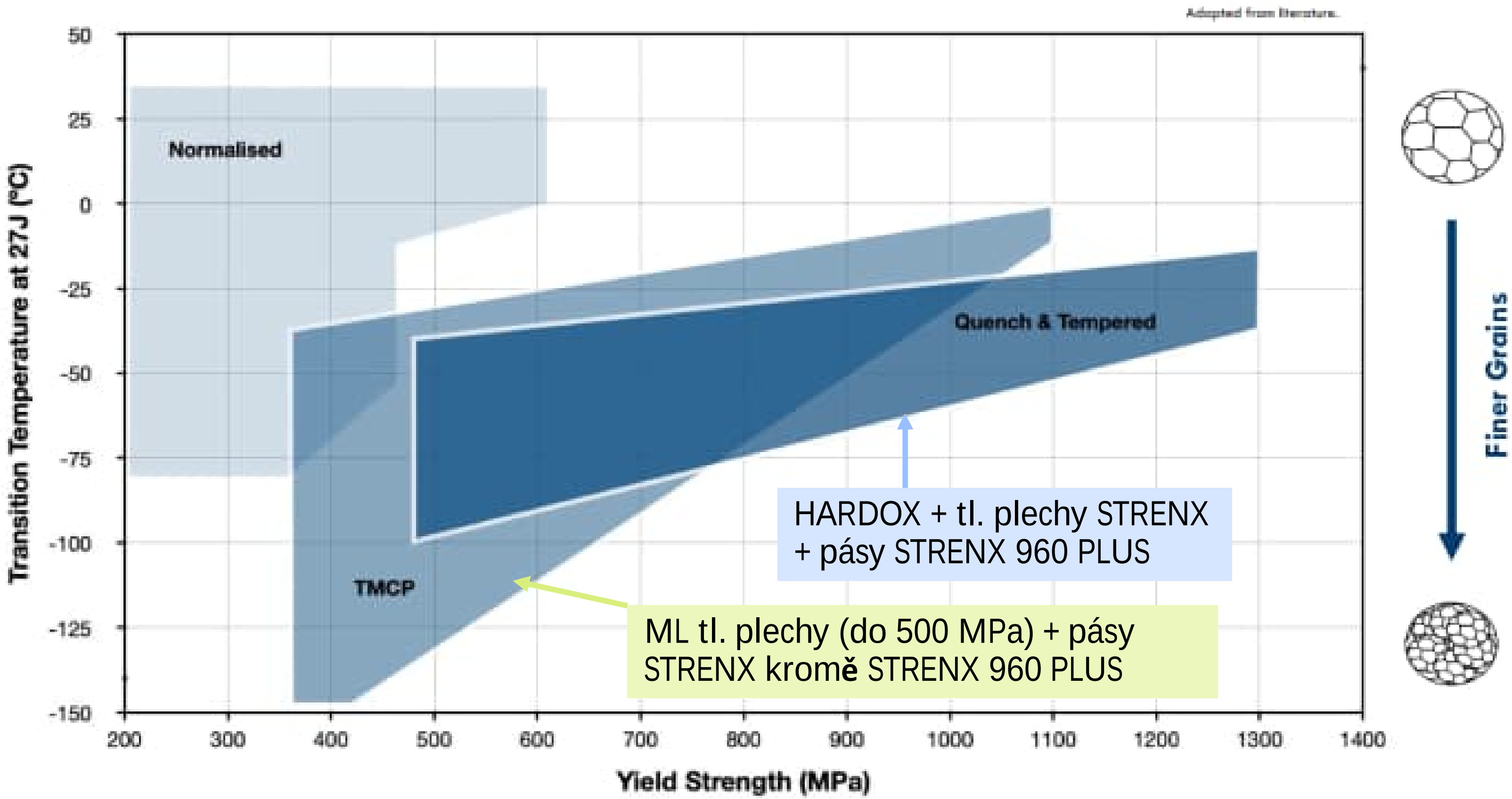
Svařování vysokopevnostních, otěruvzdorných a balistických ocelí

Zkušenosti a trendy

Tomáš Brtník

tomas.brtnik@ssab.com

Výrobní metody vs. Houževnatost vs. Pevnost (Tvrdost)



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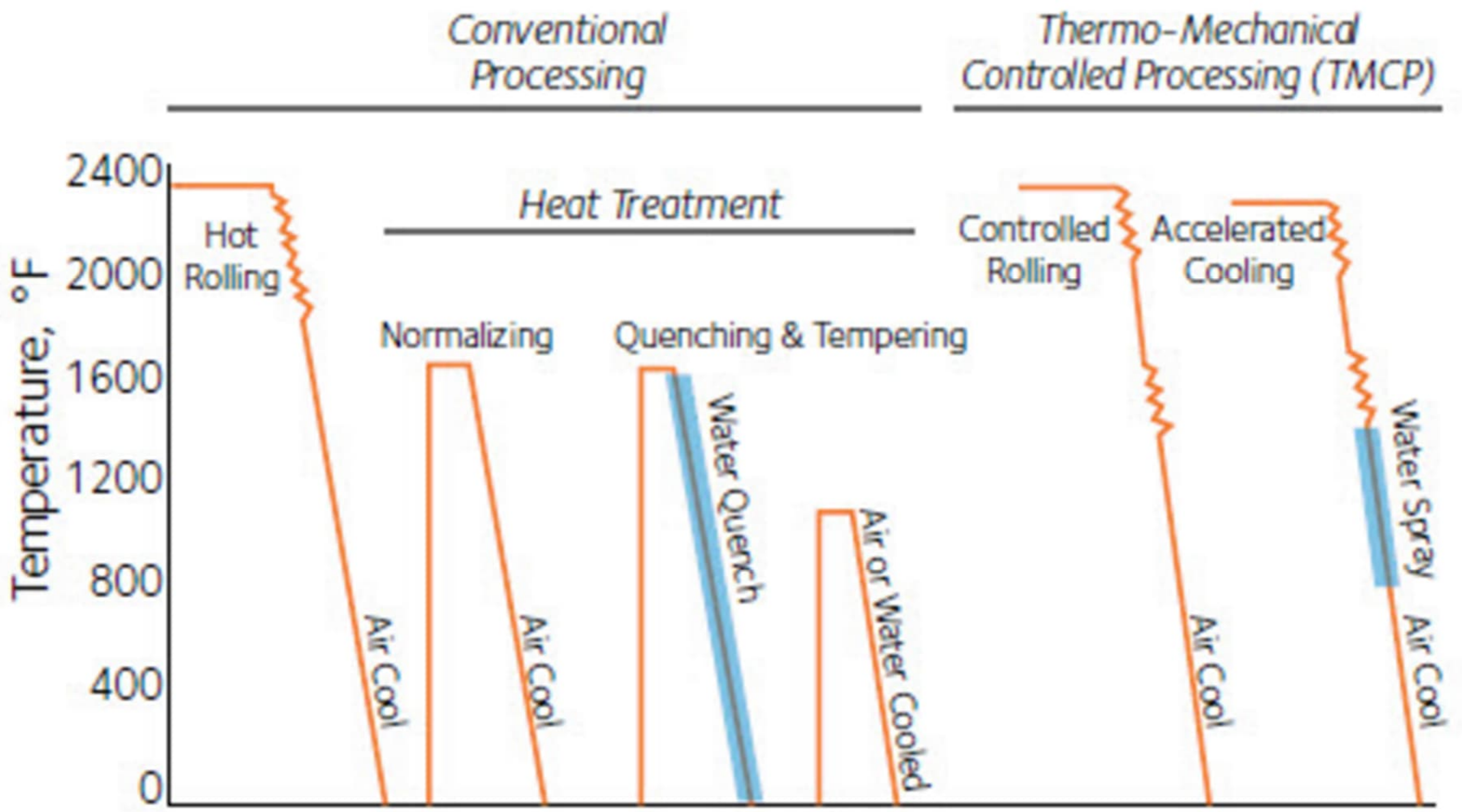
Možnosti výroby vysokopevnostních ocelí



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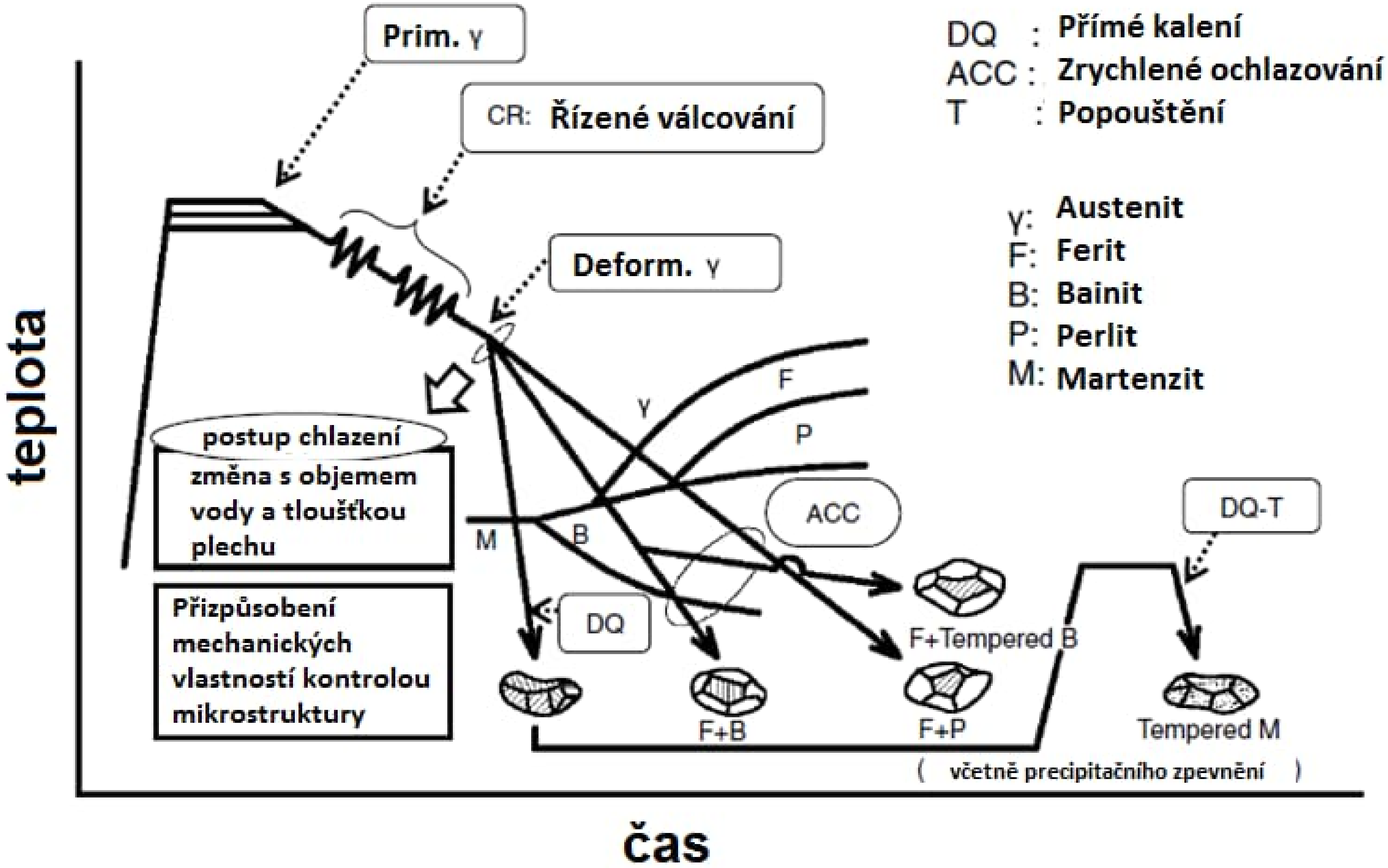
TMCP (Termomechanické válcování)



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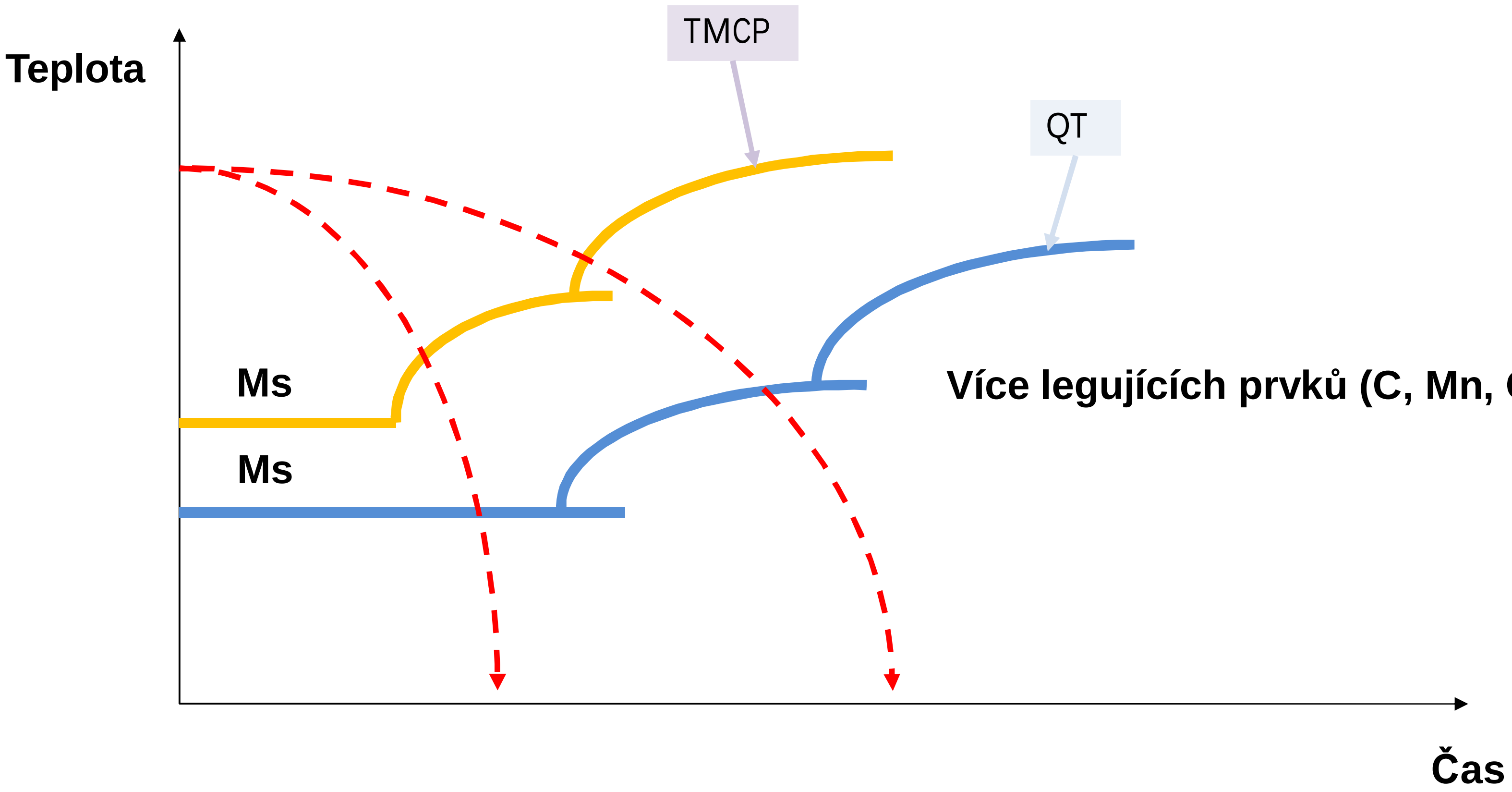
Efekt legujících prvků na ARA diagram



$$CEV = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15$$

Benefits of using high strength TM Steel

Low alloying contents for TM-steels

Typical Carbon Equivalents for different steel grades (plate thickness 50mm)

Steel grade	typical CET /%	typical CEV /%	max. CEV /% acc. EN 10025
S355J2+N	0.31	0.42	0.45
S355M/ML	0.22	0.34	0.40
S460M/ML	0.25	0.39	0.47

Carbon equivalents:
CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15
CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40

CE ↓ ⇨ cold cracking tendency ↓
⇨ toughness in HAZ ↑

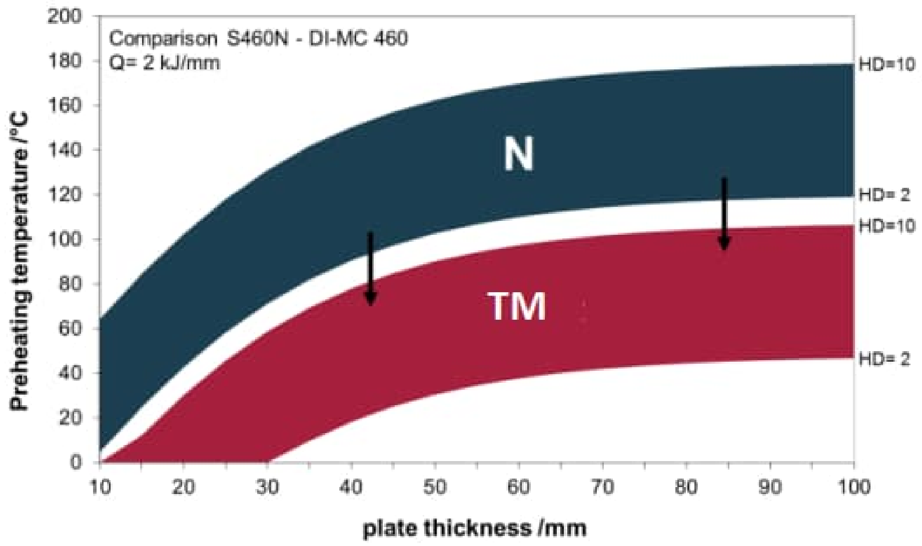
Properties of Q+T steels – Carbon Equivalents

Typical Carbon Equivalents for different steel grades (plate thickness 50mm)

Steel grade	typical CET /%	typical CEV /%	max. CEV /% acc. EN 10025
S355J2+N	0.31	0.42	0.47
S460QL	0.30	0.43	0.47
S690QL	0.35	0.52	0.65

Carbon equivalents:
CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15
CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40

Reduction of preheating according to EN 1011-2 method B



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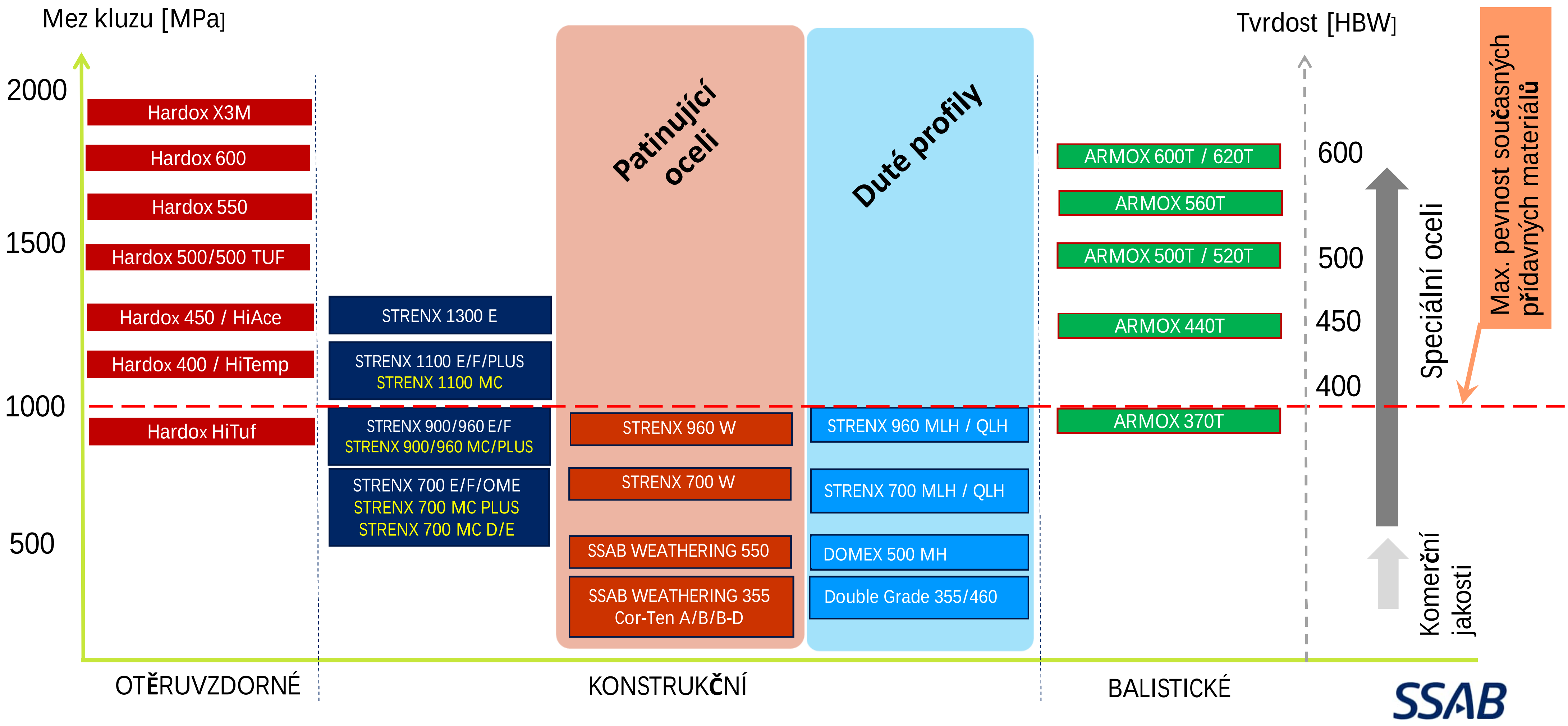
Přehled speciálních ocelí SSAB



Svařování speciálních ocelí

Vysokopevné oceli

- Předehřev
- Vysokopevný přídavný materiál
- Postup svařování

- Tepelný příkon
- Interpass teplota

Vyhnout se vodíkovým trhlinám

Zajistit pevnost ve svarovém spoji

Otěruvzdorné oceli

- Předehřev
- „Měkký“ přídavný materiál
- Postup svařování

- Tepelný příkon
- Interpass teplota

Vyhnout se vodíkovým trhlinám

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Hardox a Strenx

Extrémní čistota oceli + tepelné zpracování

- H 0,3 ppm (0.00003%)
- S 10 ppm (0.001%)
- P 80 ppm (0.008%)
- N 25 ppm (0.0025%)

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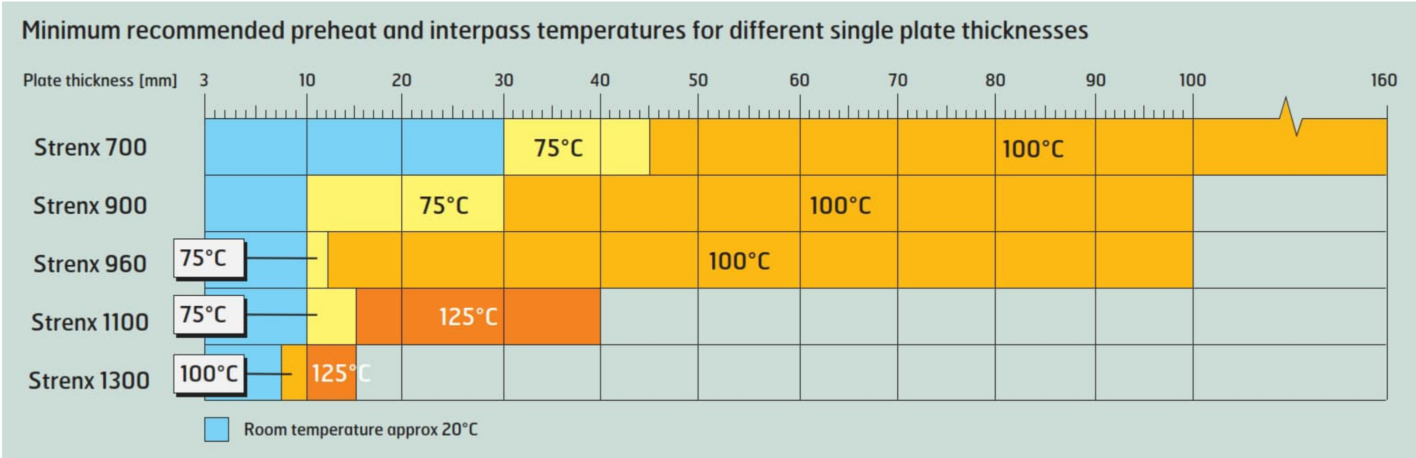
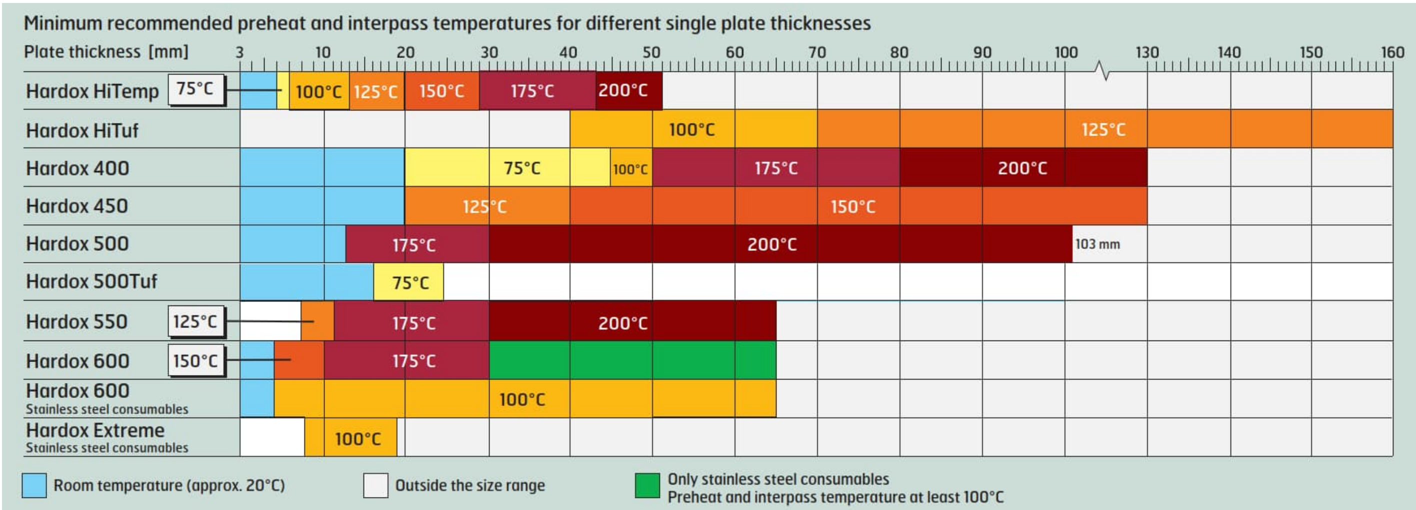
Předehřevy + interpass

- Vztaženo k tl. nejtlustšího plechu (single plate thickness…)





Maximum recommended interpass temperature

Strenx 700**	300°C
Strenx 900**	300°C
Strenx 960**	300°C
Strenx 1100	200°C
Strenx 1300	200°C
Hardox HiTemp**	300°C
Hardox HiTuf**	300°C
Hardox 400	225°C
Hardox 450	225°C
Hardox 500	225°C
Hardox 500Tuf	225°C
Hardox 550	225°C
Hardox 600	225°C
Hardox Extreme	100°C

** Interpass temperatures of up to approx. 400°C can be used in certain situations. In such cases, use WeldCalc.

Doporučené přídavné materiály ESAB

Recommended welding consumables

Base material	MMA OK	MIG/MAG OK AristoRod, OK Autrod	FCAW OK Tubrod (metal-cored)	FCAW OK Tubrod (rutile)	TIG OK Tigrod	SAW OK Autrod + OK Flux
Unalloyed steel (EN 10025-2)						
S235xxx, S275xxx, S355xxx	48.00, 53.05	12.50, 12.51	14.11, 14.13	15.14	12.64	12.10 or 12.20+10.71
Normalised fine grain steel (EN 10025-3)						
S275N, S355N, S420N	48.00, 53.05	12.50, 12.51	14.11, 14.13	15.14	12.64	12.22+10.71
S460N	55.00	12.63, 12.64	14.02	15.14	12.64	12.22+10.71
S275NL, S355NL, S420NL	48.08, 55.00	13.28, (12.63, 12.64)*	14.04	15.11, (15.17)*	13.28	12.32+10.62
S460NL	48.08, 55.00	13.28, (12.63, 12.64)*		15.11, (15.17)*	13.28	12.32+10.62
		*) -40 °C		*) -40 °C		
Thermo-mechanically treated fine grain steel (EN 10025-4)						
S275M, S355M, S420M	48.00, 53.05	12.50, 12.51	14.11, 14.13	15.14	12.64	12.22+10.71
S460M	55.00	12.63, 12.64	14.02	15.14	13.28	12.32+10.71
S275ML, S355ML, S420ML	48.08, 55.00	13.28, (12.63, 12.64)*	14.04	15.11, (15.17)*	13.28	12.32, 13.27+10.62
S460ML	48.08, 55.00	13.28, (12.63, 12.64)*		15.11, (15.17)*	13.28	12.32, 13.27+10.62
		*) -40 °C		*) -40 °C		
Weather resistent steel (EN 10025-5)						
S235J0W, S235J2W	73.08	13.26	14.01	15.17	13.26	13.36+10.71
S355J0WP (e.g. COR-TEN A), S355J2WP	73.08	13.26	14.01	15.17	13.26	13.36+10.71
S355J0W, S355J2W (e.g. COR-TEN B)	73.08	13.26	14.01	15.17	13.26	13.36+10.71
High strength steel (EN 10025-6)						
S460Q, S460QL	48.08	12.63, 12.64	14.02	15.17	13.28	12.32, 13.27+10.62
S500Q, S500QL	74.70	55	14.02	15.11	13.13	13.24+10.62
S550Q, S550QL	74.78	55	14.03	Dual Shield 55		13.40+10.62
S620Q, S620QL	75.75	62	14.03	Dual Shield 62		13.40+10.62
S690Q, S690QL (e.g. WELDOX 700 D or E)	75.75	69	14.03	15.09		13.43+10.62
S890Q, S890QL (e.g. WELDOX 900 D or E)	75.78	89	Coreweld 89			
Ultra high strength steel (Rautaruukki)						
Optim 900 QC	75.78	89	Coreweld 89			
Optim 960 QC	75.78 *	89 *	Coreweld 89 *			
Optim 1100 QC	75.78 *	89 *	Coreweld 89 *			
	* Undermatching weld metal					

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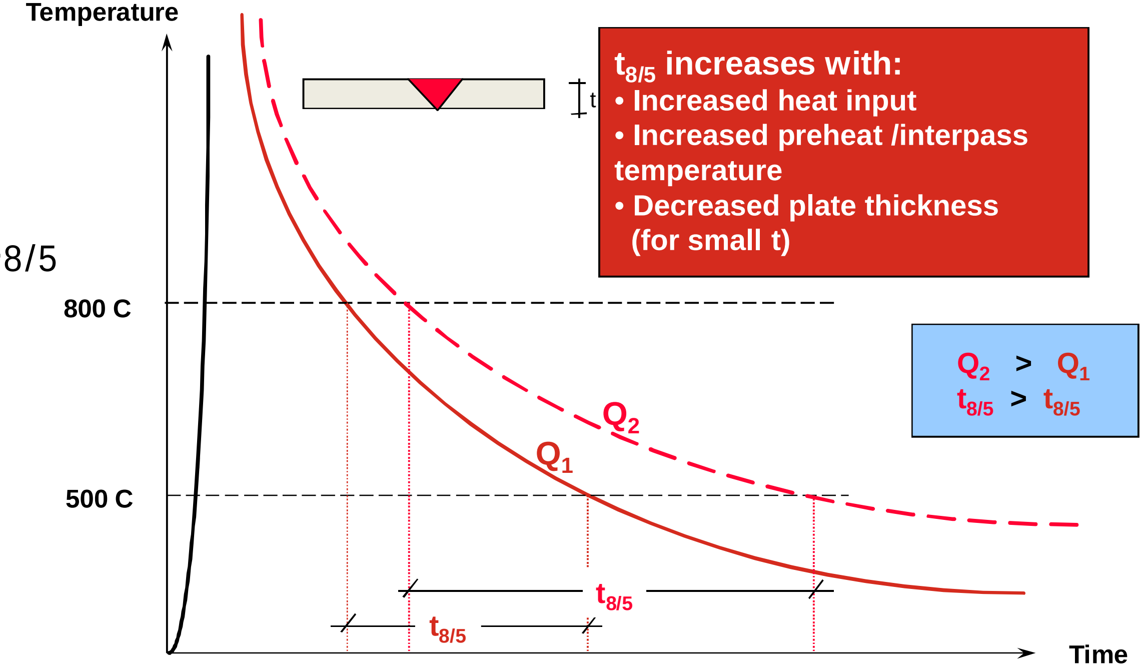
Svařitelnost - Vnesené teplo

Časy t8/5

- ► Příliš mnoho vneseného tepla - dlouhé časy $t_{8/5}$
  - ► Nižší mez pevnosti
  - ► Nižší mez kluzu
  - ► Nižší houževnatost

- ► Málo vneseného tepla – kratší $t_{8/5}$
  - ► Nižší houževnatost
  - ► Riziko neprůvarů
  - ► Nižší produktivita



►Postupy svařování lze vypočítat ručně, nebo s pomocí software SSAB WeldCalc, s kterým lze provést i dokumentaci svařovacího procesu – pWPS, WPQR atd.

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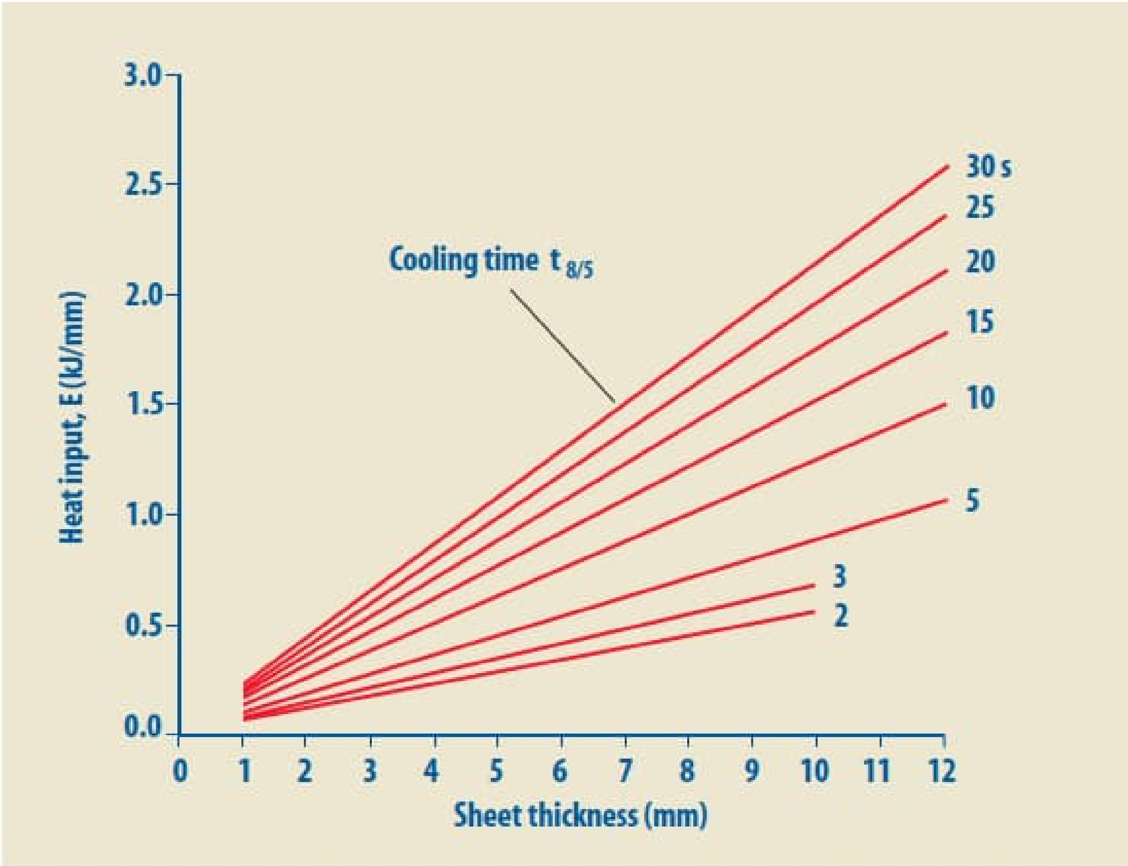
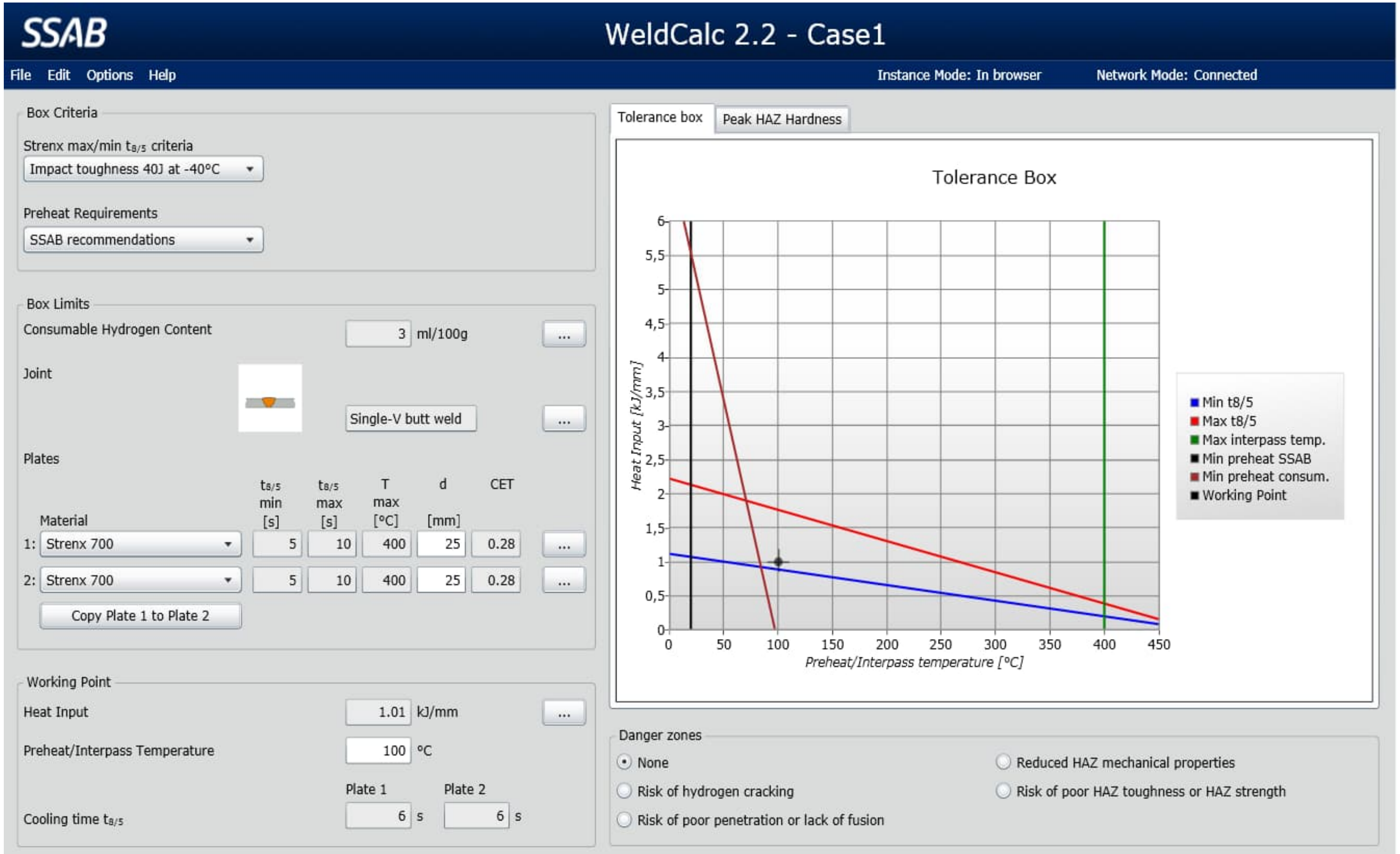


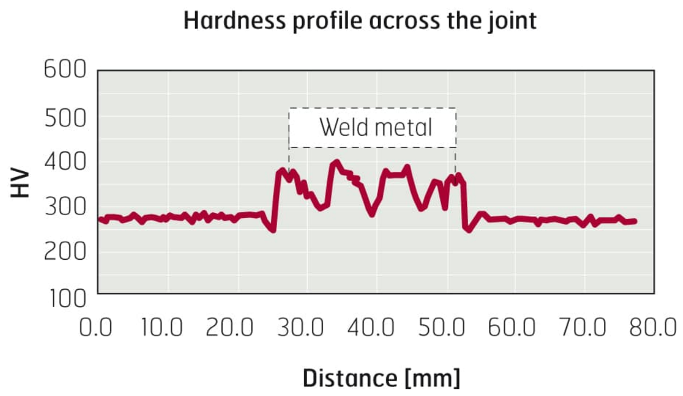
Figure 2.2 Graph for estimating $t_{8/5}$. Applies to MAG and MMA welding (butt weld, single V joint at a workpiece temperature of 20°C).

WeldCalc

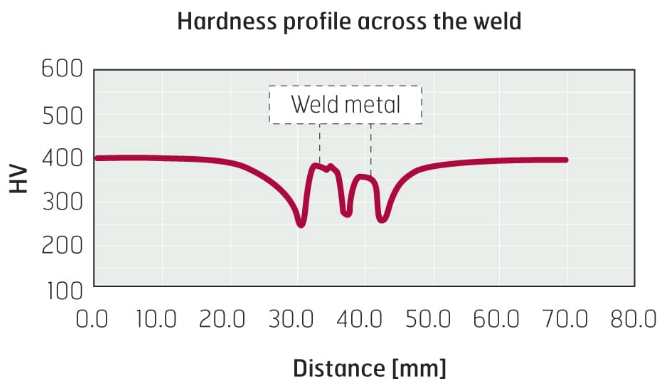


- pWPS
- WPQR

Pevnost svarových spojů



Strenx 700, 900, 960
Strenx 900 – 960 Plus
Hardox HiTemp a HiAce
Při použití přídavného materiálu stejné nebo vyšší pevnosti



Strenx 600 – 700 MC (Plus)
Strenx 1100, 1300
Strenx 900 – 1100 MC
Všechny Hardoxy kromě HiTemp a HiAce

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Doporučené intervaly $t_{8/5}$

Requirement: min. 27 J at -40ºC

Steel grade	Recommended $t_{8/5}$ values
Strenx 700	5 – 25 s
Strenx 900	5 – 20 s
Strenx 960 – 1300	5 – 15 s
S355 – 500 MC	1 – 25 s MAG 3 – 25 s
S550 MC	1 – 20 s MAG 3 – 20 s
Strenx 600 – 700 MC	1 – 20 s MAG 3 – 20 s
Strenx 700 MC Plus	1 – 20 s MAG 3 – 20 s
Strenx 900 – 960 Plus	1 – 15 s MAG 3 – 15 s
Strenx 900 MC	1 – 15 s MAG 3 – 15 s
Strenx 960 MC	1 – 15 s MAG 3 – 15 s
Strenx 1100 MC	1 – 10 s MAG 3 – 10 s

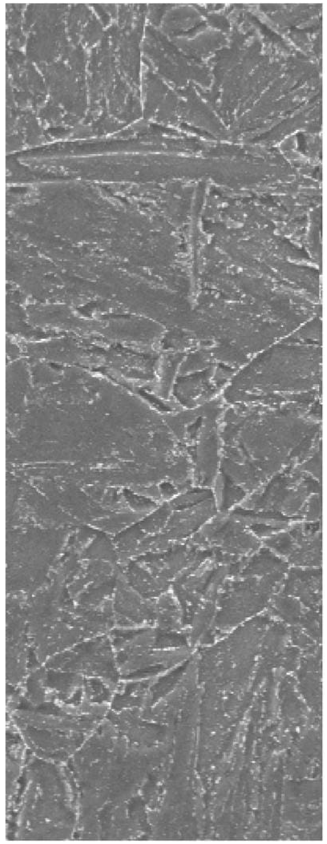
Recommended t8/5 intervals in order to fulfill the min impact toughness requirement 27J at -40ºC.

$$t_{8/5} = (6700 - 5\cdot T_0)\cdot Q\cdot\left(\frac{1}{500-T_0} - \frac{1}{800-T_0}\right)\cdot F_3$$

$$t_{8/5} = (4300 - 4{,}3\cdot T_0)\cdot 10^5\cdot\frac{Q^2}{d^2}\cdot\left[\left(\frac{1}{500-T_0}\right)^2 - \left(\frac{1}{800-T_0}\right)^2\right]\cdot F_2$$

Q = Heat input (kJ/mm)
d = Single plate thickness (mm)
T_0 = Working temperature (ºC)
F_2 = Shape factor
F_3 = Shape factor

Use WeldCalc to calculate and optimize the weld procedure



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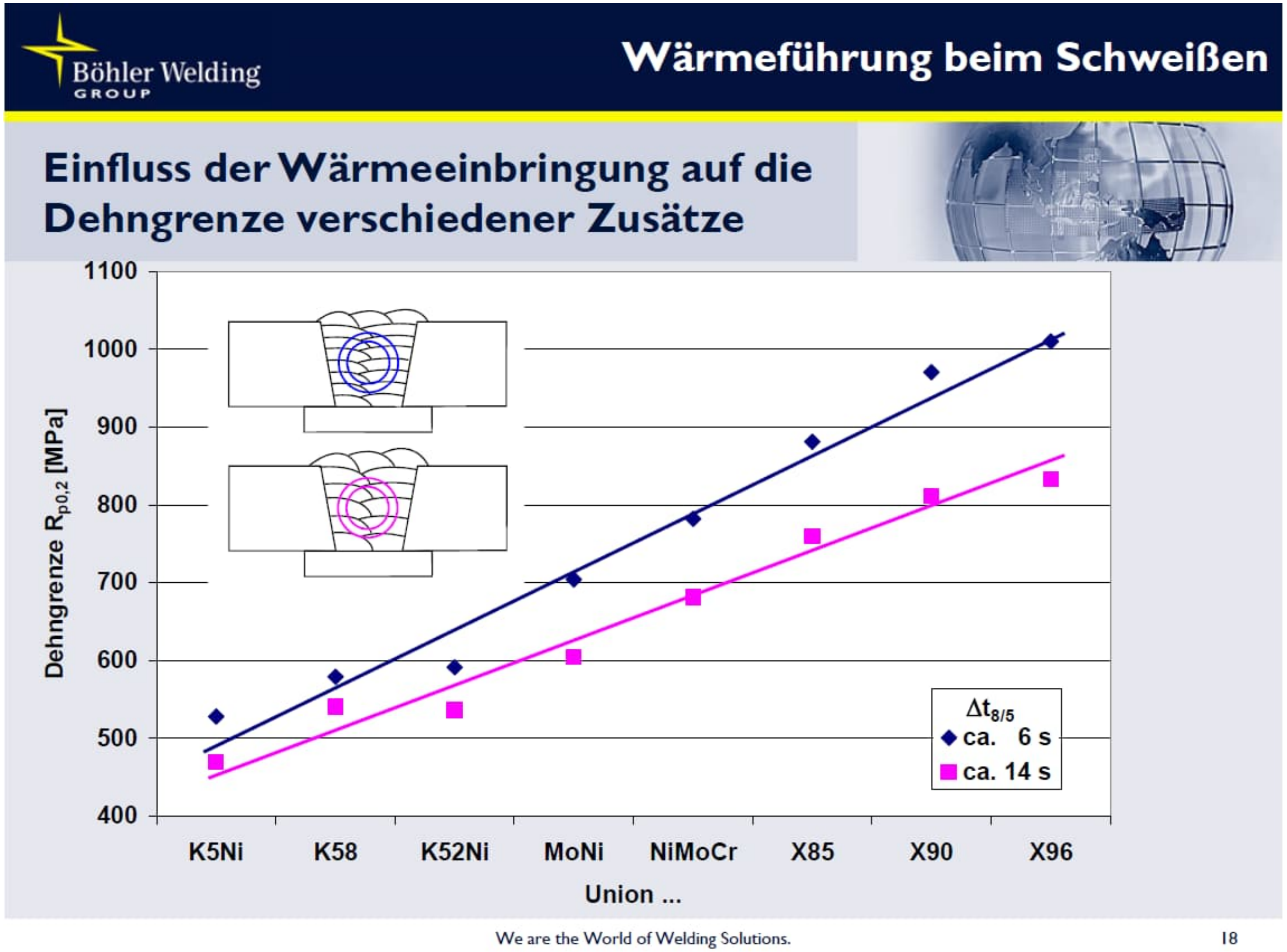
Vliv $t_{8/5}$ na pevnost SK



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Typická statická pevnost svarového spoje

Steel grade	$R_{p0,2}$ [Mpa]	R_m [Mpa]
Strenx 700	700-780	780-830
Strenx 900	780-850	940-1000
Strenx 960	900-980	1000-1050
Strenx 1100	950-1030	1010-1090
Strenx 1100 PLUS	min 1100	1160 – 1220
Strenx 1300	1000-1100	1100-1200
Strenx 600 - 700 MC	700 - 780	760 - 850
Strenx 700 MC Plus	700 - 780	760 - 850
Strenx 900 – 960 MC	800 - 1000	880 - 1080
Strenx 1100 MC	950 - 1070	1010 - 1180
Strenx 960 Plus	960 - 1070	1020 - 1140

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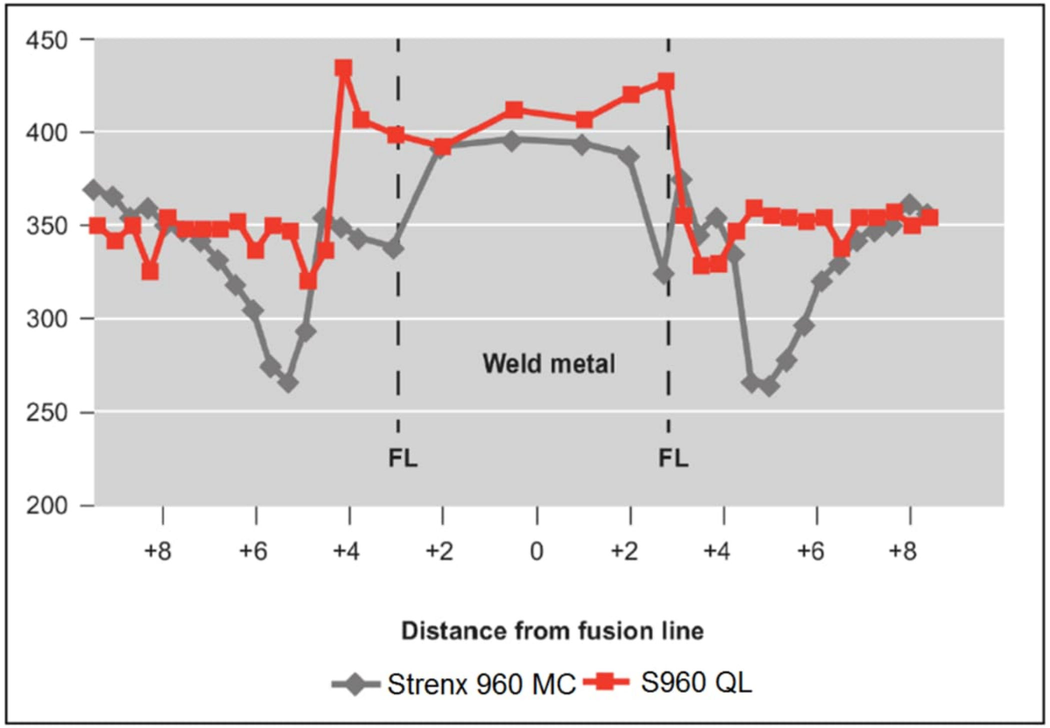
Examples of hardness profiles of the weld. Heat input [Q] is the same.



- Q=0,48 kJ/mm
- plate thickness = 6 mm
- welding wire Union X96

Strenx MC steels are not tempered and they have a lower level of alloying elements than QL steels of the same strength class

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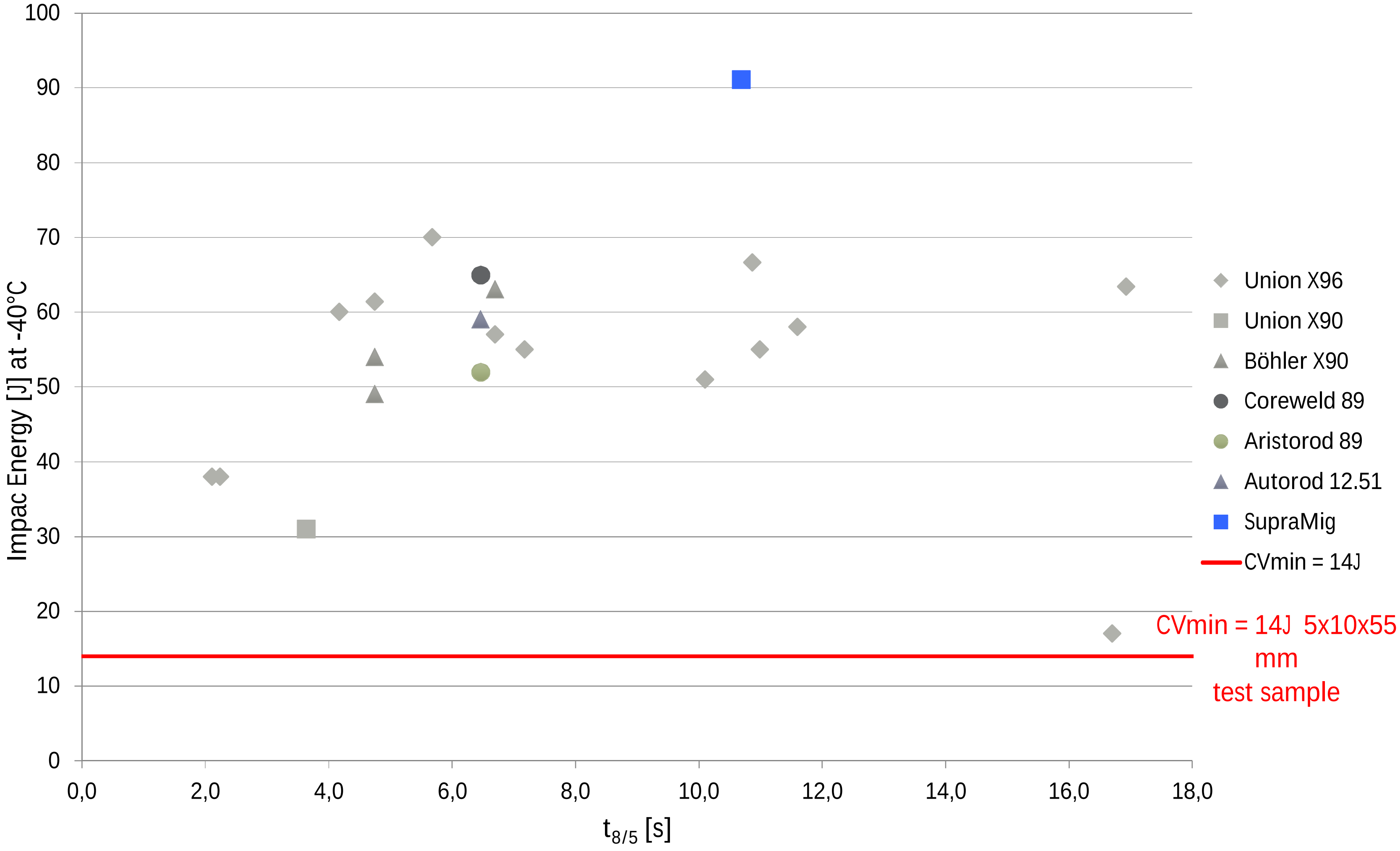
Houževnatost Strenx 960 MC HAZ (FL+1 mm)



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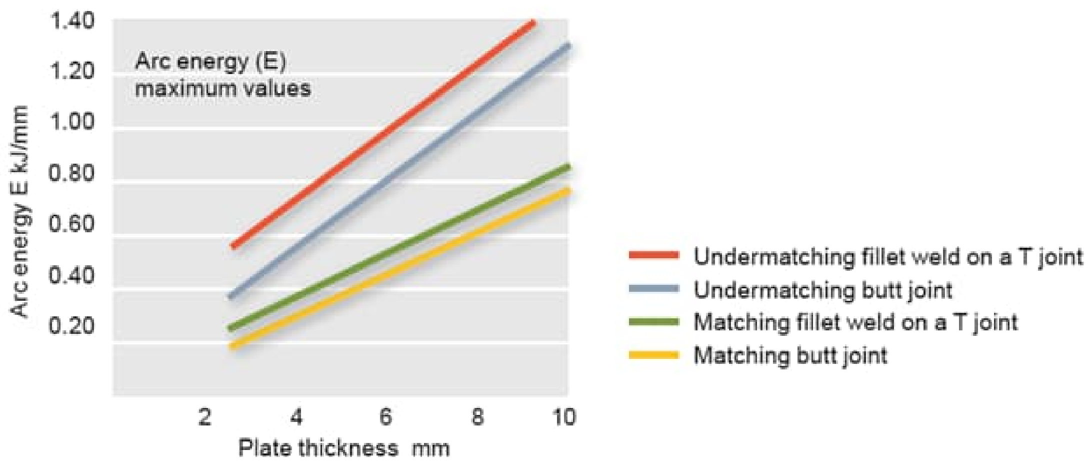
Arc energy, for fillet welds and undermatching joints it is possible to use higher arc energy than butt welds and matching joints

OPTIMIZED WELDING PARAMETERS.



Arc energy (E) and heat input (Q)

$$E = \frac{60 \times U \times I}{1000 \times v}$$

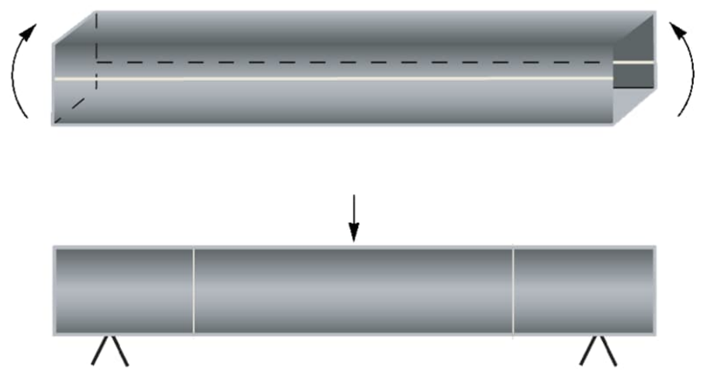
E = Arc energy (kJ/mm)
U = Voltage (V)
I = Current (A)
v = Welding speed (mm/min)

Q = k x E
Q = Heat input (kJ/mm)
k = Thermal efficiency
k = 0.8 for MIG/MAG, FCAW and MMA

Softening in the heat affected zone (HAZ) of the welded joint
Heat cycle during welding causes narrow softened HAZ. The softened HAZ is characteristic phenomenon of thermomechanical rolled ultra high strength steels. The softening can be taken into account in structures, e.g. by lowering design stress or by placing the welds in low stress area.

Undermatching filler metal can be used

- The weld is in a low stress area
- Welding to an ordinary mild steel
- Most joints subjected to fatigue loads



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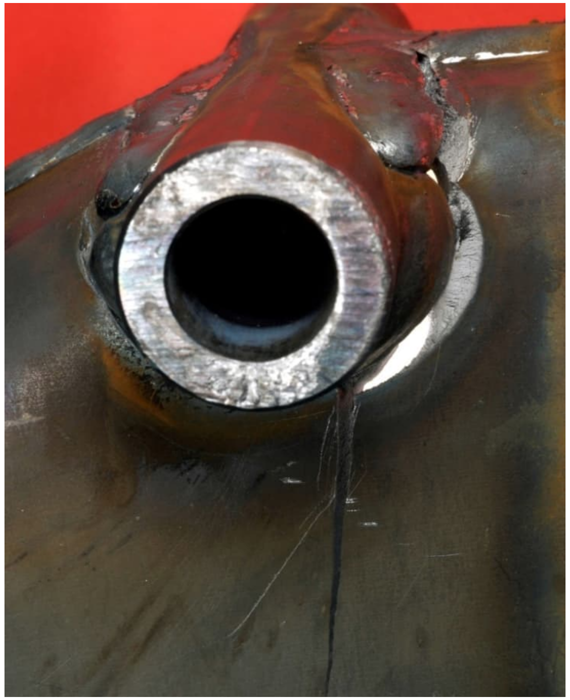
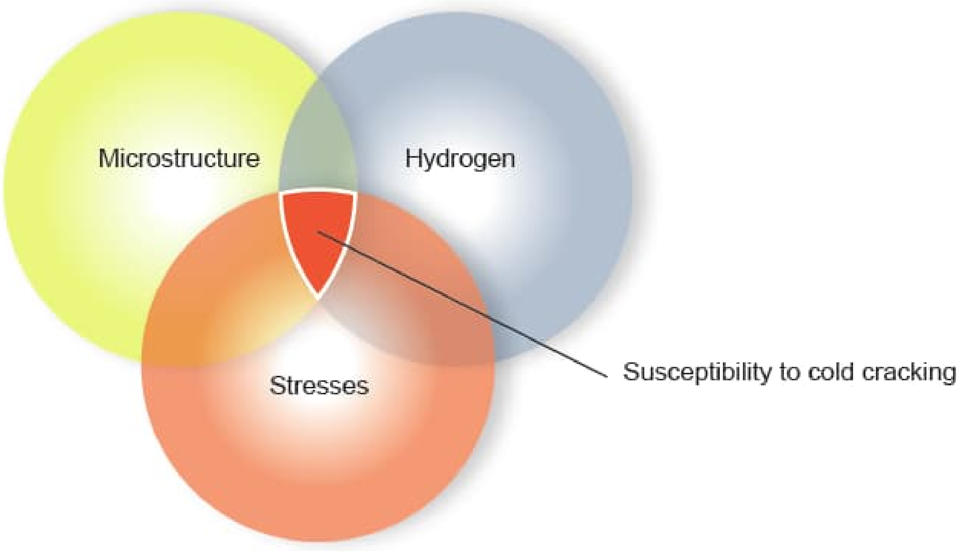


Preheating

- Preheating is not necessary when using low hydrogen welding consumables. Hydrogen content not over 5 ml/100g (H5)
- Plate thickness is thin (3-10 mm)
- CET value is quite a low
- Welding consumable important to check if preheating is needed (can be calculated acc. to EN 1011-2, method B)



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Filler material selection

- EN ISO 16834:2007 strength class 89 (Rp0.2 minimun 890 MPa).
- Impact strength class 4-6 (CV minimum 47J/-40 °C).

HIGH STRENGTH WELDING CONSUMABLES FOR LOAD BEARING WELDS

Welding process	Examples of consumables
MAG Solid wire	OK Aristorod 79/M21, Union X90/M21, Union X96/M21, OK AristoRod 89 / M21
FCAW Flux-cored	PZ 6149, Stein Megafil 1100 M
FCAW Metal-cored	Coreweld 89 / M21 or M20
MMA Covered electrode	OK 75.78, SH NNI 2 K 130, Fox EV 90

NOTE: The validity of any consumable should be verified with their manufacturer. High strength consumable may require preheating because of high alloying rate of the consumable. The need for preheating due to the consumable must be checked. Low hydrogen class ≤ H5 of consumables is essential.

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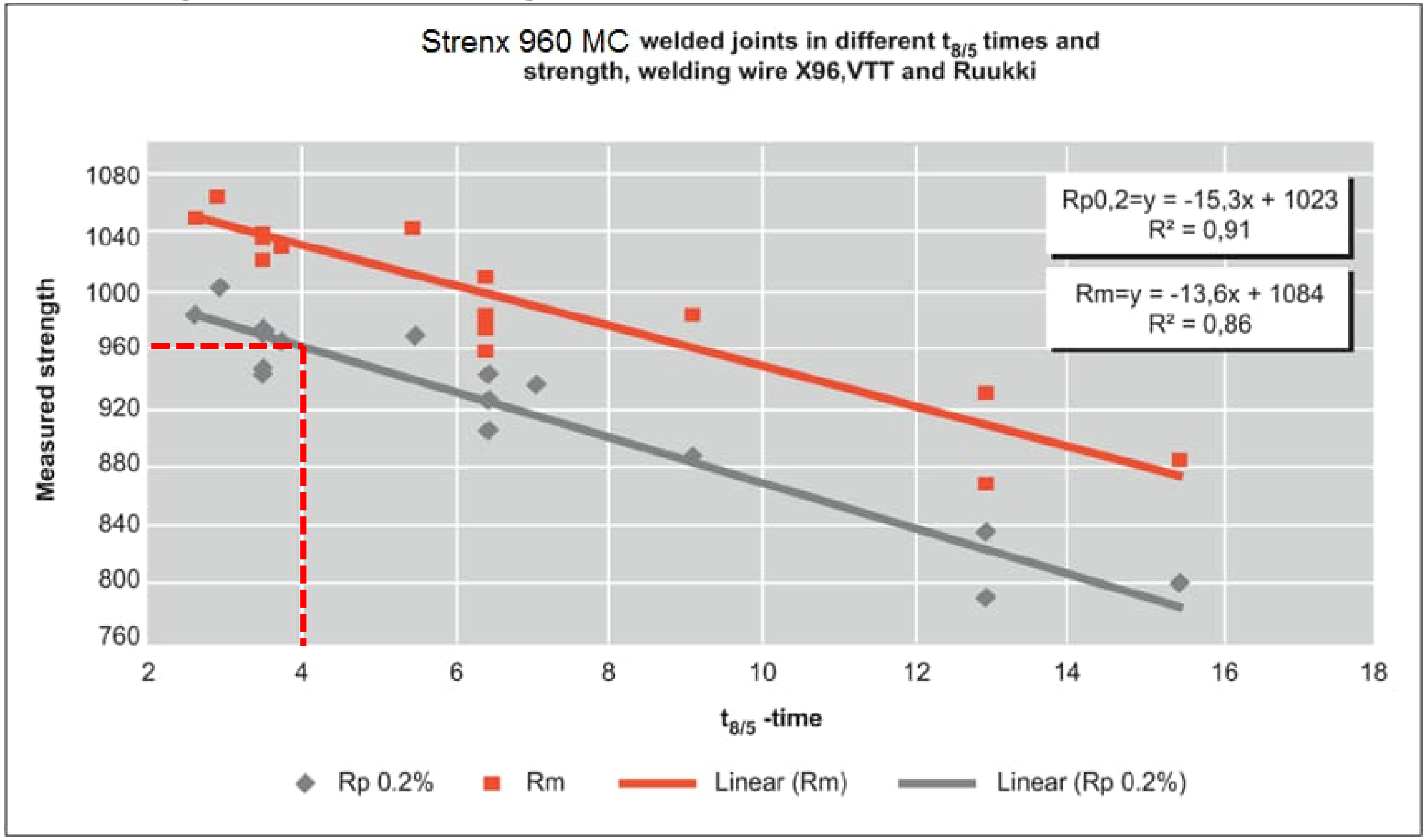
The effect of cooling time t8/5 on yield and ultimate tensile strength of butt joint



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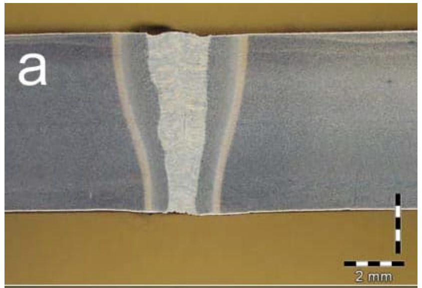
Welding processes for UHSS steel

Base material Strenx 960 MC 6mm



a) Laser

Welding speed	1,2 m/min
Welding energy	0,26 kJ/mm
Yield strength	1024 MPa

+ Low welding energy
+ Small distortion
- Small groove tolerance
- Expensive

b) Laser + MAG (Hybrid)

Welding speed	2,0 m/min
Welding energy	0,35 kJ/mm
Yield strength	979 MPa

+ Low welding energy
+ Small distortion
+ High productivity
- Expensive

c) Pulsed MAG

Welding speed	0,8 m/min
Welding energy	0,59 kJ/mm
Yield strength	981 Mpa (backing)

+ Cheap
+ Easy process
+ Also manual welding
- Lower energy density
- Lower productivity

Laser-MAG hybrid welding tests

- Tensile test results, next slide

	Laser-GMA hybrid welding		Laser tack welding	
	Y 10°	Y 20°	Y 10°	Y 20°
Laser power [kW]	9.2	10	2	2
MAG Current (mean) [A]	230	245		
MAG Voltage (mean) [V]	33	34		
Travel speed [m/min]	3.3	1.8	1	1
Filler wire feed rate	14	16		
Welding energy [kJ/mm]	0.31	0.63	0.12	0.12

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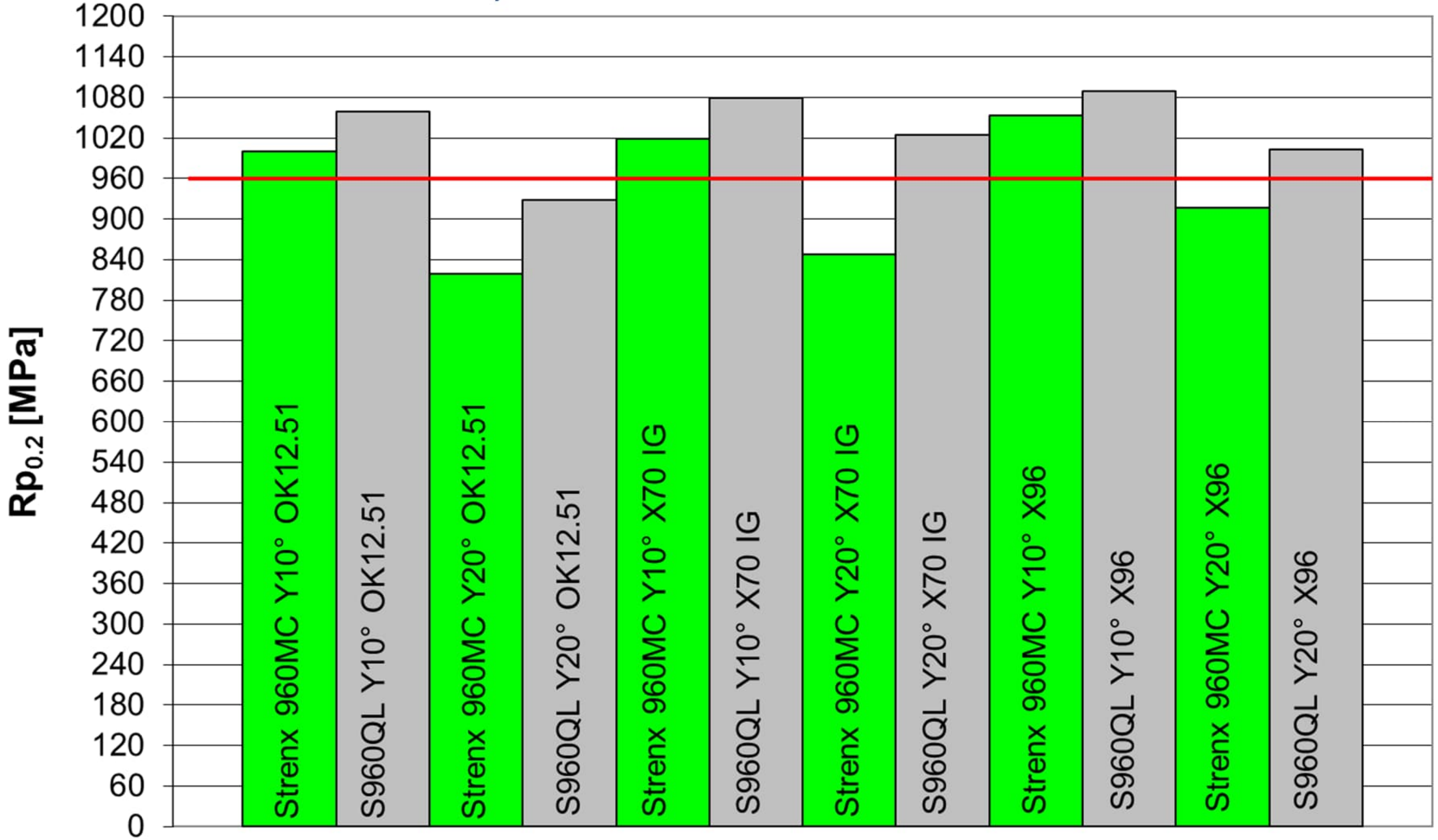
Yield strengths [MPa] of the laser-MAG hybrid welded joints. Welding consumables Esab OK12.51, Böhler X70 IG and Union X96



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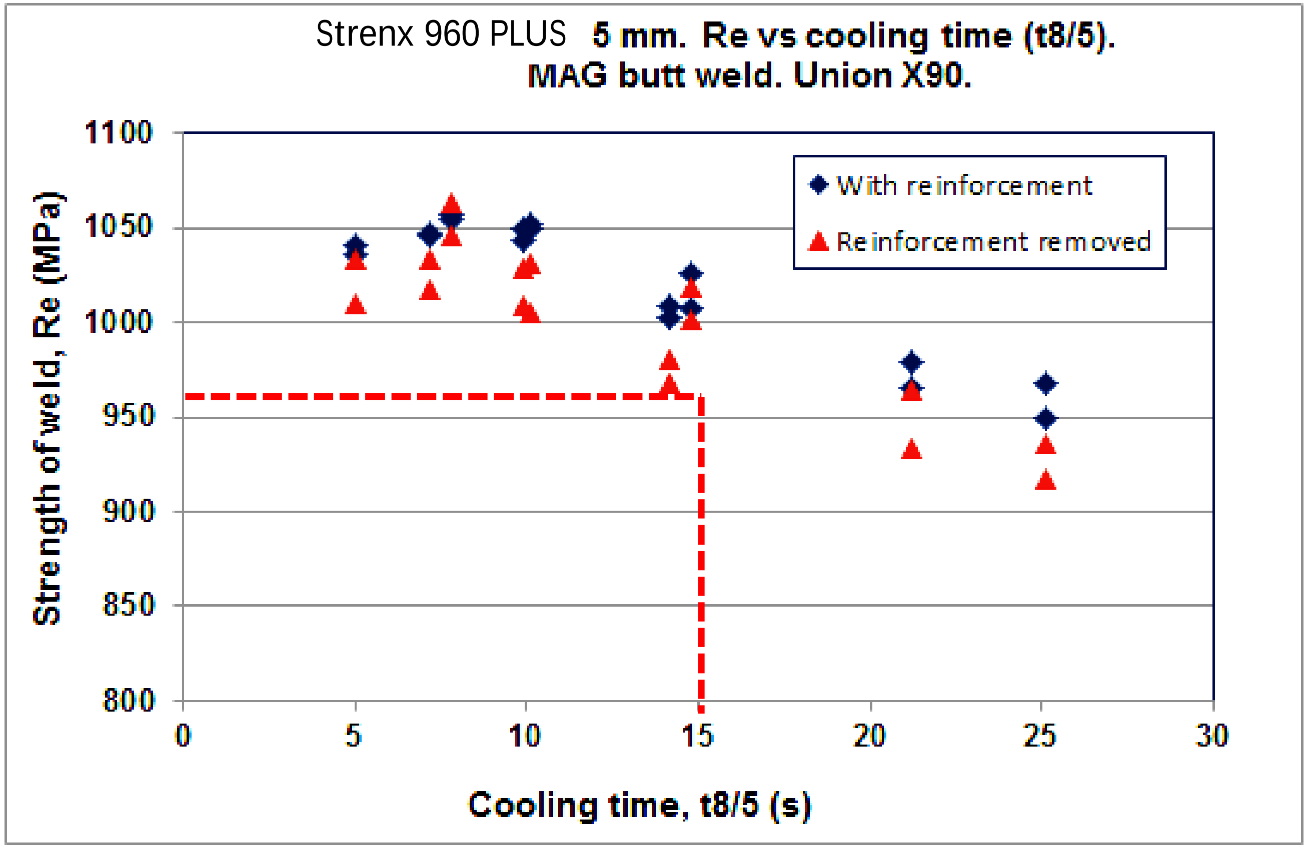
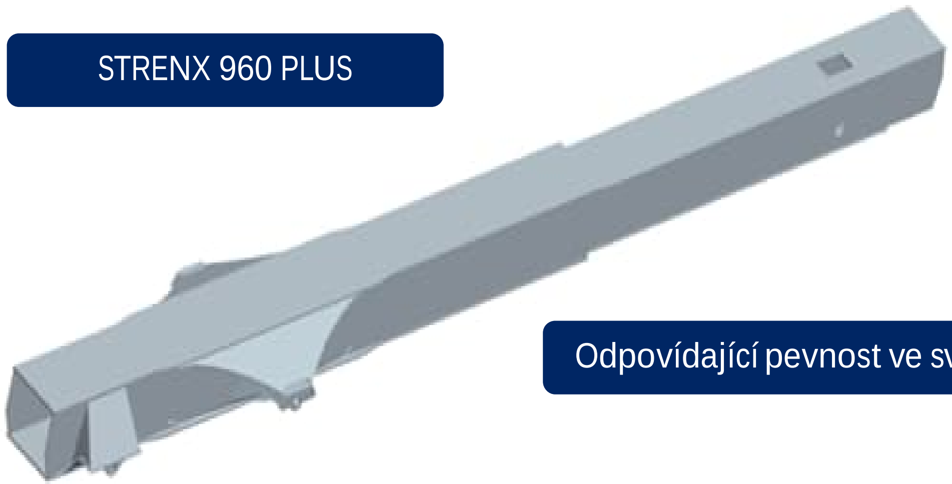
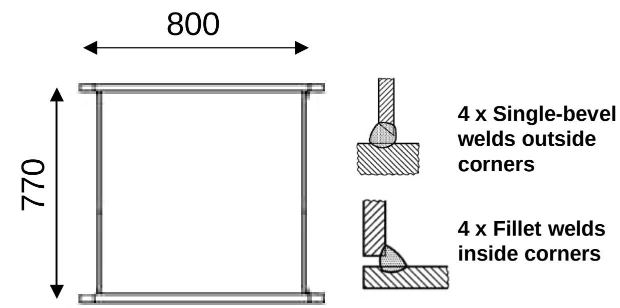
Strenx 960 PLUS



Výložník mobilního jeřábu - Strenx 960 PLUS vs Strenx 960 MC

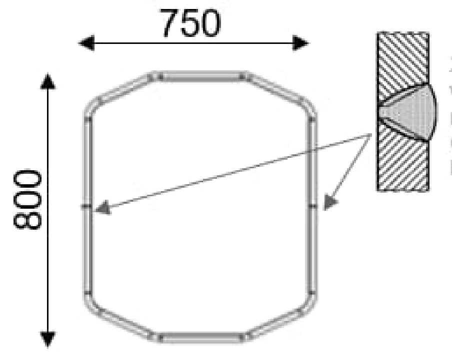
STRENX 960 PLUS

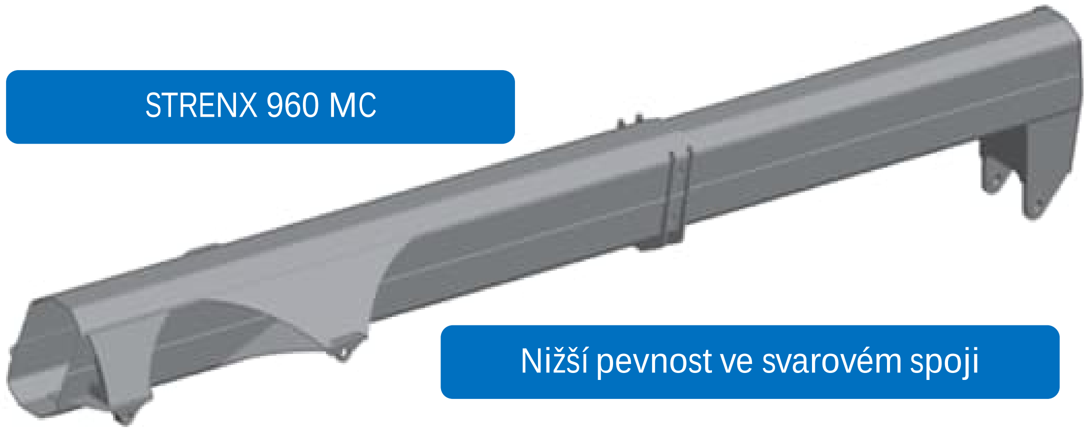




Odpovídající pevnost ve svarovém spoji

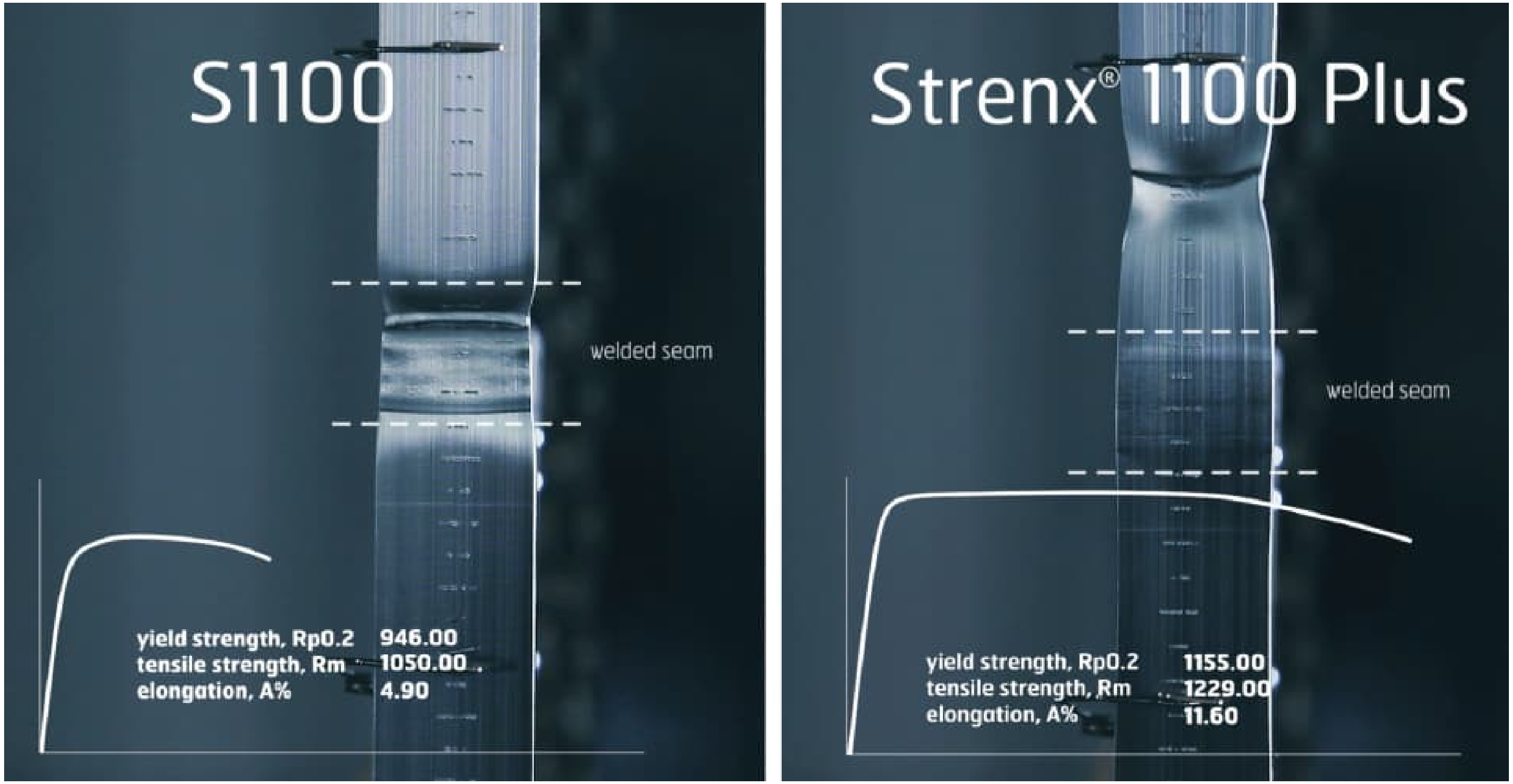
STRENX 960 MC



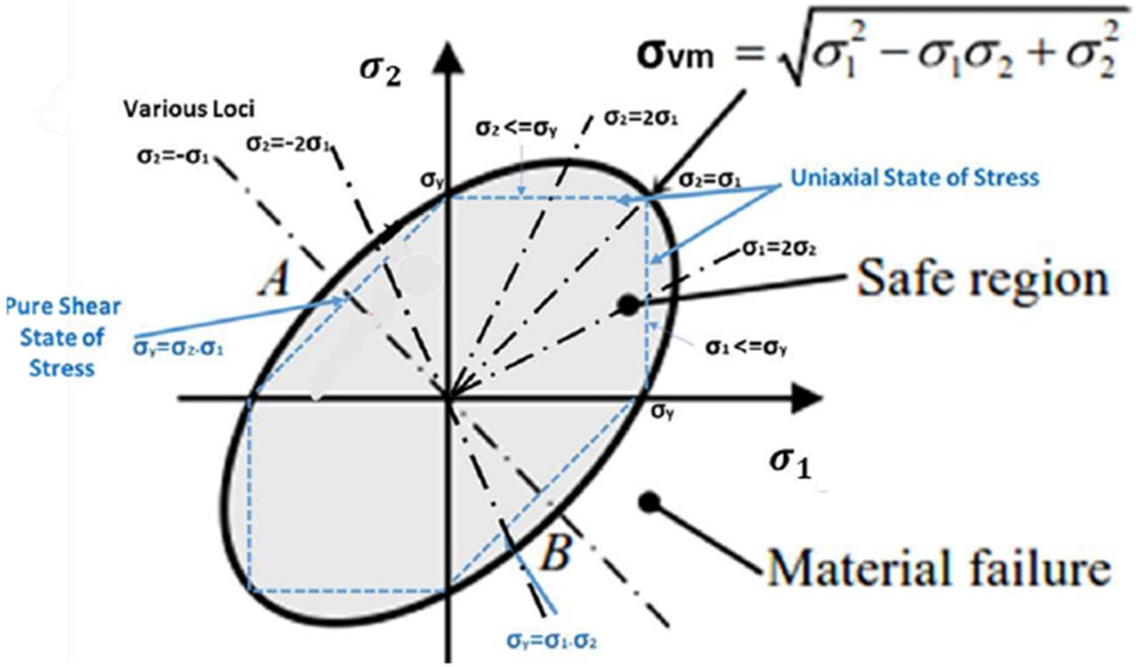


Nižší pevnost ve svarovém spoji

Tradiční Strenx 1100 vs Strenx 1100 PLUS



Obálka plastických napětí dle von Misese



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Rovnání plamenem CEN/TR 10347:2006

Flame straightening. Hot rolled steels, maximum recommended temperatures by delivery condition Source CEN/TR 10347:2006 (E)

Delivery conditions	Delivery condition designation	Maximum recommended flame straightening temperatures ° C		
		Short-term surface heating	Short-term full thickness heating	Long-term full thickness heating
Normalized, Normalized rolled	N	$\leq$ 900° C	$\leq$ 700° C	$\leq$ 650° C
Thermomechanically rolled up to strength class S460	M	$\leq$ 900° C	$\leq$ 700° C	$\leq$ 650° C
Thermomechanically rolled, strength class S500…S700	M	$\leq$ 900° C	$\leq$ 600° C	$\leq$ 550° C
Quenched and tempered	QT	Tempering temperature in manufacturing lowered 20° C. Maximum usually $\leq$ 550° C		

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PWHT (Žíhání k odstranění pnutí)

- ►Strenx 1100, 1300, Strenx 900 – 1100 MC a Strenx 900 – 960 Plus není možno žíhat

ARMOX - Preheat temperature:

Thin plates with low stress joints, preheat can be considered case by case

Plate thickness	3.0-8.0 [°C]	8.1-10.0 [°C]	10.1-12.0 [°C]	12.1-15.0 [C]	15.1-20 [°C]
Steel					
Armox 370T, Class 1, Class 2; unalloyed or low alloyed consumables	50	100	125	125	125
Armox 370T, Class 1, Class 2; Stainless consumables	RT	RT	RT	RT	RT
Armox 440T, unalloyed or low-alloyed consumables	50	75	75	125	125
Armox 440T, Stainless consumables	RT	RT	RT	RT	RT
Armox 500T, unalloyed or low alloyed consumables	50	100	125	125	125
Armox 500T, Stainless consumables	RT	RT	RT	RT	RT
Armox 600T, stainless consumables	100	100	100	100	100

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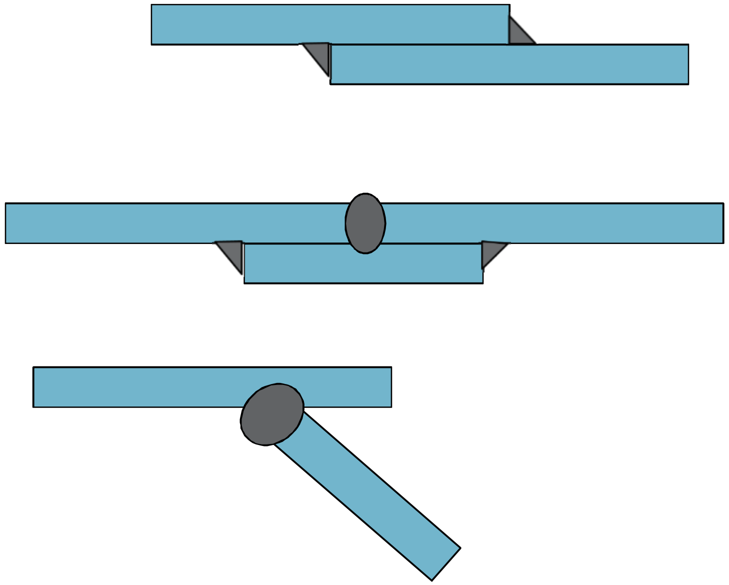
How to minimize HAZ softening effects

- ▶ Minimize or eliminate welding:
  - Use of bended components preferred option
  - Mechanical connections (bolts or studs) if possible
- ▶ Overlap joints
  - Minimum overlap recommendation 20 - 25 mm
- ▶ Backing strips
  - Narrow strip behind or top of weld
- ▶ Weld placement
  - Blind placement, hide weld from direct hit
- ▶ Low heat input butt welds
  - Use of low energy to minimize HAZ softening



Selection of welding consumables

- The selection of welding consumables:

1. Undermatching ferritic, WM yield strength max. about 500 MPa
2. High-strength ferritic, WM yield strength max. about 800 MPa
3. Undermatching austenitic, WM yield strength max. about 500 MPa

- Undermatching ferritic consumables are in most cases good cost effective alternative for all grades, easy to weld.
- High-strength ferritic consumables are more difficult to weld and benefits are limited, weld is not ”bullet proof”. Use only if especially high strength is needed for joints
- Austenitic consumables are the most commonly used consumables. The risk for cold cracking can be reduced significantly. Austenitic consumables are most beneficial also in repair welding.

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Selection of welding consumables – undermatching ferritic

▶Examples of ferritic undermatching consumables:

MAG solid wire welding	MAG flux-cored welding: Metal-cored wire	MAG flux-cored welding: Rutile flux-cored wire	Submerged arc welding: Wire+ flux	Manual metal arc welding
AWS A5.18 ER70S-X	AWS A5.18 E70C-X	AWS A5.20 E71T-X	AWS A5.17 F7X	AWS A5.1 E7018X
OK Autrod 12.51 (ER70S-6) OK AristoRod 12.63 (ER70S-6)	OK Tubrod 14.12 (E70C-6M, E70C-6C) PZ6102 (E70C-6M H4)	OK Tubrod 15.14 (E71T-1, E71T-1M)	OK Autrod 12.22+ OK Flux 10.71 (F7A5-EM12K)	OK 48.00 (E7018) OK 55.00 (E7018-1)

▶The advantages of undermatching ferritic consumables compared to high-strength consumables:

Good welding properties
Extensive selection and good availability
Cost-effective both at purchase as well as during use
Lower stress level in the weld
A tough and ductile welding consumable tolerates stress well
Lower carbon equivalent and, respectively, lower hardenability
Lower susceptibility to cold cracking
Tolerates hydrogen better than a higher-strength welding consumable
Less need to increase working temperature than with higher-strength welding consumables

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Selection welding consumables – high-strength ferritic

- Examples of ferritic high-strength consumables:

MAG solid wire welding	MAG flux-cored welding: Metal-cored wire	MAG flux-cored welding: Rutile flux-cored wire	Submerged arc welding: Wire+ flux	Manual metal arc welding
AWS A5.28: ER100S-X	AWS A5.28: E110C-X	AWS A5.29: E111T1-X	AWS A5.23: F11X	AWS A5.5: E11018X
OK AristoRod 69: ER100S-G	OK Tubrod 14.03: E110C-G	OK Tubrod 15.09: E111T1-K3MJ-H4	OK Autrod 13.43+ OK Flux 10.62: F11A8-EG-G	OK 75.75: E11018-G

- Increased risk of cold cracking
- Recommended only for special applications (e.g. weld subjected to heavy static loads)
- Better suited for thin plates, for thick t > 15 mm plates it is difficult to get good properties

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Selection of welding consumables - austenitic

► Examples of austenitic consumables:

MIG solid wire welding	MAG flux-cored welding, Metal-cored wire	MAG flux-cored welding, Rutile flux-cored wire	Submerged arc welding Wire+ flux	Manual metal arc welding
AWS 5.9 ER307	AWS 5.9 EC307	AWS 5.22 EC307T-x	AWS 5.9 ER307	AWS 5.4 E307-X
OK Autrod 16.95 (ER307)	OK Tubrod 15.34	OK Tubrodur 14.71	OK Autrod 16.97+ OK Flux 10.93	OK 67.45

► Listed consumables are so-called AWS 307 type Mn-alloyed consumables, reduced cracking possibility. AWS 309 type consumables are suitable as well.

► Advantages and properties of austenitic consumables:

Good welding properties
Good selection and availability
High purchase price
The stress level of the weld is low
Very tough and ductile welding consumable
Austenitic microstructure dissolves less hydrogen without susceptibility to cold cracking
Usually no need to increase working temperature
Withstands welding stresses

SSAB

Recommendation: Austenitic
Armox 600T/ 12 mm

- ►MAG welding
- ►High Mn austenitic wire 307 / OK 16.95 or similar
- ►Preheat +100°C for stiff joints, torch heating not recommended
- ►Target parameters (t 8/5: 10 ... 15 sec):
  - Arc energy: 1.42..1.5 kJ/mm, modern pulse machines recommended
- ►Soft HAZ area about +25 mm on both side of weld
- ►Min length of weld run 50 mm (=tacks)
- ►Gas selection:
  - Gas Ar + Co2 2 %, stable arc
  - Gas flow steady, not too high (flow = nozle diameter)

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Recomendation: Austenitic Armox 600T/

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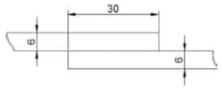
HITSAUSKOEPÖYTÄKIRJA
DETAILS OF WELD TEST

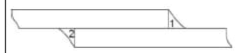
Pöytäkirjan nro Report no	978	**Työ nro** Work no	196/15	**Tilaaja** Customer	Sakari Tihinen

Paikka Location	Raahe	**Hitsausohje nro** WPS no	---	**Menetelmäkoepöytäkirjan nro** WPQR no	---
Valmistaja Manufacturer	SSAB Europe Oy	**Perusaine** Parent material spec.	Armox 600, 111835-802275		
Hitsaaja Welder	Jorma Laitinen				
Hitsausprosessi Welding process	135	**Ainepaksuus** Material thickness	6.0 mm	**Ulkohalkaisija** Outside diameter	---
Liitosmuoto Joint type	FW	**Liitoksen kuva** Joint design		**Hitsausjärjestys** Welding sequence	
Hitsausasento Welding position	PB				
Railon valmistus Edge preparation	Machining				
Railon puhdistus Cleaning	---				
Silloitus Tacking	---				
Juurituki Backing	---				
Juuren avaus Back gouging	---				
Jälkikäsittely Post-weld treatment	---				

Joint design:



Welding sequence:



Hitsauksen suoritusarvot / Welding details

Palko Run	**Prosessi** Process	**Lisäaineen mitat** Size of filler metal **mm**	**Hitsausvirta** Current **A**	**Kaarijännite** Voltage **V**	**Virtalaji/napaisuus** Type of current/ polarity	**Langansyöttö** Wire feed **m/min**	**Kuljetusnopeus** Travel speed **cm/min**	**Kaarienergia** Arc energy **kJ/mm**
1-2	135	1.0	250	29.3	DC+	13.3	47.0	0.93

Esikuumennus Preheat	--- °C	**Palkojen välinen lämpötila** Interpass temperature	25 °C	**Huom.** Notes	Joint 19-24
TIG-elektrodi, tyyppi/koko Tungsten electrode, type/size	---				

Hitsausaineet / Welding Consumables

Kauppanimi ja lisäaineen luokittelu Trade name and classification of filler metal	OK Autrod 16.95, EN ISO 14343-G 18 8 Mn				
Suojakaasu/jauhe Shielding gas/flux	Mison 2	**Juurikaasu** Backing gas	---	**Kaasun virtausnopeus** Gas flow rate	16 L/min

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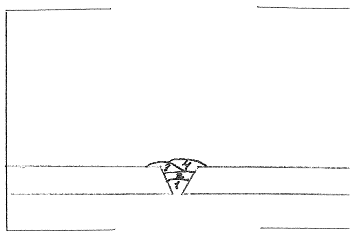
Recommendation: Soft ferritic Armox 600T/ 8 mm

- ►MAG welding with soft ferritic wire OK14.13
- ►Preheat +150°C
- ►Target parameters (t 8/5: 15…25 sec):
  - HI: 0.7 / 1.0 kJ/mm
  - D321 / D322 WPS
  - Mison 25 gas
- ►Soft HAZ area about +25 mm on both side of weld
- ►Higher energy gave better properties
- ►Min length of weld run 50 mm (=tacks)

Stålkvalitet: Armox 600
Plåttjocklek: 8 mm
Plåtidentitet: 7071276
Stämpling: D321
Svetsmetod: FCAW 136
Tillsatmaterial: OK 14.13
Mison 25
Gasförbrukning: 15-18 l/minut
Strängantal: 4
Tork. av tills.mat.: ……h……°C
Förvärmning: 150 °C
Rotbehandling: Slipning
Svetsat av: M. Fried
Datum: 13-03-06
Förb längd: …
bredd: …

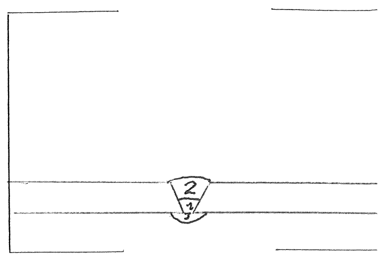
Meddelande: …
Beställare: P. Hansson



Sida nr	Sträng nr	Elek. diam. [mm]	Amp [A]	Volt [V]	Sträng längd [mm]	Bågtid [s] t8/5	Svets hastigh. [cm/min]	HI [kJ/mm]	Mellanstr temp. [°C]	Svets läge	AC/ DC
1	1	1,2	150	19			25	0,55	150	PA	DC
"	2	"	176	20,8		14,6	25	0,70	"	"	"
"	3	"	"	"			"	"	"	"	"
"	4	"	"	"			"	"	"	"	"

Stålkvalitet: Armox 600
Plåttjocklek: 8 mm
Plåtidentitet: 7071276
Stämpling: D322
Svetsmetod: FCAW 136
Tillsatmaterial: OK 14.13
Mison 25
Gasförbrukning: 15-18 l/minut
Strängantal: 3
Tork. av tills.mat.: ……h……°C
Förvärmning: 150 °C
Rotbehandling: Slipning
Svetsat av: M. Fried
Datum: 13-03-07
Förb längd: …
bredd: …

Meddelande: …
Beställare: P. Hansson



Sida nr	Sträng nr	Elek. diam. [mm]	Amp [A]	Volt [V]	Sträng längd [mm]	Bågtid [s] t8/5	Svets hastigh. [cm/min]	HI [kJ/mm]	Mellanstr temp. [°C]	Svets läge	AC/ DC
1	1	1,2	150	19			25	0,55	150	PA	DC
	2	"	220	21,5		24,7	"	0,91	"	"	"
2	3	"	150	19			"	0,55	"	"	"

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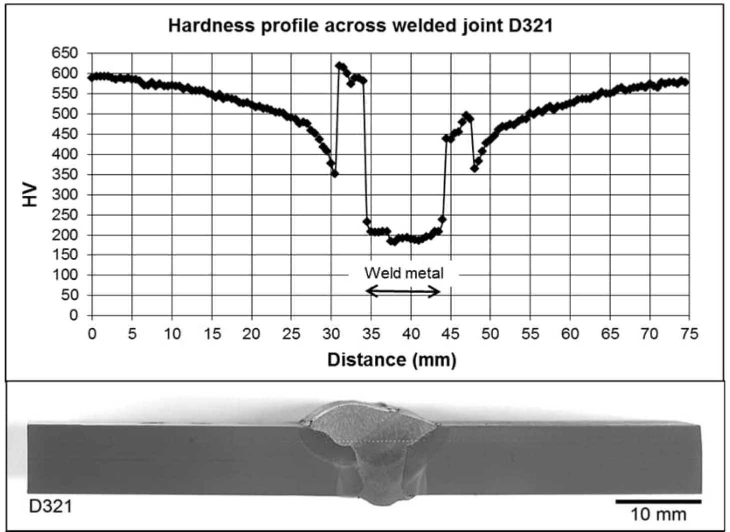
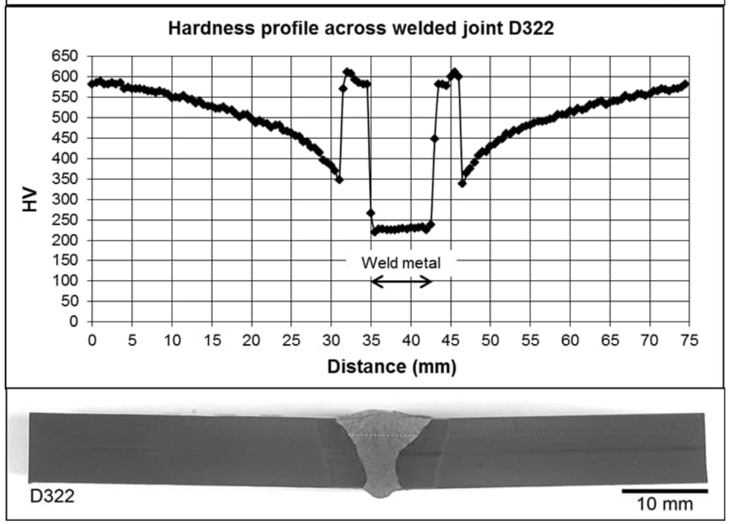
Recomendation: Soft ferritic Armox 600T/ 8 mm results

- ▶Strength:
  - D321 (15 s)
    - Rm 767 / 850 Mpa
  - D322 (25 s)
    - Rm 898 / 940 Mpa
- ▶Charpy V average (-40°c)
  - D321 (15 s) / D322 (25 s)
    - WM 36 J/ 34 J
    - FL 39 J/ 21 J
    - FL+1 13 J/ 29 J
    - FL+3 17 J/ 27 J
    - FL+5 20 J/ 27 J
    - FL+7 21 J/ 21 J





Děkuji za pozornost

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