

TECHSUPPORT #60

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

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 the next page.

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.

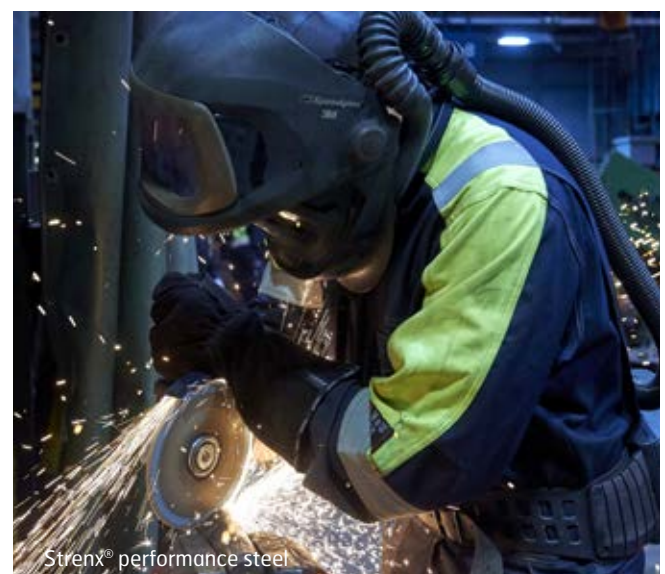
Preheat/interpass temperatures due to consumable properties

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.



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.



Toolox® engineering & tool steel



ArmoX® protection plate

Welding consumables, AWS class

Welding consumables, AWS class

R _{po.2} MPa (ksi)	Welding consumables, AWS class						TIG
	MMA	SAW (solid wire/- flux combinations)	MAG (solid wire)	MAG (flux cored wires)	MAG (metal cored wires)		
900 (130)							
800 (116)	AWS A5.5 E120X	AWS A5.23 F12X	AWS A5.28 ER120S-X	AWS A5.29 E12XT-X	AWS A5.28 E120C-X	AWS A5.28 ER120X	
700 (100)	AWS A5.5 E110X	AWS A5.23 F11X	AWS A5.28 ER110S-X	AWS A5.29 E11XT-X	AWS A5.28 E110C-X	AWS A5.28 ER110X	
600 (87)	AWS A5.5 E100X	AWS A5.23 F10X	AWS A5.28 ER100S-X	AWS A5.29 E10XT-X	AWS A5.28 E100C-X	AWS A5.28 ER100X	
500 (70)	AWS A5.5 E90X	AWS A5.23 F9X	AWS A5.28 ER90S-X	AWS A5.29 E9XT-X	AWS A5.28 E90C-X	AWS A5.28 ER90X	
400 (58)	AWS A5.5 E80X	AWS A5.23 F8X	AWS A5.28 ER80S-X	AWS A5.29 E8XT-X	AWS A5.28 E80C-X	AWS A5.28 ER80X	
	AWS A5.5 E70X	AWS A5.23 F7X	AWS A5.28 ER70S-X	AWS A5.29 E7XT-X	AWS A5.28 E70C-X	AWS A5.28 ER70X	

Recommended strength of consumables for highly stressed joints

Recommended strength of consumables for other joints

* Including MC, PLUS, CR grades

Welding consumables, EN class

Welding consumables, EN class

R _{po.2} MPa (ksi)	Welding consumables, EN class						TIG
	MMA	SAW (solid wire/- flux combinations)	MAG (solid wire)	MAG (all types of tubular cored wires)			
900 (130)							
800 (116)	EN ISO 18275 (-A) E 89X 800	EN ISO 26304 (-A) S 89X	EN ISO 16834 (-A) G 89X	EN ISO 18276 (-A) T 89X	EN ISO 18276 (-A) T 89X	EN ISO 16834 (-A) W 89X	
700 (100)	EN ISO 18275 (-A) E 69X	EN ISO 26304 (-A) S 69X	EN ISO 16834 (-A) G 69X	EN ISO 18276 (-A) T 69X	EN ISO 18276 (-A) T 69X	EN ISO 16834 (-A) W 69X	
600 (87)	EN ISO 18275 (-A) E 62X	EN ISO 26304 (-A) S 62X	EN ISO 16834 (-A) G 62X	EN ISO 18276 (-A) T 62X	EN ISO 18276 (-A) T 62X	EN ISO 16834 (-A) W 62X	
500 (70)	EN ISO 18275 (-A) E 55X EN ISO 2560 E 50X	EN ISO 26304 (-A) S 55X EN ISO 14171 (-A) S 50X	EN ISO 16834 (-A) G 55X EN ISO 14341 (-A) G 50X	EN ISO 18276 (-A) T 55X EN ISO 17632 (-A) T 50X	EN ISO 18276 (-A) T 55X EN ISO 17632 (-A) T 50X	EN ISO 16834 (-A) W 55X EN ISO 636 (-A) W 50X	
400 (58)	EN ISO 2560 E 46X EN ISO 2560 E 42X	EN ISO 14171 (-A) S 46X EN ISO 14171 (-A) S 42X	EN ISO 14341 (-A) G 46X EN ISO 14341 (-A) G 42X	EN ISO 17632 (-A) T 46X EN ISO 17632 (-A) T 42X	EN ISO 17632 (-A) T 46X EN ISO 17632 (-A) T 42X	EN ISO 636 (-A) W 46X EN ISO 636 (-A) W 42X	

Recommended strength of consumables for highly stressed joints

Recommended strength of consumables for other joints

* Including 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)
AWS Class	ER 70X*	ER 80X	ER 90X	ER100X*	ER110X	ER120X
ELGA	Elgamic 100 Elgamic 103	Elgamic 162	Elgamic 163	Elgamic 135 Elgamic 147		Elgamic 138
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	EMK6 EMK8	NiCu1-IG DCMS-IG	CM2-IG	Union NiMoCr	X70-IG alform 700-IG	Union X90 Union X96
OERLIKON	Carbofil 1 Carbofil 1 Gold	Carbofil NiCu		Carbofil NiMoCr Carbofil NiMo1		Carbofil 120

* X can stand for one or several code characters

MAG, flux cored wire

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
AWS Class	ER 7X*	ER 8X*	ER 9X*	ER10X*	ER11X*	ER12X*
ELGA	Elgacore DWA 51B Elgacore DWA 50	Elgacore DWA 55L	Elgacore DWA 65L		Elgacore R690	
ESAB	Tubrod 15.00 Filarc PZ 6113S	OK Tubrod 15.17	Dual-Shield 55 Dual-Shield CrMo2	Dual-Shield 62	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 101Ni-HSR	Outershield 690-H	
BÖHLER	Ti52-FD Union TG 55 M	Ti 60-FD Ti 2 Ni T-FD	Kb 65 T-FD		Kb 85 T-FD	
OERLIKON	Fluxofil 14HD Fluxofil 19HD	Fluxofil 20 Fluxofil 20HD				

* X can stand for one or several code characters

MAG, metal cored wire

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
AWS Class	ER 7X*	ER 8X*	ER 9X*	ER10X*	ER11X*	ER12X*
ELGA	Elgacore MXA 100 Elgacore MXA 100XP	Elgacore MXA 55T			Elgacore M690	
ESAB	OK Tubrod 14.13 PZ6105R				OK Tubrod 14.03	Coreweld 89
LINCOLN ELECTRIC	Outershield MC710- H Outershield MC715- H					
BÖHLER	HL 46-MC HL 51 T-MC	HL53 T-MC NiCu1 T-MC	HL65 T-MC	HL75 T-MC	alform 700-MC	alform 900-MC alform 960-MC

MMA

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
AWS Class	E7016-X* E7018-X*	E8016-X* E8018-X*	E9018-X*	E10018-X*	E11018-X*	E12018-X*
ELGA	P48S P51	P48K P65MR			P110MR	
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 AWS E7018-1	Fox ev 60 Fox Fox 2.5Ni	Fox ev 70		Fox EV 85 Fox alform 700	
OERLIKON	Carbofil 1 Carbofil 1 Gold	Tenacito 70	Tenacito 65R	Tenacito 75	Tenacito 80	Tenacito 100

* X can stand for one or several code characters

SAW

Consumable manufacturer/ Min yield strength MPa (ksi)	400 (58)	470 (68)	540 (78)	610 (97)	680 (100)	745 (108)
AWS Class	F7X*	F8X*	F9X*	F10X*	F11X*	F12X*
ELGA	Elgasaw 102/ Elgaflux 251B Elgasaw 102Si/ Elgaflux 251B	Elgasaw 102Mo/ Elgaflux 251B				
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/Lincoln- weld MIL 800-H		
BÖHLER	EMS 2/BB 24 Union S 2/ UV 420TT	EMS 2 Mo/BB 24	3NiMo 1-UP/BB24		3 NiMoCr/BB24 Union S 3 NiMoCr/ UV 420TT	
OERLIKON	OE-S3/OP121TT	OE-S2Mo/ OP121TT	OE-S3NiMo1/ OP121TT			

* X can stand for one or several code characters

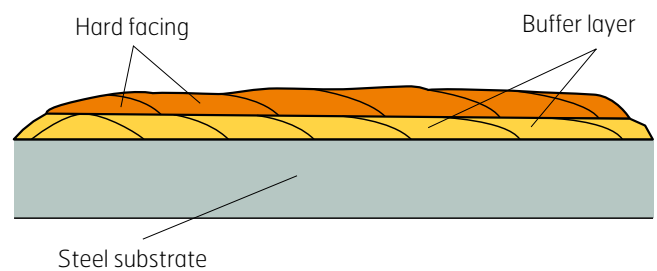
Stainless steel consumables

Hardox®, Strenx®, Armox® and Toolox® steel can always be welded with austenitic stainless steel consumables of type 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. Consumables according to AWS 307 are listed in the table below.



Stainless consumables

Consumable manufacturer/ Min yield strength MPa (ksi)	MMA	MAG, solid wire	MAG, flux cored wire	MAG, metal cored wire	SAW
AWS Class	A5.4: E307X*	A5.9: E307	A5.22: E307X*	A5.22: E307X*	
ELGA		Cromamig 307Si			
ESAB	OK 67.45 OK67.52	OK 16.95		OK Tubrod 15.34	
LINCOLN ELECTRIC	Arosta 307	LNM 307			
BÖHLER	Fox A7	A7-IG	A7-FD	A7-MC	
OERLIKON	Supercromax R	Inertfil 307	Fluxinox 307		

* X can stand for one or several code characters

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SSAB
SE-613 80 Oxelösund
Sweden

T +46 155 25 40 00
F +46 155 25 40 73
contact@ssab.com

www.ssab.com

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