

Consumables for welding Hardox[®], Strenx[®], Toolox[®] and Armox[®] steel

#60

In this TechSupport, SSAB offers suggestions for suitable consumables for welding Hardox[®] wear plate, Strenx[®] performance steel, Toolox[®] engineering & tool steel and Armox[®] protection plate. Note that the consumables listed are only examples. In addition to these, there are numerous suitable products that meet the recommendations from SSAB. The consumables are classified into two main groups – unalloyed and low-alloyed grades, which are the most common – and stainless steel consumables.



Unalloyed and low-alloyed consumables

General

Unalloyed and low-alloyed consumables should meet the specified strength criteria, their hydrogen content should be lower or equal to 5 ml of hydrogen per 100 g of weld metal.

Strength

Suitable strength levels for consumables used for welding Strenx®, Hardox®, Toolox® and ArmoX® steels are given in the chart on page 4.

Hydrogen content

The hydrogen content of consumables depends on factors such as the welding method used. Solid wires for MAG with solid wire and TIG welding can meet the hydrogen content criteria for all types of consumables. Flux-cored wires for MAG welding, which fulfil the hydrogen content criteria, are available for both basic and rutile types of consumables.

Metal-cored wires used in MAG welding can have suitable hydrogen contents for certain brand names. Among consumables for submerged arc welding, the combination of solid wire/basic flux can produce sufficiently low hydrogen contents in the weld metal.

Manufacturers of consumables can provide information regarding the hydrogen content of a specific consumable. In addition, SSAB has specified suggestions for suitable consumables. The types suggested in this TechSupport are sorted according to welding method and strength class.

Preheat/interpass temperatures due to consumable properties

When welding with consumables with yield strengths ($R_{p0.2}$) up to 700 MPa (100 ksi) the consumable properties typically don't influence the minimum preheat temperature of the joint.

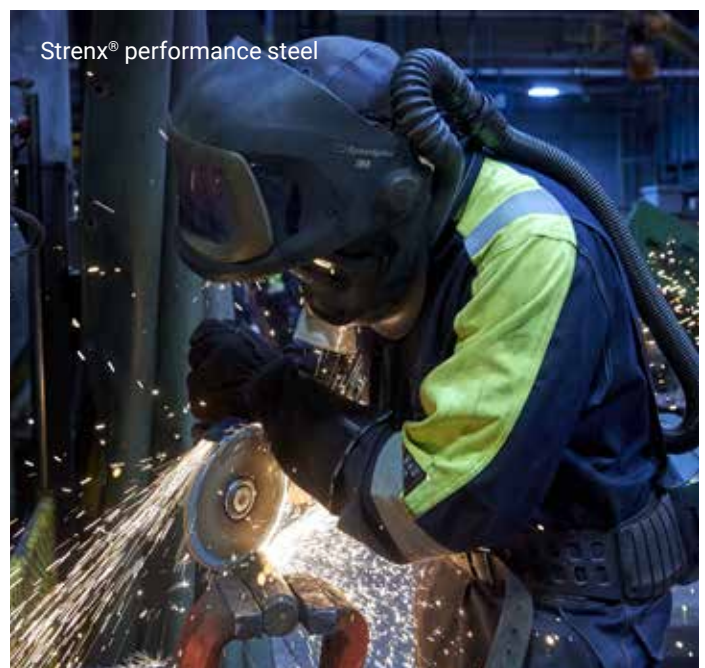
The reason is that the carbon equivalent (CET), of the parent metal typically exceeds that of the weld metal by at least 0.03 units of percentage. For consumables with yield strengths of 700 MPa (100 ksi) and higher, the CET value for the consumable versus the CET value for Strenx® is normally so high that the minimum preheating temperature of both, the steel and the consumable, are to be considered.

In this situation, the highest minimum preheat temperature of either the joint plates or the consumable should be used. SSAB's software WeldCalc™ can simplify these calculations. As for all types of low-alloyed consumables, the maximum hydrogen content is set to 5 ml/100 g of weld metal.

Toolox® can in certain cases be welded with consumables that have matching hardness to the unaffected parent metal. This type of consumable is designed especially for welding tool steels. This means that their mechanical properties are typically stated in hardness of the all-weld metal and not by their strength. For this type of welding performance, contact SSAB for further information regarding welding recommendations including e.g. selection of suitable consumables.



Hardox® wear plate



Strenx® performance steel

High strength, low-alloy consumables with yield strengths (R_{p0.2}) higher than 700 MPa (100 ksi)

Strenx® 900-1300 steel types are frequently welded with consumables that have yield strengths of about 750-900 MPa (109-130 ksi) in the all-weld metal. The Toolox® grades can also be welded with these types of consumables, although to a less extent compared to the Strenx® grades.

This group of consumables represents the highest strength available on the market. The manufacturers of consumables do not normally specify preheat/interpass temperatures for these types of consumables. The actual temperature can, for example, be determined in accordance with the European standard EN 1011-2, Method B. In addition, SSAB has made its own general estimates of the lowest suitable preheat/interpass temperature in accordance with the table below. This is possible since the alloying concepts are similar for the relevant consumables. Consumables are sensitive to high interpass temperatures. All recommended consumables can achieve high strengths due to the high strength microstructures, such as martensite, in the weld metal. Due to the high content of alloying elements, martensite transformation takes place at low temperatures. This is why SSAB considers that the interpass temperature should be set at a maximum of 210 °C (410 °F).

High strength consumables are normally sensitive to high heat inputs. Excessively high heat input will impair the mechanical properties of the joint. However, the permissible heat input follows our normal recommendations for the relevant steel grade.

The estimated minimum preheat/interpass temperatures for high strength low-alloyed consumables with yield strengths of 750 MPa (109 ksi) or more.

Single plate thickness, welded joint mm (in.)	Minimum preheat/interpass temperature* in °C (°F)
≤ 10.0 (0.394)	125 (275)
10.1-20.0 (0.398 - 0.787)	140 (284)
20.1-40.0 (0.791 - 1.575)	175 (347)
> 40.0 (1.575)	190 (374)

*SSAB does not take formal responsibility of these temperatures since they depend on the individual characteristics of the consumables.



R_{p0.2} MPa (ksi) Examples of suitable welding consumables according to AWS classification

R _{p0.2} MPa (ksi)	Examples of suitable welding consumables according to AWS classification					
	MMA	SAW (Solid wire/- flux combinations)	MAG (Solid wire)	MAG (Flux cored wires)	MAG (Metal cored wires)	TIG
900 (130)						
800 (116)						
700 (100)						
600 (87)						
500 (70)						
400 (580)						
* Including MC, PLUS, CR grades						

Recommended strength of consumables for highly stressed joints

Recommended strength of consumables for other joints

R_{p0.2} MPa (ksi) Examples of suitable welding consumables according to EN/ISO classification

R _{p0.2} MPa (ksi)	Examples of suitable welding consumables according to EN/ISO classification				
	MMA	SAW (Solid wire/- flux combinations)	MAG (Solid wire)	MAG (All types of tubular cored wires)	TIG
Recommended strength of consumables for highly stressed joints	900 (130)	EN ISO 18275 (-A) E 89X	EN ISO 16834 (-A) G 89X	EN ISO 18276 (-A) T 89X	EN ISO 16834 (-A) W 89X
	800 (116)	EN ISO 18275 (-A) E 79X	EN ISO 16834 (-A) G 79X	EN ISO 18276 (-A) T 79X	EN ISO 16834 (-A) W 79X
	700 (100)	EN ISO 18275 (-A) E 69X	EN ISO 16834 (-A) G 69X	EN ISO 18276 (-A) T 69X	EN ISO 16834 (-A) W 69X
Recommended strength of consumables for other joints	600 (87)	EN ISO 18275 (-A) E 62X	EN ISO 16834 (-A) G 62X	EN ISO 18276 (-A) T 62X	EN ISO 16834 (-A) W 62X
	500 (70)	EN ISO 18275 (-A) E 55X	EN ISO 16834 (-A) G 55X	EN ISO 18276 (-A) T 55X	EN ISO 16834 (-A) W 55X
		EN ISO 2560 E 50X	EN ISO 14341 (-A) G 50X	EN ISO 17632 (-A) T 50X	EN ISO 636 (-A) W 50X
		EN ISO 2560 E 46X	EN ISO 14341 (-A) G 46X	EN ISO 17632 (-A) T 46X	EN ISO 636 (-A) W 46X
		EN ISO 2560 E 42X	EN ISO 14341 (-A) G 42X	EN ISO 17632 (-A) T 42X	EN ISO 636 (-A) W 42X

Recommended strength of consumables for highly stressed joints

Recommended strength of consumables for other joints

Hardox®

Armox®

Toolox®

Strenx® 700*, 100, 100XF

Strenx® 110XF

Strenx® 900 – 1 300, MC, PLUS, CR grades

Examples of suitable low-alloy consumables

Suggestions for various suitable consumables are given in the following tables. Note that the consumables are arranged according to the yield strength ($R_{p0.2}$) for which they are classified. In reality, a given consumable normally has a higher yield strength than its standard designation. The mechanical properties of a given consumable can be obtained from its manufacturer.

MAG, solid wire

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
ELGA	Elgomatic 100 Elgomatic 103	Elgomatic 162		Elgomatic 135 Elgomatic 147		
ESAB	OK Aristorod 12.50 OK Aristorod 12.63	OK Aristorod 13.09 OK Aristorod 13.12	OK Aristorod 13.22	OK Aristorod 55 OK Autrod 13.25	OK Aristorod 69	OK Aristorod 79
LINCOLN ELECTRIC	LNM 25 SUPRAMIG HD	LNM Ni1 LNM Ni2.5		LNM MoNi Superarc AK 10-TM	LNM MoNiVa	LNM MoNiCr
BÖHLER	BÖHLER EMK 6-Ultra BÖHLER EMK 8-Ultra	BÖHLER 2,5 Ni-IG BÖHLER EMK 8-Ultra	BÖHLER NiMo 1-IG	Union MoNi	Union NiMoCr BÖHLER X 70-IG	Union X 85, Union X90, Union X96, diamondspark 1100-MC
OERLIKON	Carbofil 1 Carbofil 1 Gold	Carbofil NiCu		Carbofil NiMoCr Carbofil NiMo1		Carbofil 120

MAG, flux cored wire

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
ELGA	MEGAFIL® 731 B MEGAFIL® E 713 B	MEGAFIL® 821 R MEGAFIL® 819 R	MEGAFIL® 610 R		MEGAFIL® 742 B MEGAFIL® 690 R	
ESAB	Tubrod 15.00 Filarc PZ 6113S	OK Tubrod 15.17	Dual-Shield 55 Dual-Shield CrMo2		Dual-Shield 69 OK Tubrod 15.27	Filarc PZ 6149
LINCOLN ELECTRIC	Outershield 71E-H Outershield 71MS-H	Outershield 12-H Outershield 19-H	Outershield 20-H		Outershield 690-H	
BÖHLER	FOXcore 71 RC diamondspark 52 RC	diamondspark Ni1 RC diamondspark Ni2 RC	diamondspark 550 RC	diamondspark 620 RC	diamondspark 700 RC	diamondspark 900 BC
OERLIKON	Fluxofil 14HD Fluxofil 19HD	Fluxofil 20 Fluxofil 20HD				

MAG, metal cored wire

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
ELGA	Elgacore MXA 100 Elgacore MXA 100XP MEGAFIL® 710 M ELGACORE MATRIX	Elgacore MXA 55T MEGAFIL® 240 M			MEGAFIL® 742 M	MEGAFIL® 1100 M
ESAB	OK Tubrod 14.13 PZ6105R				OK Tubrod 14.03	Coreweld 89
LINCOLN ELECTRIC	Outershield MC710H Outershield MC715H					
BÖHLER	FOXcore 70 MC diamondspark 52 MC	diamondspark Ni1 MC	diamondspark 550 MC	diamondspark 620 MC	diamondspark 700 MC	diamondspark 900 MC, diamondspark 1100-MC

Examples of suitable low-alloy consumables

MMA

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
ELGA	P 48S or P 48M P 51	P 63MR P 62MR			P 110YS	
ESAB	OK 48.00 OK 48.50	OK 73.68 OK 73.15	OK 74.78	OK 74.86 Tensitrode	OK 75.75 Filarc 118	OK 75.78
LINCOLN ELECTRIC	Basic 7018 Baso 100	Conarc 74	Conarc 60G Conarc 70G	Conarc 80	Conarc 85	
BÖHLER	FOX EV 50	FOX EV 60 BÖHLER FOX 2,5 Ni	BÖHLER FOX EV 65	BÖHLER FOX EV 75	BÖHLER FOX EV 90	BÖHLER FOX EV 100 BÖHLER FOX EV 105
OERLIKON	Carbofil 1 Carbofil 1 Gold	Tenacito 70	Tenacito 65R	Tenacito 75	Tenacito 80	Tenacito 100

SAW

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
ELGA	SDX S2Si-EM12/K SWX 120 SDX S2Si-EM12/K SWX 150				SubCOR SL742/ SWX 150	
ESAB	OK Autrod 12.22/ OK Flux 10.62 OK Autrod 12.32/ OK Flux 10.62	OK Autrod 12.24/ OK Flux 10.62 OK Autrod 12.34/ OK Flux 10.62	OK Autrod 12.44/ OK Flux 10.62	OK Autrod 13.40/ OK Flux 10.62	OK Autrod 13.43/ OK Flux 10.62	
LINCOLN ELECTRIC	L-61/Lincolnweld 8500 L-50M/P 240	LNS 40A/ Lincolnweld 8500 LNS 150/P 240	LNS 164/839 LNS 151/P 240	LA82/Lincolnweld MIL 800-H LA100/Lincolnweld MIL 800-H		
BÖHLER	Union S 2 Si // UV 408 TT	Union S 3NiMo // UV 420 TTR	Union S 3 NiMo 1 // UV 420 TTR-W	Union S 3 NiMo 1 // UV 420 TTRC	Union S 3 NiMoCr // UV 418 TT	diamondspark S 770 // UV 422 TT-LH diamondspark S 900 HP // UV 422 TT-LH
OERLIKON	OE-S3/OP121TT	Union S 3NiMo // UV 420 TTR	OE-S3NiMo1/ OP121TT			

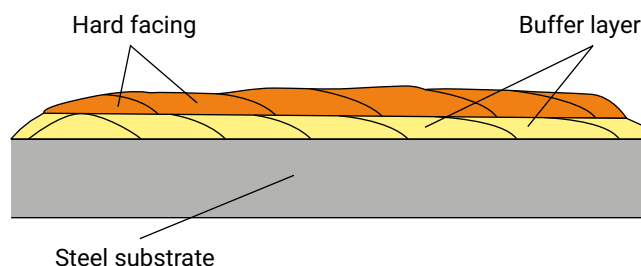
Stainless steel consumables

Hardox®, Strenx®, Armox® and Toolox® steel can always be welded with austenitic stainless steel consumables of type AWS 307 and similar types stated as AWS~307. The typical basic chemical composition for this grade is 18 % Cr, 8 % Ni, 6 % Mn. After welding, high resistance is achieved to avoid both hydrogen cracks and hot cracks in the joint. The structure of the weld metal will contain austenite, which contributes to a high toughness of the weld metal. The yield strength ($R_{p0.2}$) of this type of consumable is around 450-500 MPa (65-70 ksi).

Other important benefits of welding with this type of consumable are:

- Preheat/interpass temperatures of +20 °C (68 °F) or more in the joint as well as in the surrounding air can be avoided on all Hardox® and Strenx® steels, with the exception of Hardox® 600 and Hardox® Extreme. Further information is available in the Welding of Hardox® and Strenx® steel brochures.
- Preheat/interpass temperatures for Armox® can often be lowered. Further information is found in the workshop brochure for Armox®.
- If these consumables are applied for welding of Toolox®, contact SSAB for further information regarding preheat temperatures.
- Welding operations can be performed for the welding of Hardox®, Strenx®, Toolox® and Armox® grades to other kinds of steels, such as:
 - Stainless steels
 - Manganese steels (Hadfield steel)
 - Steels that are difficult to weld, such as spring steels

This type of consumable is suitable as the buffer layer in hard facing. An alternative to the welding consumable AWS 307 is an austenitic stainless steel consumable according to AWS 309. However, the risk of hot cracking is somewhat higher when using consumables of type AWS 309 compared to ones according to AWS 307 and AWS~307. Consumables according to AWS 307 and AWS~307 are listed in the table below.



Stainless steel consumables

Consumable manufacturer	MMA	MAG, solid wire	MAG, flux cored wire	MAG, metal cored wire	SAW
ELGA	Elgaloy MIX 18 Elgaloy MIX 18B	Cromamig 307Si			
ESAB	OK 67.45 OK 67.52	OK 16.95		OK Tubrod 15.34	
LINCOLN ELECTRIC	Arosta 307	LNM 307			
BÖHLER	BÖHLER FOX A 7	Thermanit X	FOXcore 307-T0 FOXcore 307-T1	FOXcore 307-MC	Thermanit X - Marathon 203
OERLIKON	Supercromax R	Inertfil 307	Fluxinox 307		

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