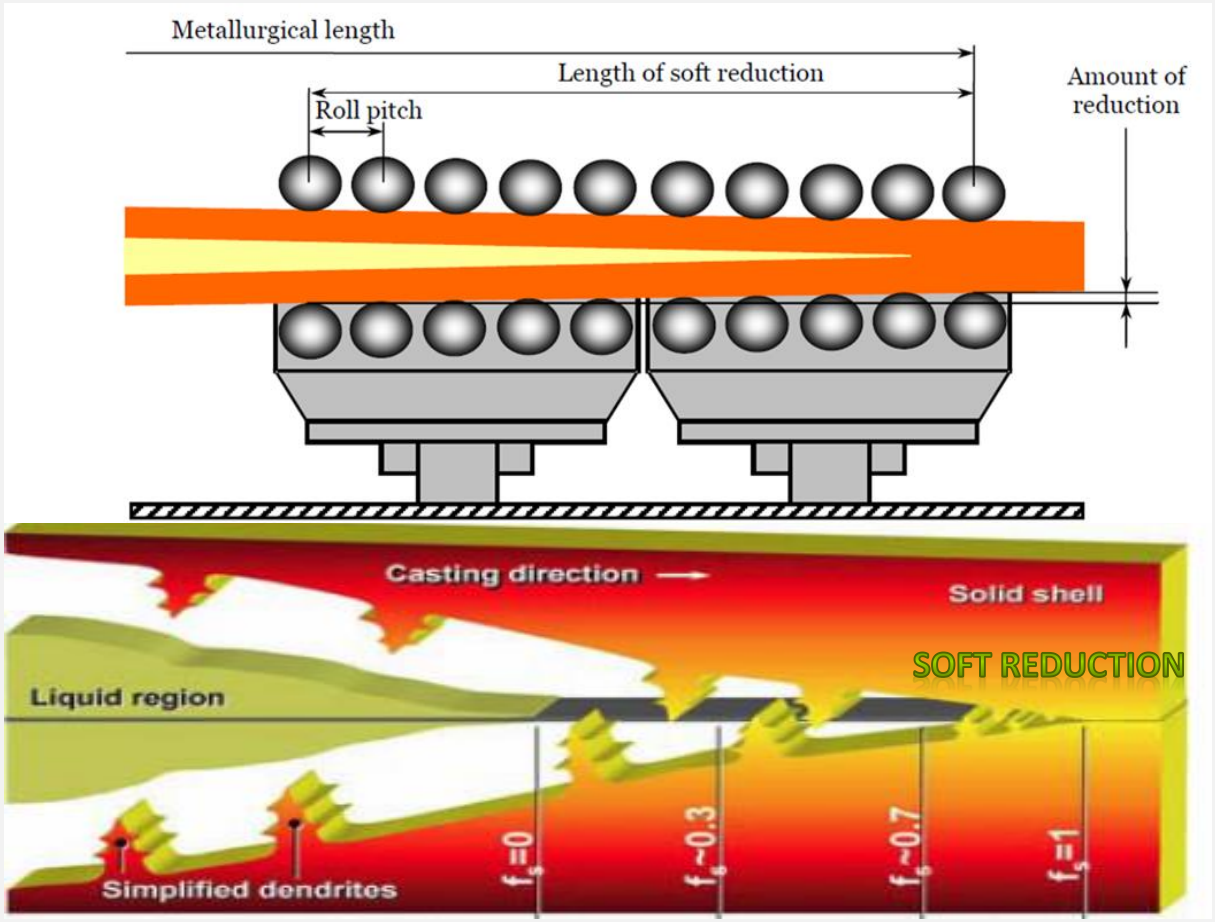
Key Process nr 1- Casting

Unique soft reduction



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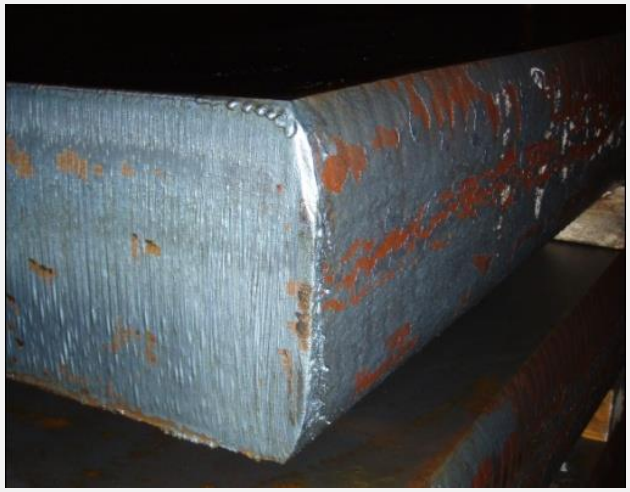
Key Process nr 2 - Rolling

Properties – what and where is it measured?

- Mechanical properties is measured..
  - Hardness, toughness and so on



- What about cleanliness and consistent properties? Are those measured, does they matter. Are they measurable?

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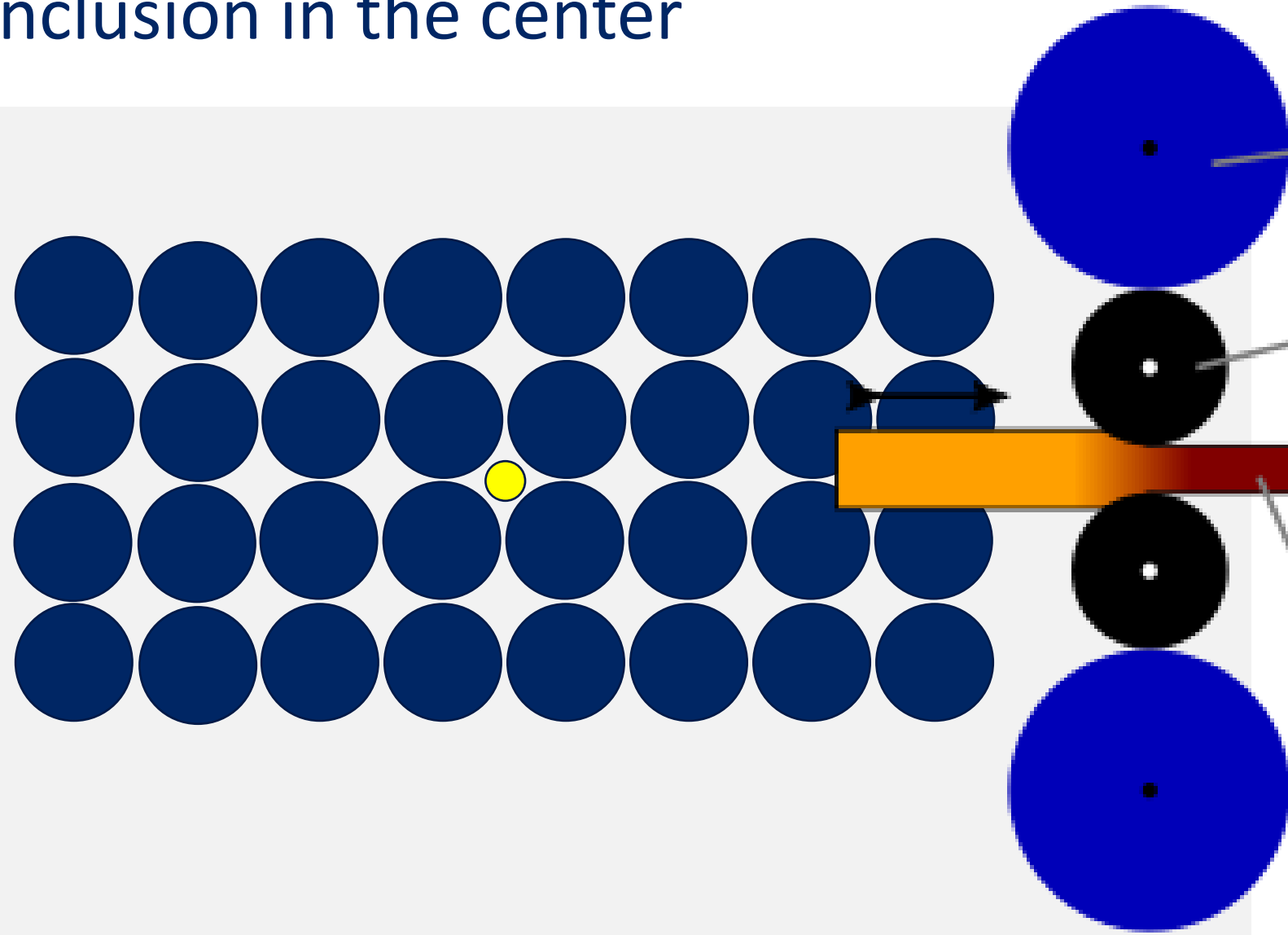
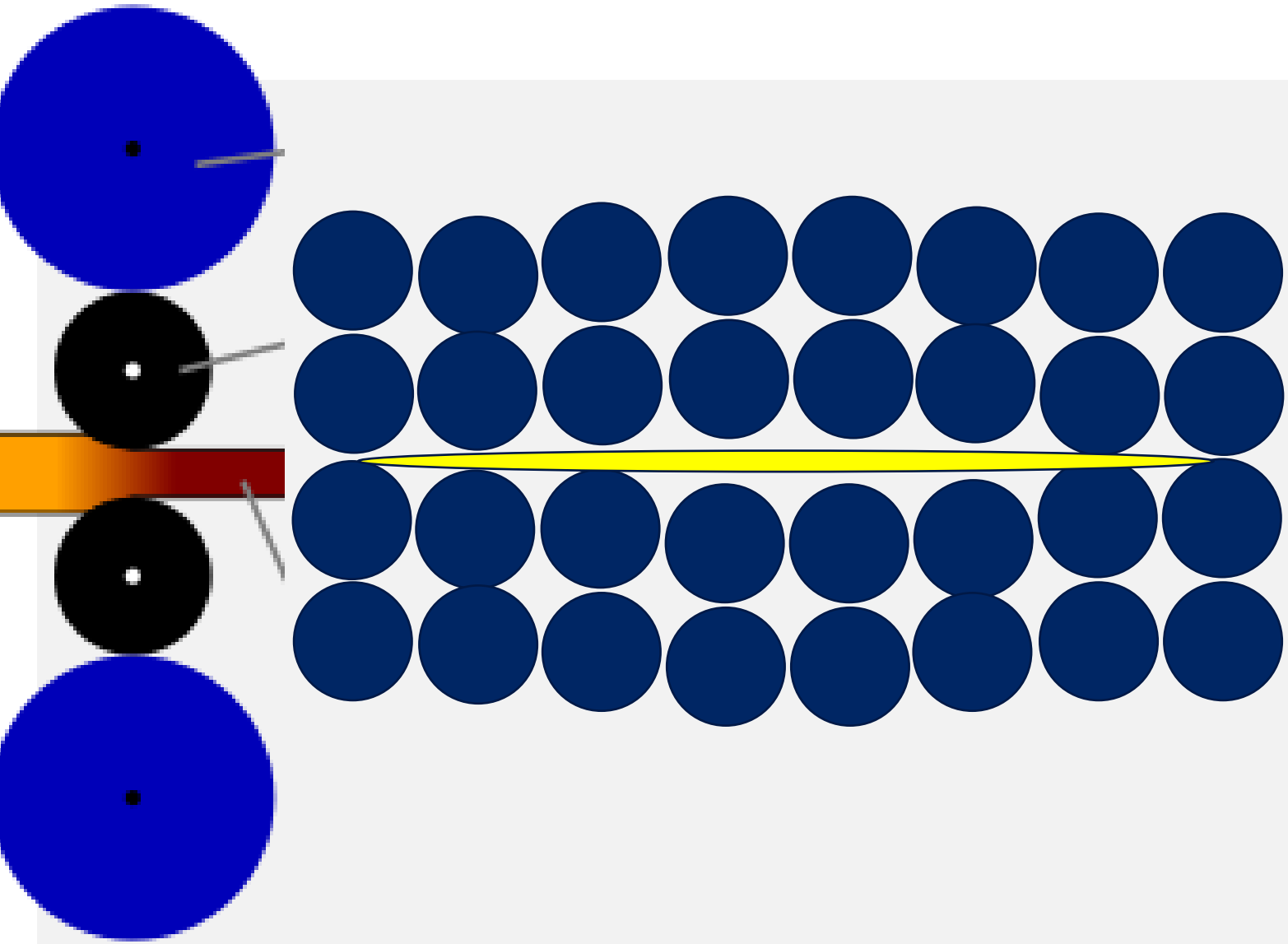
MnS inclusion in the center

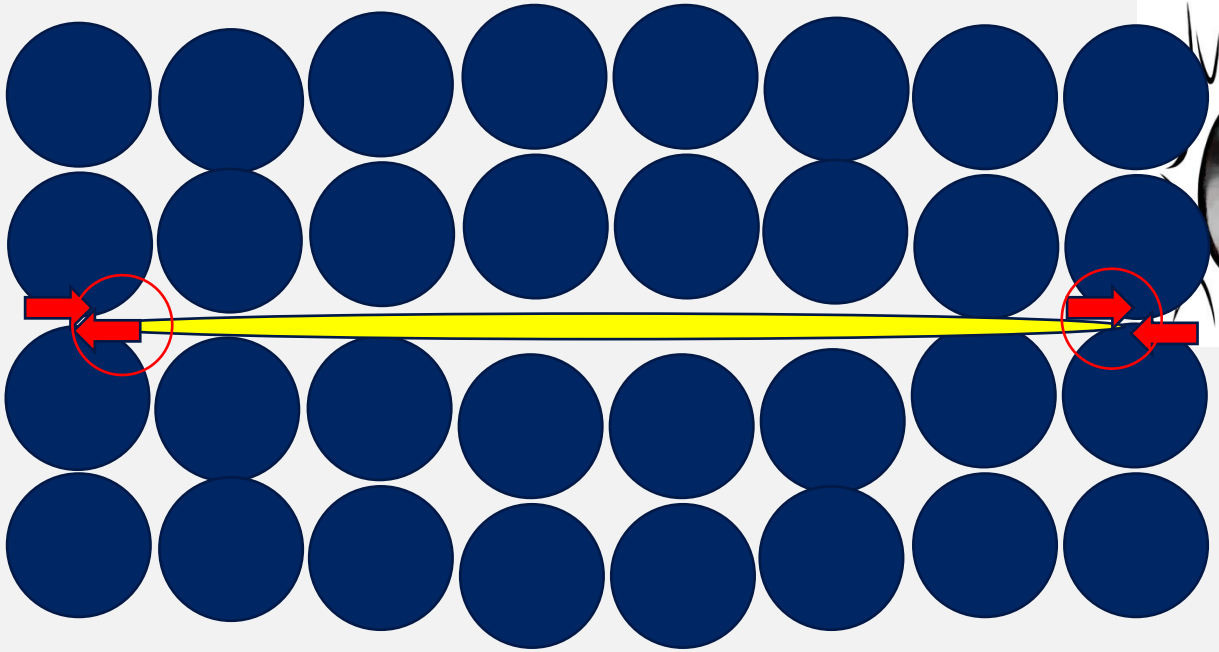


MnS inclusion in the center

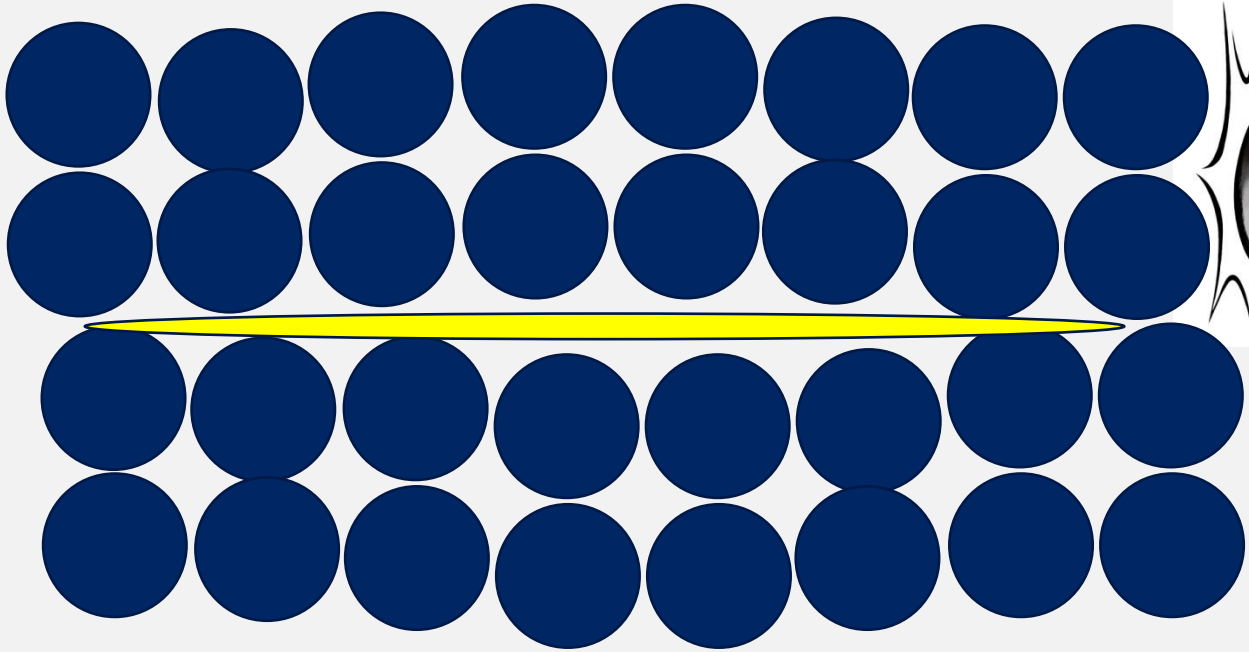


SSAB

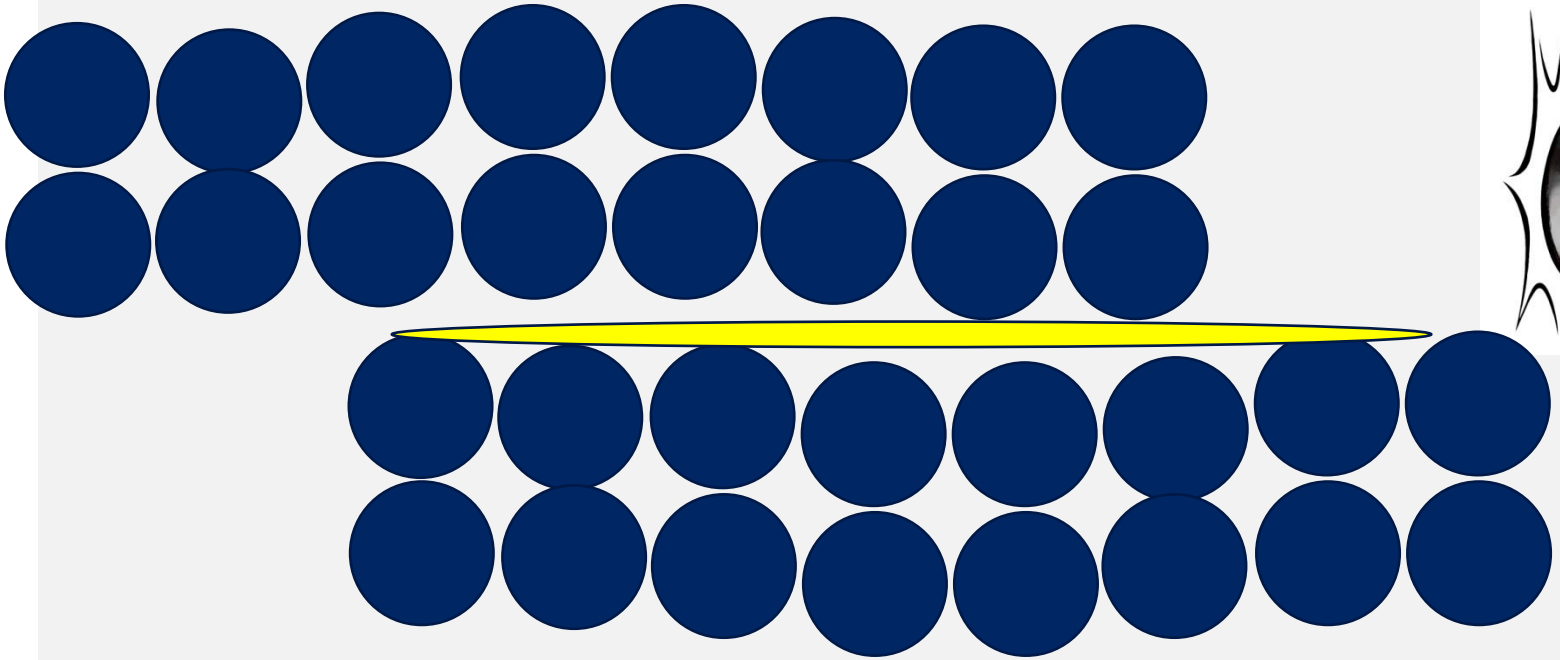
MnS inclusion in the center



MnS inclusion in the center

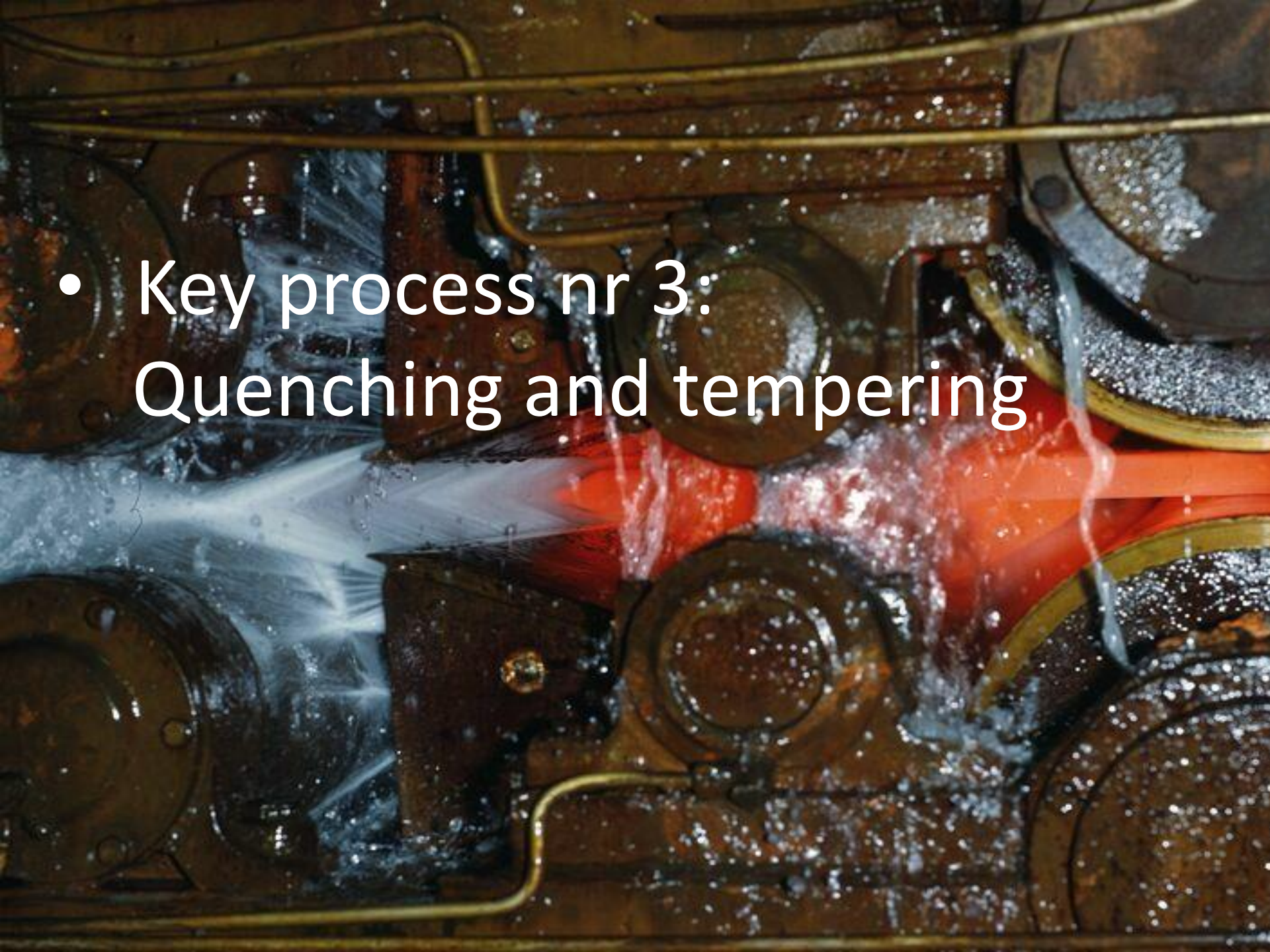


MnS inclusion in the center



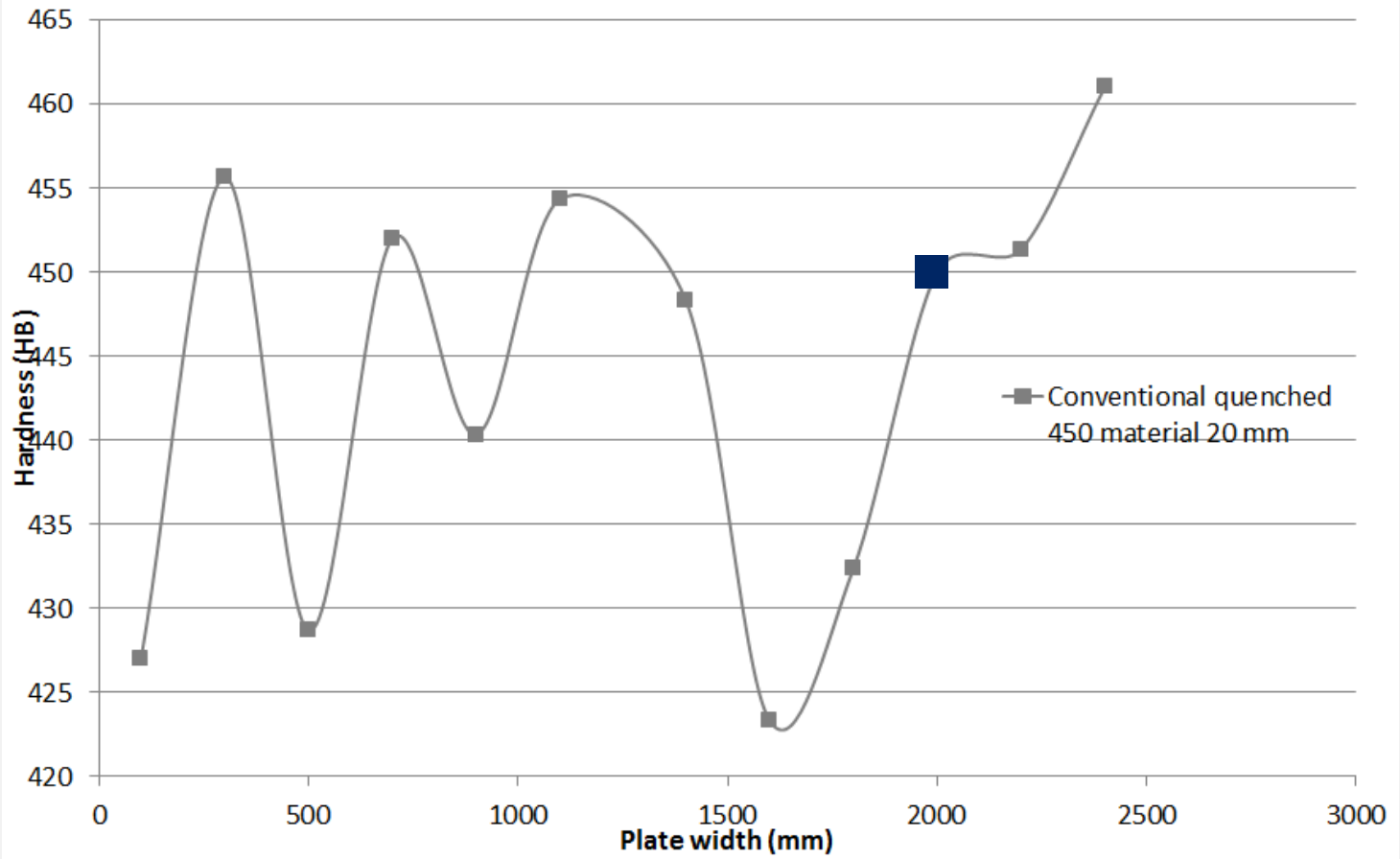
Woops…

This is why SSAB guarantees the impact strength in the worst direction



- Key process nr 3: Quenching and tempering

Consistent properties within and between plates



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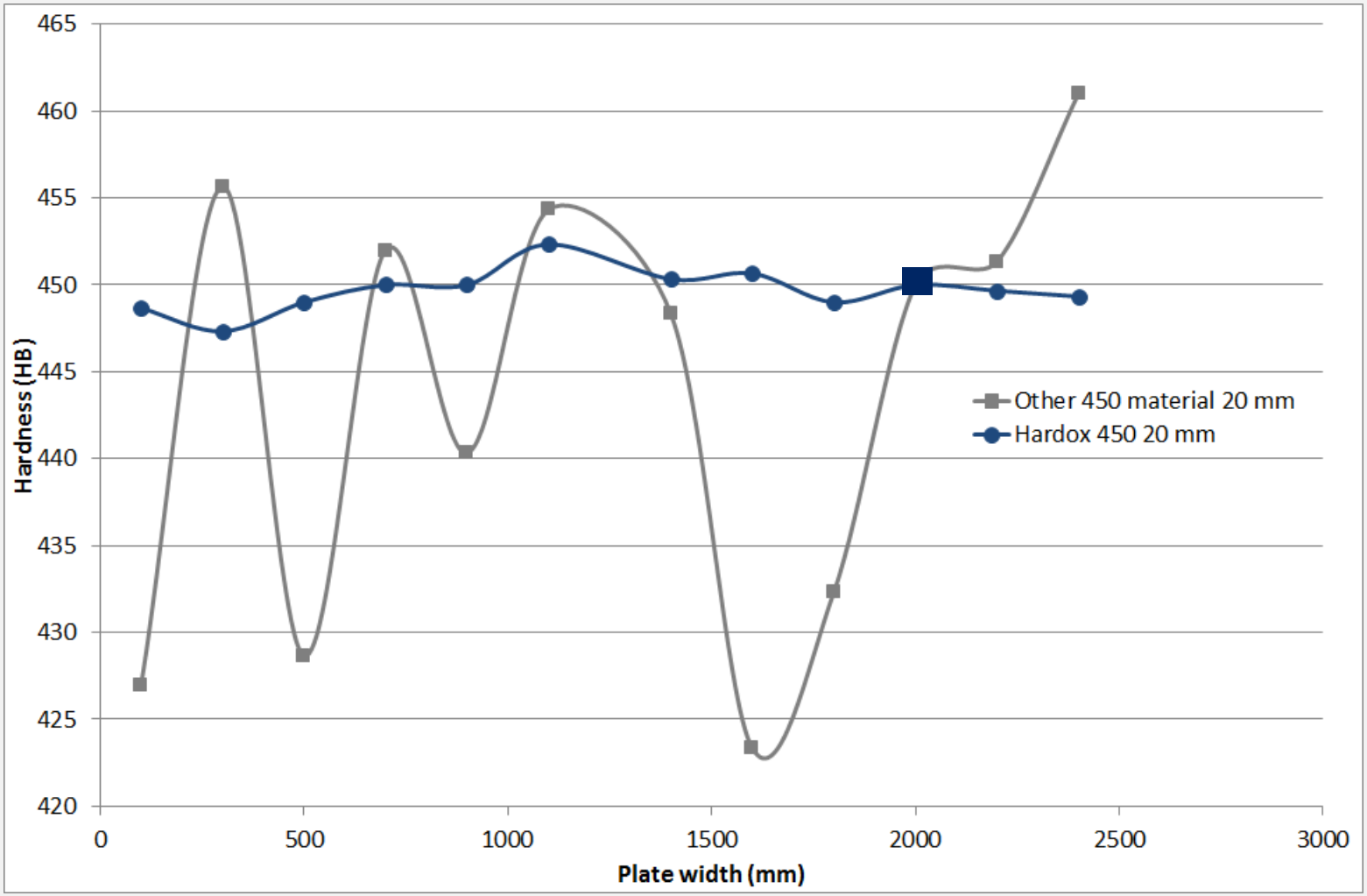
Consistent properites within and between plates



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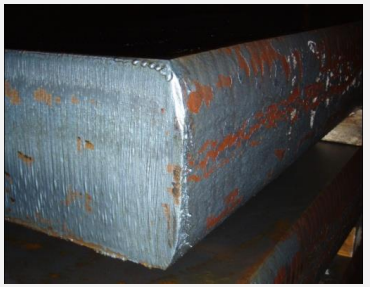
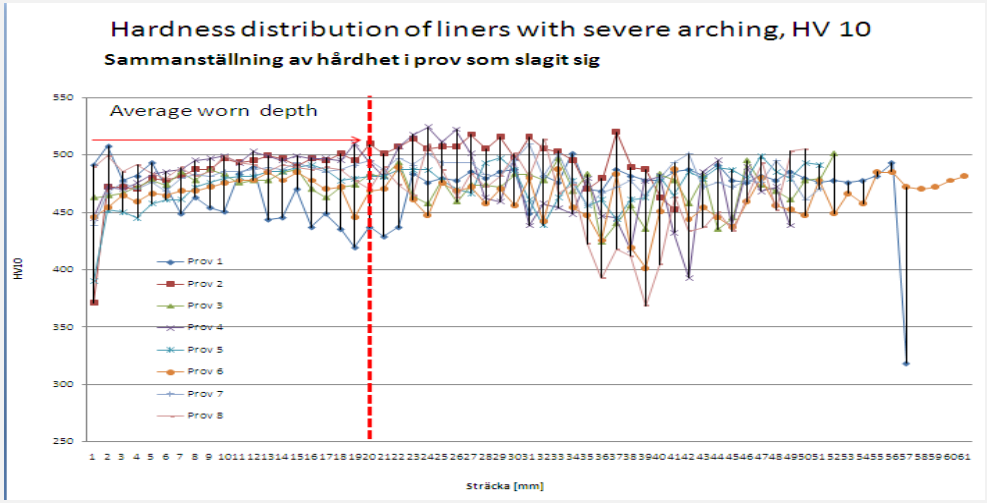
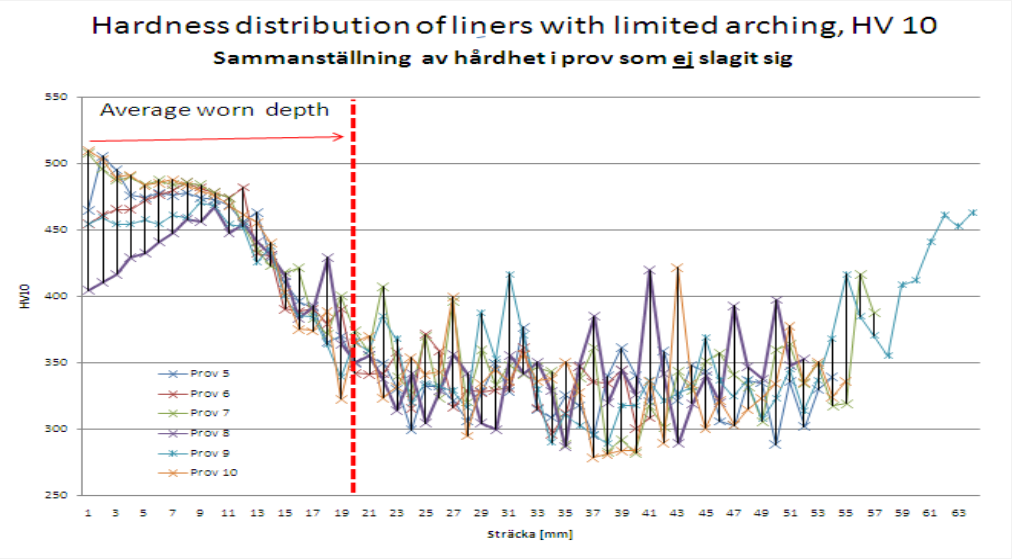
Who is the steel designed for?





HARDOX 500 75 mm

60-100 % longer up-time
(slide , copper mines)



Competitor material
AR 500 75 mm

SSAB

Competition – data sheet says it all?

HARDOX® WEAR PLATE

Data Sheet 152en Hardox 500 2013-06-17

Hardox 500

General Product Description

Hardox 500 is an abrasion resistant steel with a nominal hardness of 500 HBW. Typical applications are components and structures subject to wear. For more information on applications see www.ssab.com

Available dimensions

Hardox 500 is available in thicknesses of 4.0 – 80 mm. Hardox 500 Tuf is available in thicknesses of 4 – 65 mm.
Both grades are available in widths up to 3350 mm and lengths up to 14630 mm. More detailed information on dimensions is provided in the dimension program at www.ssab.com.

Mechanical Properties

Thickness mm	Hardness HBW min – max [1]	Typical yield strength MPa, not guaranteed
4 - 32	470 – 530	1250
(32) - 80	450 - 540	1250

[1] Brinell hardness, HBW, according to EN ISO 6506-1, on a milled surface 0.5 – 3 mm below surface. At least one test specimen per heat and 40 tons. The nominal material thickness will not deviate more than ±15 mm from that of the test specimen.

The plates are through-hardened to a minimum of 90 % of the guaranteed minimum surface hardness.

Impact properties	Hardox 500	Hardox 500 Tuf Transverse test, guaranteed	Longitudinal test, typical
Impact energy (J) for transverse tests Charpy V 10x10 mm test specimen [2]	–	27 J/0 °C	37 J/-40 °C

[2] For thicknesses between 6 - 11.9 mm, subsize Charpy V-specimens are used. The specified minimum value is then proportional to the cross-sectional area of the test specimen, compared to a full-size specimen (10 x 10 mm). Impact testing according to ISO EN 148 per heat and thickness group. Average of three tests. Single value minimum 70% of specified average. Impact test is performed from 6 mm.

Ultrasonic testing

Plates in thickness of 80 mm are delivered in Class E_2S_2 in accordance with EN 10 160, other thicknesses are delivered in Class E_1S_1.

Chemical Composition (heat analysis)

C [*] Max %	Si [*] Max %	Mn [*] Max %	P Max %	S Max %	Cr [*] Max %	Ni [*] Max %	Mo [*] Max %	B [*] Max %
0.30	0.70	1.60	0.020	0.010	1.50	1.5	0.60	0.005

The steel is grain refined. *) Intentional alloying elements.

Maximum carbon equivalent CET (CEV)

Thickness mm	- (5)	5 - (10)	10 - (20)	20 - (40)	40 - 80
CET (CEV)	0.34 (0.49)	0.36 (0.52)	0.43 (0.64)	0.45 (0.66)	0.47 (0.75)

$$CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40} \qquad CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

www.hardox.com

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HARDOX® WEAR PLATE

Data Sheet 170en Hardox HiTuf 2013-04-25

Hardox HiTuf

General Product Description

Hardox HiTuf is an abrasion resistant steel with a nominal hardness of 350 HBW. Typical applications are components structures with need for high toughness and abrasions resistance . For more information on applications see www.ssab.com

Available dimensions

Hardox HiTuf is available in thicknesses of 40 – 160 mm. Hardox HiTuf is available in widths up to 3350 mm and lengths up to 14630 mm. For thicknesses over 100 mm preferred width is 1650 mm with untrimmed edges.
More detailed information on dimensions is provided in the dimension program at www.ssab.com.

Mechanical Properties

Thickness mm	Hardness HBW min – max [1]	Typical yield strength MPa, not guaranteed
40 - 160	310 - 370	850

[1] Brinell hardness, HBW, according to EN ISO 6506-1, on a milled surface 0.5 – 3 mm below surface. At least one test specimen per heat and 40 tons. The nominal material thickness will not deviate more than ±15 mm from that of the test specimen.

The plates are through-hardened to a minimum of 90 % of the guaranteed minimum surface hardness.

Impact properties	Hardox HiTuf
Minimum impact energy (J) for transverse tests Charpy V 10x10 mm test specimen [2]	40/-40 °C

[2] Impact testing according to ISO EN 148 per heat and thickness group. Average of three tests. Single value minimum 70% of specified average.

Ultrasonic testing

Plates in thicknesses of 80 - 160 mm are delivered in Class E_2S_2 in accordance with EN 10 160, other thicknesses are dilivered in Class E_1S_1.

Chemical Composition (heat analysis)

C [*] Max %	Si [*] Max %	Mn [*] Max %	P Max %	S Max %	Cr [*] Max %	Ni [*] Max %	Mo [*] Max %	B [*] Max %
0.20	0.60	1.60	0.020	0.020	0.70	2.0	0.70	0.005

The steel is grain refined. *) Intentional alloying elements.

Maximum carbon equivalent CET (CEV)

Thickness mm	40 - 70	(70) - 160
CET (CEV)	0.38 (0.57)	0.41 (0.66)

$$CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40} \qquad CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

www.hardox.com

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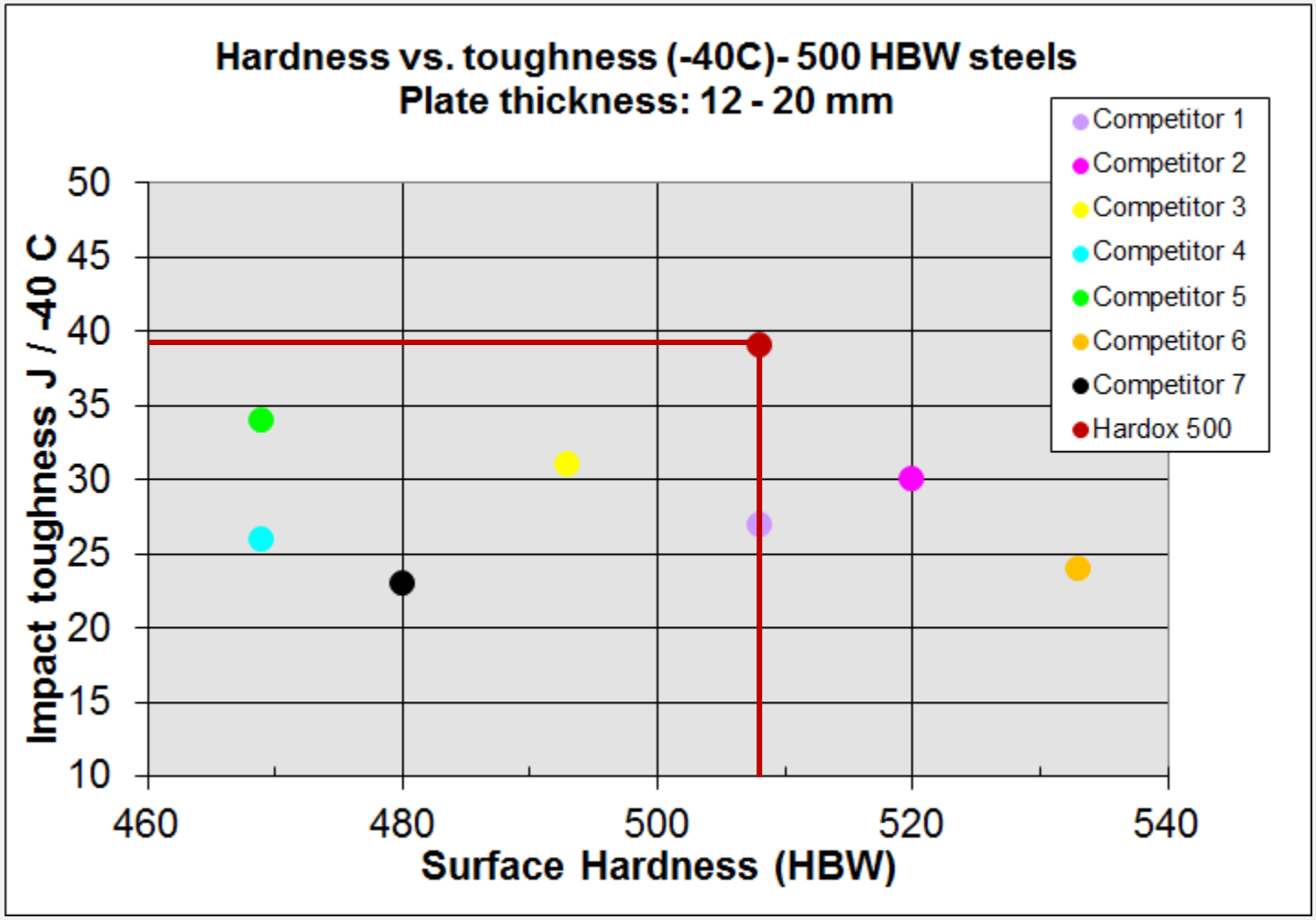
Data sheet, guarantees and reality…



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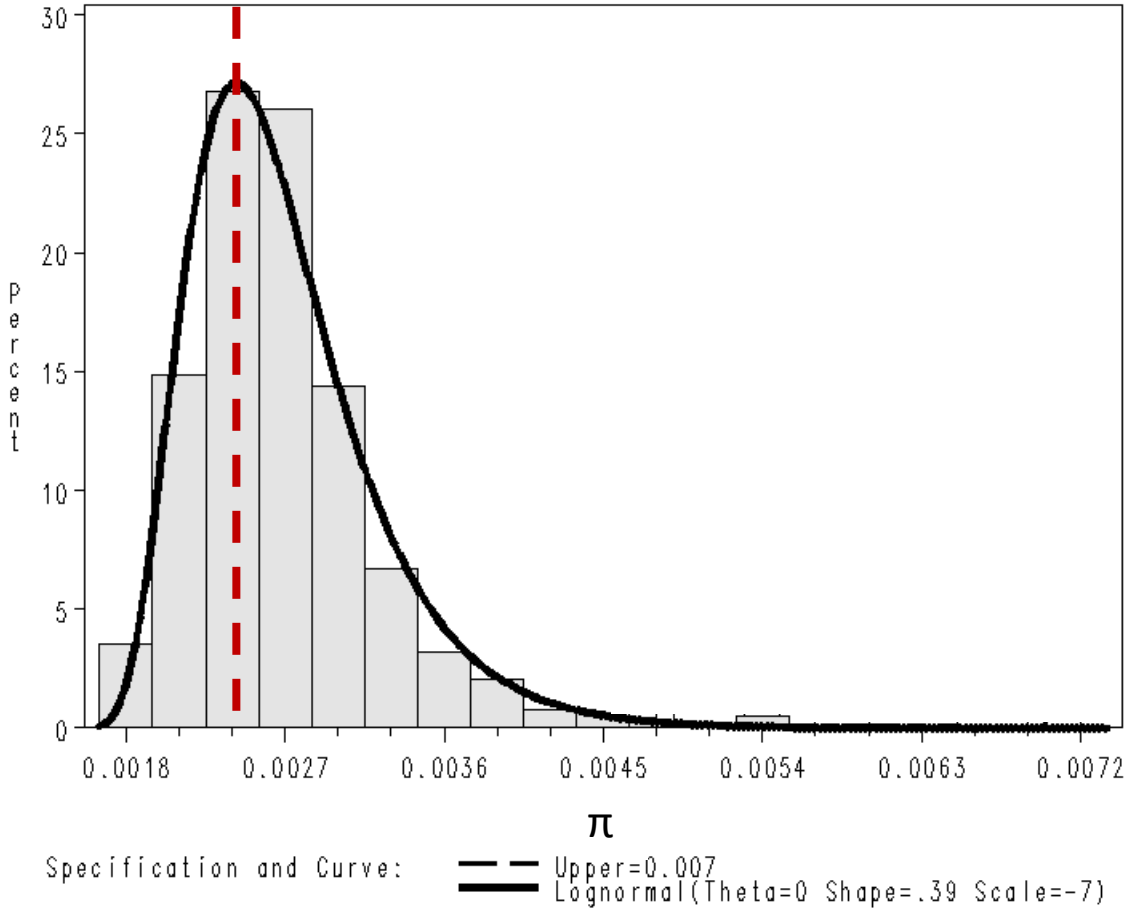
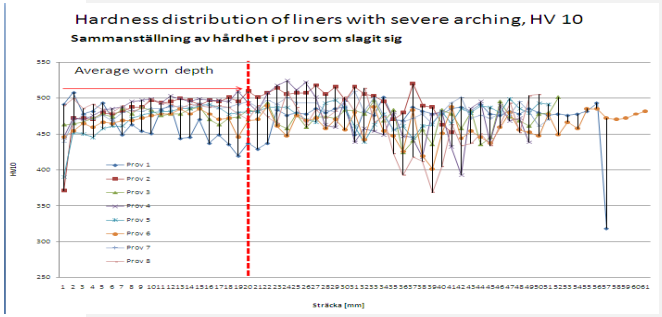
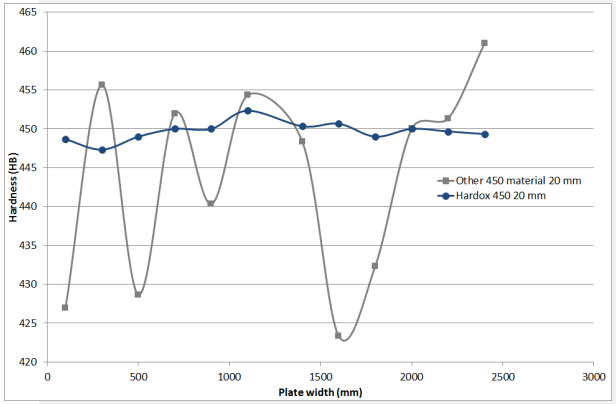
Cleanliness - SSAB Oxelösund vs. competitors

Oxelösund



Competitors





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A stronger,
lighter and more
sustainable world