Repair and maintenance welding

STRENGTH THROUGH **COOPERATION**

Welding, an important repair method

Welding is the most common method of joining metals, widely applied in workshops for the manufacture of products. Welding is also an important repair method for restoring damaged and worn workpieces and other items.
This brochure provides an overview of common applications of repair and maintenance welding:

- Gouging and cutting
- Difficult-to-weld steels
- Welding dissimilar metals
- Surfacing and hardfacing
- Welding cast iron
- Welding wear resistant steels
- Welding aluminium

The descriptions include details of recommended consumables:

- MMA: OK covered electrodes
- MIG/MAG welding: OK Autrod solid wires
- FCAW: OK Tubrodur flux-cored wires
- TIG welding: OK Tigrod wires

Further information about repair welding can be found in ESAB's Repair and Maintenance Welding Handbook.

ESAB's range of welding consumables is one of the most extensive in the market. The welding consumables catalogue provides detailed information about product information and comprehensive selection charts for different materials. Further product information can be found on your local ESAB web site under Products/ Welding consumables.

An overview of repair and maintenance applications

- **Basics of repair welding**
- **Welding instructions for different materials**
- **Hardfacing**
- **Illustrated applications**
- **Consumables product data**
- **Application index**

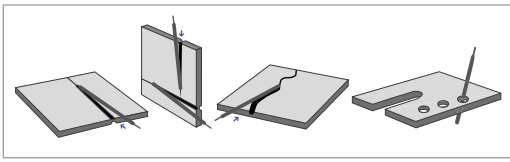
The catalogue features some 450 individual consumables.

A. Consumables for mild steels
B. Consumables for low-alloyed steels
C. Consumables for stainless and high-alloyed steels
D. Consumables for aluminium alloys
E. Consumables for nickel-based alloys
F. Consumables for copper-based alloys
G. Consumables for cast iron
H. Consumables for dissimilar materials
I. Consumables for hardfacing
J. Special products

ESAB's consumables factories have various international certifications, including ISO 9001 certified quality management systems, manufacturer/ product approvals required by the European Pressure Equipment Directive and the Construction Product Directive, and ISO 14001 / OHSAS 18001 certified environmental, health and safety programmes.

Occupational health and fire safety must be given appropriate consideration in repair welding. Working conditions are often worse compared to normal production environments. Information about the health and safety aspects of welding consumables is provided in the safety data sheet of each product. The sheets can be printed from your local ESAB web site.

Gouging and cutting electrode



Gouging electrode OK 21.03

The gouging and cutting electrode is commonly used in repair applications for the removal of weld defects, for removing cracks prior to welding, for preparing grooves and holes and for cutting sheets and bars. The arc gouging electrode is equally suitable for non-alloyed steels and stainless steels, cast iron, aluminium and copper alloys, except pure copper.

Arc gouging is based on the same principle as the welding electrode; the arc burns between the end of the electrode and the workpiece. However, the special coating of the arc gouging electrode forms a powerful gas spray which blows away the material melted by the arc, providing a shape such as a groove. The work can be carried out using ordinary MMA welding equipment; compressed air or special electrode holders are not required (air carbon arc gouging). These electrodes require very high arc voltages to work properly. While carbon arc gouging is a lot more effective at removing material, it requires special equipment and a compressed air supply which may not be always available.

Electrode diameters are 2.5–5.0 mm; the voltage range is 130–180 Amps for a Ø 3.2 mm electrode and 170–230 Amps for a Ø 4.0 mm electrode. The arc is initiated by striking the electrode more or less at 90 degrees to the work piece and once the arc is established the electrode must have a 10 to 15 degree inclination to the work piece. Immediately thereafter it should be moved rapidly back and forth at the same time moving in the direction of the defect.. Deep grooves can be made by repeated gouging. Normally, welding can follow without further preparation; however, when gouging stainless steel, the carbonised surface layer should be removed by grinding.

Dissimilar metals

In many applications, there is often a need to join non- or low-alloyed steel with austenitic stainless steel, e.g. S355/AISI 316. These are called dissimilar joints. With the right choice of consumables, these joints are easy to weld. Suitable filler materials are overalloyed stainless consumables which give a weld metal that mixes with non-stainless steel to form a high-tensile austenitic or austenitic-ferritic weld despite being “tempered”. When selecting consumables, the Schaeffler diagram can be used to determine the microstructure of the weld.

Consumables

The product range includes a number of over alloyed consumables.

- **18%Cr-8%Ni-6%Mn (AWS 307)**

  OK 67.45

  OK Autrod/Tigrod 16.95

  OK Tubrod 14.37

  OK Tubrod 15.34

- **23%Cr-13%Ni**

  CrNi over alloyed (AWS 309L)

  OK 67.60

  OK Autrod/OK Tigrod 309LSi

  Shield-Bright 309L, 309 X-tra

- **23%Cr-13%Ni-3%Mo**

  Cr-Ni over alloyed (AWS 309MoL)

  OK 67.70

  OK Autrod/OK Tigrod 309MoL

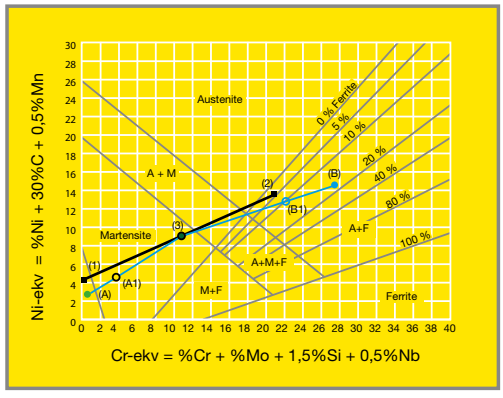
  Shield-Bright 309MoL X-tra

  • A high Ni alloy

  A dissimilar joint of heat-resisting CrMo steel and stainless steel (for high temperatures)

  OK 92.26

  OK Autrod/Tigrod 19.85



Schaeffler diagram. (1) Non-alloy steel S355, (2) stainless steel AISI 316L, (3) dissimilar weld welded without consumables, (A) electrode OK 48.00 for mild steels and (A1) its dissimilar weld, (B) over-alloyed electrode OK 67.70 and (B1) its dissimilar weld.

Difficult-to-weld steels

Repair and maintenance welding often involves repairing so-called “difficult-to-weld” steels. These include high carbon steels, quenched and tempered steels, tool-making steels, wear resistant steels and spring steels. “Unknown” steels are often included in this group – as a precaution, if the composition is not known or the type of steel is unclear, these steels should be treated as difficult-to-weld steels. Typical applications include shafts, gears, machine components, etc.

In terms of weldability, a common characteristic of these steels is their high tendency to harden along with hard and brittle HAZ structures, which result in a high cracking tendency during welding. Preventing these requires preheating or post heat treatment, which is out of the question in many repair cases.

Welding with austenitic stainless or nickel-based consumables is a common and effective method of preventing hydrogen cracks (cold cracks). These weld metals tolerate high dilution, and they have a high-tensile austenitic or austenitic-ferritic microstructure. Furthermore, the solubility of hydrogen – the source of cracking – is so high that it stops the damaging hydrogen from entering the heat affected zone (HAZ), thereby preventing the formation of cracks despite the hardening of the HAZ. The most commonly used consumable in repair welding is austenitic-ferritic stainless steel 29%-9%Ni.

There are other interesting applications for these consumables, such as removing a broken bolt with an electrode, or repairing a scratched hydraulic cylinder piston. A new bolt head is built on top of the broken-off bolt; this can then be used to turn the bolt and pull it out of the hole. Scratches on hydraulic rams can be built up and ground smooth.

Consumable 29%Cr-9%Ni (AWS 312)

- A universal consumable for repair welding
- The weld metal has a high tolerance for impurities
- The weld metal tolerates high dilution

OK 68.82: the “miracle electrode” of repair welding

OK Autrod 312/OK Tigrod 312

18%Cr-8%Ni-6%Mn

- A high-tensile weld metal (AWS 307)

OK 67.45

OK Autrod 16.95/OK Tigrod 16.95

OK Tubrodur 14.71, also without shielding gas

A high Ni alloy

- The highest tensile strengh of all weld metals
- Lowest crack sensitivity

OK 92.26

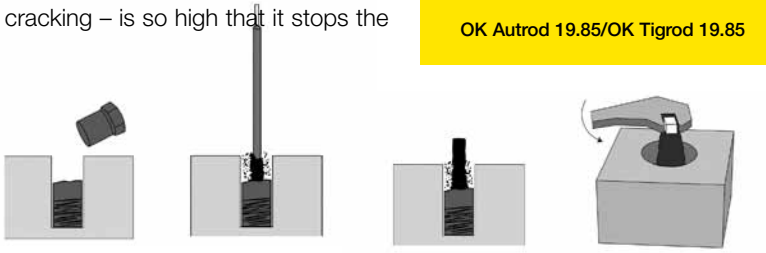
OK Autrod 19.85/OK Tigrod 19.85

Bevel gear repair.

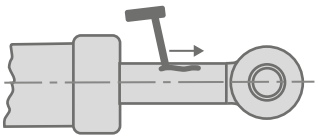
Drive shaft repair on a heavy duty vehicle.

Repair of a broken driveshaft.

Repair of a broken transformer support.



Removing a broken bolt.



Hydraulic ram.

Cast iron

Cast irons are iron alloys which contain 2–5% carbon and some silicon and manganese. Certain cast iron grades may also contain other elements. The most common grades are grey cast iron and ductile iron. Graphite (carbon) grows as flakes in grey cast iron and as spheres in ductile cast iron. Welding cast iron is different from steel welding, and most cast iron grades are difficult to weld. Cast irons have a low tensile strength and deformability which makes them brittle. For that reason, welding stresses can easily cause cracks and flaws in weld joints. Cast iron hardens easily at the HAZ around the weld. In addition, pieces which need repairing will often have absorbed oil or other contaminants, which also makes welding difficult. Welding is nevertheless possible, and cast iron pieces are commonly repaired by welding.

Cast iron is normally MMA welded by cold-welding which means generating as little heat as as possible in the work piece. In practice, this means welding short beads and hammering them lightly to release stresses. After welding, each must be hand warm until touchable before welding the next bead in order to reduce stresses. Buffering is beneficial in some cases; this involves surfacing the joint faces before completing the rest of the joint if possible. If the work involves repairing a crack, holes should be drilled at each end of the crack to prevent it from progressing further.

Nickel or nickel-iron electrodes are used, since these provide a soft, high-tensile and machinable weld metal. Welds should be stress relieved by peening.

Consumables for welding cast iron

Ni consumable

- **A slightly softer weld than NiFe**

OK 92.18

NiFe consumable

- **A slightly stronger weld than Ni**
- **Less sensitive to impurities than Ni**
- **Cheaper than Ni**

OK 92.58 or OK 92.60

Nicore 55, cored wire

Marine diesel exhaust manifold. New price € 820.00. Repaired for € 225.00

Exhaust outlet. No spares available. Repair necessary.

Wear resistant steels

Typical applications for wear resistant steels.

Wear resistant steels are used in applications where the wear resistance provided by regular, reasonably soft structural steels is not enough. Typical applications include structures which are exposed to abrasion from soil, rock or gravel in locations such as quarries, mines, loaders and earth movers, e.g. conveyors, lip shrouds, dumper platforms, screens, chutes, etc. Modern wear resistant steels, such as Rautaruukki's Raex 400/500 and SSAB's HARDOX 400/500 (the number refers to the surface hardness which is 400 or 500 HB) are easy to weld.

RAEX AR 400 is two to three times more wear-resistant and the 500 is three to four times more wear-resistant than structural steel S355. Wear resistant steels are normally hardened and sometimes quenched (i.e. tempered and quenched). Due to the hardenability of wear resistant steels, thicker sheets must be preheated to prevent cracking. The need for preheating depends on not only the sheet thickness but also the hydrogen content and heat input of the weld. Rough values are :

400 HB:

- from approx. 20 mm: 75-150 ºC (depending on plate thickness)

500 HB:

- from approx. 10 mm: 100-200 ºC (depending on plate thickness)

Rautaruukki and SSAB have produced good brochures on the welding of these steels.

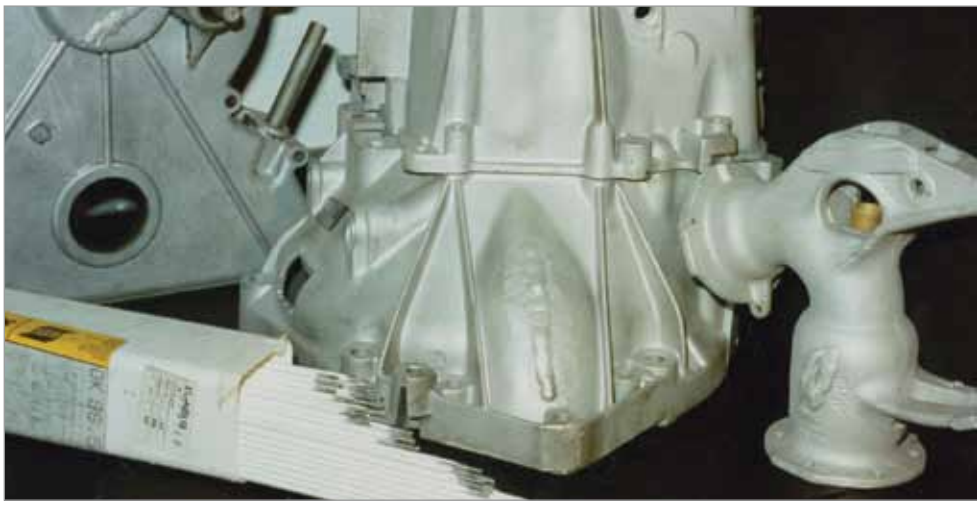
Consumables are selected on a case-by-case basis depending on the properties required from the weld. Generally, soft and high tensile consumables such as OK 48.00 and corresponding wires are used in joint welding. The welds are often located in places where these softer consumables can be used.

Especially when welding large thickness of wear resistant steel, the need for preheating – which is required for harder steel grades in installation conditions – can be eliminated by using austenitic stainless consumables; the most common of these is the 18%Cr-8%Ni-6%Mn composition. If a high strength weld is required, low-alloyed high strength consumables are used, but for root runs non-alloyed consumables should be used. If a highly wear resistant weld is required, hardfacing consumables are used to provide suitable hardness in the final pass, when filler passes are made with soft consumables. Despite their high resistance against abrasion, these wear resistant steels may sometimes require hardfacing to improve the wear resistance of the surface - in most cases only locally. In this case, welding a high-tensile buffer layer before hardfacing prevents cracking of the base metal or the hardfacing weld, and it also prevents the hardfacing weld from coming loose. Suitable consumables are austenitic stainless consumables such as 18%Cr-8%Ni-6%Mn ("AWS 307") or 23%Cr-13%Ni ("AWS 309L"). Consumables suitable for hardfacing include hardenable, high chromium content alloy steels and similar, see page 9.

Consumable

- **Undermatching (soft/tough) non-alloy steel**
  OK 48.00
  OK Autrod 12.51
- **Over alloyed stainless steel**
  18%Cr-8%Ni-6%Mn
  OK 67.45
  OK Autrod 16.95
  OK Tubrodur 14.71
- **Matching low alloyed steel**
  OK 75.75
  OK AristoRod 13.29
  OK Tubrod 14.03 ja 15.09
- **Hardfacing consumable,**
  hardness about 30-35 HRC
  OK 83.28
  OK Autrod 13.89
  OK Tubrodur 15.43
- **Hardfacing consumable,**
  hardness about 50-60 HRC
  OK 83.65
  OK Autrod 13.91
  OK Tubrodur 15.50

Aluminium



Due to its leight weight, good conductivity, high corrosion resistance and weldability, aluminium is widely used in many industrial applications from shipbuilding to transport equipment, packing materials, and the electrical and aviation industries. Aluminium is a light-weight metal whose specific weight is approximately a third of that of steel.

Aluminium welding is very common. Production welding generally involves MIG or TIG welding. MMA welding is used rarely, generally in small repair applications and especially when gas-shielded arc welding cannot be used or equipment is not available.

The melting point of aluminium is around 600°C. Aluminium's thermal conductivity is four times that of steel, which means that a relatively high amount of heat is required when welding aluminium. Thick materials require preheating. The thermal expansion coefficient of aluminium is approximately twice as high as that of steel, which means that distortion from welding is similarly higher.

Due to its good corrosion resistance, the aluminium surface has an extremely thin oxide film with a melting point of over 2000°C. This layer must be removed from the application area before welding – for example, using a stainless steel brush – and its reformation during welding must be prevented. In MIG and TIG welding, the arc breaks the oxide film and the inert shielding gas (argon) prevents its formation. In MMA welding, the flux coating of the electrode dissolves the oxide film and protects the weld pool.

Proper cleaning of the welding area is important, as aluminium is highly susceptible to pores in the weld. The porosity is due to the very high solubility of hydrogen in molten aluminium. As the work hardens rapidly, some of the dissolved gases remain in the weld and form pores.

Many aluminium alloys are fairly susceptible to heat cracks, which means that the weld is easily cracked as the weld pool hardens. For that reason, the right choice of consumables is imperative to avoid creating a crack sensitive composition in the weld pool.
In addition to pure aluminium, there are different aluminium alloys, such as AlMn, AlMg, AlSi and AlMgSi. Recommended consumables for aluminium alloys are specified in the table on page 11.

The consumable is chosen based on the workpiece alloy. Due to their high corrosion resistance to seawater, AlMg alloys are often referred to as sea-water aluminiums, and they are used in boats and ships.

Consumables for aluminium

Consumable alloy type: AlSi12

- **Used for cast alloys**
  OK 96.50
  OK Autrod/OK Tigrod 4047

Consumable alloy type: AlSi5

- **Used for AlMgSi alloys**
  OK Autrod/OK Tigrod 4043

Consumable alloy type: AlMg5

- **Used for AlMg3, AlMg5 and AlMgSi alloys**
  OK Autrod/OK Tigrod 5356

Surfacing and hardfacing

Wear and tear causes considerable costs in different industries as worn-out materials and equipment require repairing. Surfacing is a commonly used method for repairing worn-out pieces and extending their life. Surfacing is also a useful method for extending the service life of new parts before they are put into service. Surfacing is often referred to as hardfacing, even though hardness is not always desirable in terms of wear resistance. Hardfacing specifically refers to surfacing using a hard and wear resistant consumable. Depending on the application, softer consumables and corrosion resistant consumables can also be used for surfacing.

There are various forms of wear, and this should be the main factor when choosing consumables. The forms of wear can be divided into the following categories: abrasion, metal to metal, impact wear, corrosion and high temperatures. Therefore the conditions should be determined first before choosing the consumable.

Abrasive wear occurs when hard particles slide across a metal face, removing material from the surface. Increasing the surface hardness usually reduces wear. Suitable consumables include high-carbon content alloy steels which provide a hard weld, i.e. it hardens during cooling after welding. The most common alloying elements are chrome, molybdenum, tungsten and vanadium. With many alloying elements, carbon forms carbides whose hardness can be as high as 3000 HV.

Metal-on-metal wear occurs when two metal surfaces slide against one another – for example, in rotating or dragging metal surfaces. The high surface pressure between two metal surfaces generates small scale “micro welds” (sticking). As the motion continues, the weld fails on the side of the weaker base metal, causing surface wear. Low-alloy steels are suitable for anti-wear applications.

Impact wear occurs when a metal surface is subjected to impacts which cause local breakages or distortion, such as in rock crushing. The magnitude of wear depends on the strengh and hardness of the metal. Manganese steel is a common and ideal material due to the work hardening of its surface, which means that the surface hardness increases while the inside remains tough.

Corrosion (“rusting”) has many forms. It can be uniform across the surface or localised. Corrosion removes material from the metal surface. Corrosion can be prevented by using certain stainless steels which contain a sufficient level of chrome and in many cases nickel and molybdenum.

Transverse cracks in a hardfacing layer.

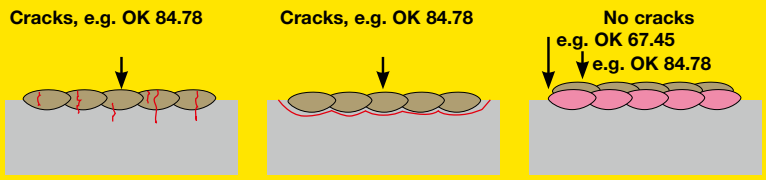
High temperatures make materials softer and oxidizes their surface. High chrome content prevents the reduction of hardness together with certain other alloying elements. High chrome content prevents oxidisation.

A vast range of surfacing consumables is available with different compositions, characteristics and micro structures and it is not always easy to choose the best or the most hard-wearing consumable. There is no single universal material; consumables are selected on a case-by-case basis depending on the conditions.

If the weld is to be machined using cutting tools after welding, this must be taken into account when choosing consumables. The hardness limit for machinability is approximately 40 HRC, although certain high-power machines and steel bits can be used to machine harder welds.

In hardfacing, preheating is often required either to prevent the hardening base metal from cracking – i.e. the weld bead becoming detached – or to prevent the hardfacing consumable from cracking.

The preheating requirements of hardfacing consumables are specified on the product page of the consumables catalogues. The risk of cracking can be reduced by surfacing ("buffering") the workpiece surface first using a high-tensile austenitic stainless consumable; suitable materials are specified in the previous chapter, "Difficult-to-weld steels".



Consumable

Hardness range: 30–35 HRC

- A "soft" hardfacing consumable
- High machinability
- Metal-on-metal wear: Slip surfaces, shafts, rollers, wheels, gears, etc.

OK 83.28

OK Tubrodur 15.43, also Ø 1.2 mm and without shielding gas

OK Autrod 13.89, Ø 1.0 and 1.2 mm

Hardness range: 50–60 HRC

- Universal hardfacing consumable
- Resistant to both impacts and abrasion
- Excavation and earthmoving machinery, agricultural and forestry machinery, feed worms, etc.

OK 83.50, also for welding with small transformers

OK 83.65, excellent welding properties

OK 84.58, reasonable resistance to corrosion

OK Tubrodur 15.50, also Ø 1.2 mm

OK Tubrodur 15.52, also without shielding gas

OK Autrod 13.91, Ø 1.0 and 1.2 mm

Hardness range: 60–65 HRC

- "Chrome iron"
- High resistance against abrasion from granular materials etc.
- Low impact strength
- Feed worms, fan blades, drag buckets, etc.

OK 84.78, easy to weld, high efficiency electrode

OK Tubrodur 14.70, also without shielding gas

Tools and hardfacing

- Hot-work tool steel
- Hot work tools, etc.

OK 85.58

High-speed steel

- Blades of cutters and cutting tools
- Wood cutting blades

OK 85.65

Hardfacing consumables for corrosion resistance

- Stainless steel 13%Cr

OK 84.42

PZ6166

Hardfacing of Mn steels

- Improving surface wear resistance

OK 84.58 and 84.78

OK Tubrodur 15.52 and 14.70

Surfacing of Mn steels

- Mn steel type consumables

13%Mn: OK 86.08

13%Mn-3%Ni: OK 86.28, OK Tubrodur 15.60

- Ni improves the tensile strength of the weld

14%Mn-18%Cr: OK 86.30, OK Tubrodur 15.65

- Cr alloy improves heat and corrosion resistance

Recommended welding consumables for different base metals

Base metal	MMA welding OK	MIG/MAG welding OK AristoRod, OK Autrod	MAG cored wire welding OK Tubrod (Metal cored)	MAG cored wire welding OK Tubrod (Rutile cored)	TIG welding OK Tigrod
Non-alloy structural steels (EN 10025-2)					
S235xxx, S275xxx, S355xxx	48.00	12.50, 12.51	14.12	15.14	12.64
Normalised fine-grain structural steels (EN 10025-3)					
S275N, S355N, S420N	48.00	12.50, 12.51	14.12	15.14	12.64
S460N	55.00	12.63, 12.64	14.02	15.14	12.64
S275NL, S355NL, S420NL	48.08, 55.00	13.28, (12.50, 12.63)*	14.04	15.11, (15.17)*	13.28
S460NL	48.08, 55.00	13.28, (12.63)*		15.11, (15.17)*	13.28
			*) -40 oC		*) -40 °C
Thermomechanical rolled fine-grain steels (EN 10025-4)					
S275M, S355M, S420M	48.00	12.50, 12.51	14.12	15.14	12.64
S460M	55.00	12.63, 12.64	14.02	15.14	13.28
S275ML, S355ML, S420ML	48.08, 55.00	13.28, (12.50, 12.63)*	14.04	15.11, (15.17)*	13.28
S460ML	48.08, 55.00	13.28, (12.63)*		15.11, (15.17)*	13.28
			*) -40 °C		*) -40 °C
Weathering structural steels (EN 10025-5)					
S235J0W, S235J2W	73.08	13.26	14.01	PZ6112, 15.17	13.26
S355J0WP (esim. COR-TEN A)	73.08	13.26	14.01	PZ6112, 15.17	13.26
S355J0W, S355J2W (esim. COR-TEN B)	73.08	13.26	14.01	PZ6112, 15.17	13.26
Quenched and tempered structural steels (EN 10025-6)					
S460Q, S460QL	48.08, 55.00	12.63, 12.64	14.02	15.17	13.28
S500Q, S500QL	74.78	55	14.02	15.11	13.13
S550Q, S550QL	74.78	55	14.03	Dual Shield 55	13.29
S620Q, S620QL	75.75	69	14.03	Dual Shield 62	13.29
S690Q, S690QL	75.75	69	14.03	15.09	13.29
S890Q, S890QL	75.78	89	Coreweld 89		
Ultra-strong structural steels (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 *)		
		*) Slightly undermatching consumables			
Heat-resisting non-alloy and alloy steels: plates (EN 10028-2) and tubes(EN 10216-2)					
P235GH...P355GH	48.00	12.50, 12.51	14.12	15.14	12.64
16Mo3	74.46	13.09	14.02	Dual Shield MoL	13.09
13CrMo4-5	76.18	13.12		Dual Shield CrMo1	13.12
10CrMo9-10	76.28	13.22		Dual Shield CrMo2	13.22
X10CrMoVNb9-1	76.98	13.38			13.38
Wear resistant steels					
e.g. Hardox 400...600 and Raex AR 400...500					
If a matching strength/hardness is not required:					
non-alloy, high-tensile consumable	48.00	12.50, 12.51	14.12	15.14	12.64
Matching hardness: suitable hardfacing consumable					
for final passes	83.50	13.91	15.52		
Matching strength: low-alloy consumable	75.75	69	14.03	15.09	13.29
Austenitic stainless steels					
18Cr-8Ni steels (“stainless”)				Shield-Bright	
1.4404 (304L), 1.4307 (304L), 1.4301 (304) etc.	61.30	308LSi	15.30	308L, 308L X-tra	308LSi
1.4541 (321), 1.4550 (347)	61.30, 61.81	308LSi, 347	15.30	308L, 308L X-tra	308LSi, 347
18Cr-12Ni-3Mo steels (”acid-resistant”)				Shield-Bright	
1.4404 and 1.4432 (316L), 1.4401 and 1.4436 (316) etc.	63.30	316LSi	15.31	316L, 316L X-tra	316LSi

Base metal	MMA welding	MIG/MAG welding	MAG cored wire welding	MAG cored wire welding	TIG welding
	OK	OK AristoRod, OK Autrod	OK Tubrod (Metal cored)	OK Tubrod (Rutile cored)	OK Tigrod
High-alloy special steels					
1.4438 (317L)	64.30	317L			317L
1.4539 (e.g. Outokumpu 904L)	69.33	385			385
1.4547 (e.g. Outokumpu 254SMO)	92.45	19.82			19.82
1.4652 (e.g. Outokumpu 654SMO)	92.59	19.81			19.81
Austenitic-ferritic stainless steels (duplex steels)					
1.4162 (esim. Outokumpu LDX2101)	67.56	2307			2307
1.4462 (esim. Outokumpu 2205)	67.50	2209	15.37	14.27	2209
1.4410 (esim. Outokumpu 2507)	68.53	2509		14.28	2509
Aluminium and aluminium alloys					
1050A (Al99,5), 1070A (Al99,7), 1200 (Al99,0)		1070			1070
4045 (AlSi10)		4043, 4047			4043, 4047
5019 (AlMg5), 5086 (AlMg4), 5754 (AlMg3)		5356			5356
5083 (AlMg4,5Mn0,7)		5183			5183
6060 (AlMgSi), 6061 (AlMg1SiCu)		4043, 5356			4043, 5356
6063 (AlMg0,7Si), 6082 (AlSi1MgMn)		4043, 5356			4043, 5356
7021 (AlZn5,5Mg1,5Si), 7029 (AlZn4,4Mg1Si)		5356			5356
Cast iron					
Different cast iron gradest	92.18, 92.58			Nicore 55	
Dissimilar metals ("steel/stainless steel welding")					
Non-alloy or low-alloy/austenitic stainless steel				Shield-Bright	
Working temperature less than 300 oC and no annealing	67.60, 67.70	309LSi, 309MoL		309L, 309L X-tra	309LSi,309MoL
Working temperature over 300 oC and/or annealing	92.26	19.85			19.85
Repair welding					
Difficult-to-weld steels, "unknown" steels,,	68.82, 67.45	312, 16.95	15.34	OK Tubrodur 14.71	312, 16.95
highly hardenable steels, etc.	92.26	19.85			19.85

Other alternatives exist for many base metals; ask your ESAB representative for further advice.

Selection of hardfacing consumables, comparison of properties

Hardness

Low — High

Mn steels	Hardenable alloy steels		
20 HRC (-> 45) *	30-50 HR	50-60 HRC	55-60 HRC
OK 86.08*	OK 83.27	OK 83.50	OK 83.53
	OK 83.28	OK 83.65	OK 84.84
OK 86.28*	OK 83.29	OK 84.58	OK Tubrodur 15.80
OK 86.30*	OK 83.30	OK Tubrodur 15.52	OK Tubrodur 15.81
OK Tubrodur 15.60*	OK Autrod 13.89	OK Autrod 13.90	OK Tubrodur 15.82
OK Tubrodur 15.65*	OK Tubrodur 15.43	OK Autrod 13.91	
	OK Tubrodur 15.40		
	OK Tubrodur 15.42		

Stainless Cr steels		Chrome irons
OK 84.42	OK Tubrodur 15.73	OK 84.78
OK 84.52		OK 84.80
		OK Tubrodur 14.70

Austenitic CrNi steels	Austenitic CrNiMn steels	Ferritic-austenitic CrNi steels	Tool-making steels
OK 67.70	OK 67.42*	OK 68.81*	OK 85.58
OK Autrod 309LSi	OK 67.45*	OK 68.82*	OK 85.65
	OK 67.52*	OK Autrod 312	OK Tubrodur 15.84
	OK Autrod 16.95*		
	OK Tubrodur 14.71*		

Ni alloys	Co alloys ("stellites")		
OK 92.26*	OK 92.35* Stellite 6	Stellite 12	Stellite 1
OK Autrod 19.85*	("Hastelloy C")		
("Inconel 600")			

* Work hardening consumable

Low — High

Thermal and corrosion resistance

High — Low

Impact resistance

Welding consumables product data

Arc gouging and cutting electrode

Special coated electrode OK 21.01 for arc gouging **Difficult-to-weld steels and dissimilar metals**

Consumable	C (%)	Si (%)	Mn (%)	Cr (%)	Ni (%)	Other (%)
OK electrode						
67.45	0.1	0.5	6.0	18.5	8.5	
67.60	0.03	0.7	0.9	24.0	13.0	
67.70	0.03	0.7	0.9	23.0	13.0	Mo: 2.8
68.82	0.12	1.0	0.9	29.0	9.0	
92.26	0.02	1.0	6.6	15.8	> 67	Nb: 1.7
OK Autrod/Tigrod						
309LSi	0.02	0.8	1.8	24.0	13.0	
309MoL	0.02	0.5	1.6	22.0	15.0	Mo: 2.8
312	0.10	0.5	1.7	29.0	9.5	
16.95	0.1	1.0	6.5	18.5	8.5	
19.85	0.05	0.5	3.0	20.0	> 67	Nb: 2.5
OK Tubrodur						
14.71	0.1	0.1	5.5	19.0	9.0	

Consumables for hardfacing

Consumable	C (%)	Si (%)	Mn (%)	Cr (%)	Ni (%)	Hardness[1] (HRC)
OK electrode						
83.28	0.1	0.5	0.7	3.2		28-32
83.50	0.4	0.5	1.0	6.0	Ni: 0.6	50-60
83.65	0.8	4.0	0.5	2.0		58-63
84.42	0.12	0.5	0.5	13.0		49-55
84.58	0.7	0.6	0.7	10.0		53-59
84.78	4.5	0.8	1.5	33		59-63
85.58	0.35	1.1	1.0	1.8	W: 8, Co: 2	42-50
85.65	0.9	1.5	1.3	4.5	Mo: 7.5, W: 1.8	59-61
OK Autrod						
13.89	0.7	0.4	2.0	1.0	Ti: 0.2	50-60
13.91	0.45	3.0	0.8	9.0		50-60
OK Tubrodur						
14.70	3.5	0.4	0.9	22.0	Mo: 3.5, V: 0.4	48-59
15.43	0.14	0.5	1.1	1.0	Mo: 0.5, Ni: 2.2	30-40
15.50	0.7	0.8	0.8	5.5	Mo: 1.0	55-62
15.52	0.4	0.3	1.2	5.0	Mo: 1.2, Al: 0.6	50-57
Cored wire						
PZ 6166	0.03	0.7	1.2	13	Ni: 4.5, Mo: 0.5	30-40

1) Hardness of deposited metal

Welding consumables for cast iron

Consumable	C (%)	Si (%)	Mn (%)	Ni (%)	Fe (%)
OK electrode					
92.18	0.9	0.9	0.6	> 92	3.5
92.58	1.5	0.7	0.8	51	46
Cored wire					
Nicore 55	2.0	3.0	1.0	51	46

Welding consumables for aluminium alloys

Consumable	Si, Mg (%)	Al (%)
OK electrode		
96.50	Si: 12	remainder
OK Autrod/Tigrod		
4047	Si: 12	remainder
4043	Si: 5	remainder
5356	Mg: 5	remainder

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Reg. No: XA00095820 – 01 / 2012.