Repair and Maintenance Welding Handbook

Second Edition

ESAB

XA00086820

Selection and Application Guide
Esab Repair & Maintenance Consumables

Contents

Foreword

Every day, welders throughout the world encounter the initials OK on the consumables they use. OK for Oscar Kjellberg, the founder of Esab AB. Oscar Kjellberg first invented a new welding technique and followed it up with the covered electrode. These inventions are the origins of Esab.

Oscar Kjellberg qualified as an engineer and worked for several years on a couple of Swedish steamships. It was during this period at the end of the 1890s that he came across the problem for which there was no effective solution at that time. The riveted joints on steam boilers often leaked. Attempts were made to repair the leaking joints with nails which were forged to produce small wedges which were then pushed into the joints. Simple electrical welding was already in use, but Oscar Kjellberg had seen electrical welding repairs and the results were poor, as there were still cracks and pores.

He realized, however, that the method could be developed and was supported by the leading shipyards. Oscar Kjellberg set up a small experimental workshop in the harbour in Göteborg.

In the shipyards of Göteborg, the method quickly attracted a great deal of interest. It was obvious that it could provide tremendous benefits when welding and repairing ships. Since then, this repair technique has been further developed and implemented in other segments.

Today, Esab can offer repair and maintenance consumables for most materials and welding processes.

In this handbook, you will find Esab Repair & Maintenance products and a number of applications in which these products are used. The products shown for each application are general recommendations and should only be used as a guide.

For further product information, please refer to the ESAB Welding Handbook or to your local Esab dealer.

Abbreviations

R_m = tensile strength
$R_{p\ 0.2}$ = yield strength
A = elongation after rupture
HRC = hardness HRC
HB = hardness Brinell
HV = hardness Vickers
a w = as-welded
w h = work-hardened

SMAW = shielded metal arc welding (manual metal arc welding)
FCAW = flux-cored arc welding
GMAW = gas metal arc welding
SAW = submerged arc welding

DC + = direct current – reverse polarity
DC – = direct current – straight polarity
AC = alternating current
OCV = open circuit voltage

Chemical symbols

Al	Aluminium
B	Boron
C	Carbon
Cr	Chromium
Co	Cobalt
Cu	Copper
Mn	Manganese
Mo	Molybdenum
Nb	Niobium
Ni	Nickel
P	Phosphorus
S	Sulphur
Si	Silicon
Sn	Tin
Ti	Titanium
W	Tungsten
V	Vanadium

Gouging – Cutting – Piercing

General

OK 21.03 is a specially-designed electrode for gouging, cutting and piercing in steel, stainless steel, manganese steel, cast iron and all metals except pure copper.

The coating develops a strong gas jet, which blows away the melted material.

No compressed air, gas or special electrode holder is necessary, as standard welding equipment is used. The grooves are very even and smooth so welding can follow without any further preparation. Preparation in stainless steel and manganese steel may, however, require a little grinding.

Note: The electrode is not designed to produce a weld metal.
The electrode is available in ∅ 3.25, 4.0 and 5.0 mm.

Applications

OK 21.03 is suitable for gouging when welding on site and when equipment for carbon arc gouging is impractical.

It is excellent for the preparation of repairs in cast iron, as it dries out and burns away impurities/graphite on the surface and thus reduces the risk of cracking and porosity when welding.

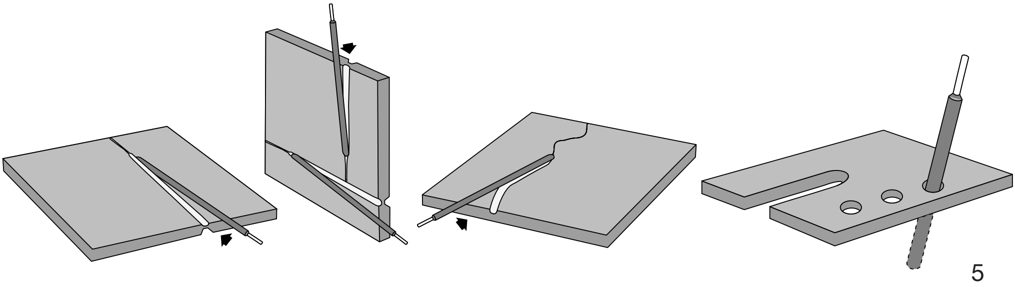
The gouging of manganese steel is another suitable application.

Procedure

Use mainly DC– or AC. For cutting and piercing, DC+ is recommended.

Strike the arc by holding the electrode perpendicular to the workpiece, whereafter the electrode should be pointed in the appropriate direction, inclined about 5–10° from the workpiece and pushed forward. Keep the electrode in contact with the workpiece and move it like a handsaw. If a deeper cut is required, repeat the procedure until the desired depth is reached.

Piercing holes is very easy. Hold the electrode in the vertical position, strike an arc and push the electrode down until it penetrates the material. Manipulate the electrode with a sawing motion to enlarge the hole.



Preheating & interpass temperatures

To obtain a crack free weld metal, the preheating temperature is most important, as is the interpass temperature.

Preheating reduces:

- the risk of hydrogen cracking
- the shrinkage stress
- the hardness in the heat affected zone (HAZ)

The need for preheating increases with the following factors

- the carbon content of the base material
- the alloy content of the base material
- the size of the workpiece
- the initial temperature
- the welding speed
- the diameter of the consumable

How to determine the preheating temperature

The composition of the base material must be known to select the correct preheating temperature, as the preheating temperature is controlled by two major factors

- the carbon content of the base material
- the alloy content of the base material

Basically, the higher the carbon content of the base material, the higher the preheating temperature that is required. This is also true of the alloy content, but to a slightly lesser degree.

One way to determine the preheating temperature is to calculate the carbon equivalent, C_{eq}, based on the chemical composition of the base material

$$C_{eq} = \%C + \%Mn/6+(\%Cr +\%Mo+\%V)/5 + (\%Ni+\%Cu)/15$$

The higher the C_{eq}, the higher the preheating temperature that is required.

Another major factor in determining the preheating temperature is the thickness and size of the component. The preheating temperature increases with the size and thickness of the component.

When the correct preheating temperature has been determined, it is essential that this temperature is obtained and maintained during the welding operation.

When preheating, soaking time is important to bring the entire component to the required temperature. Normally, all preheated welding applications should be slow-cooled.

The table shows the recommended preheating temperatures for a number of different materials.

Recommended preheating temperatures

Base material Filler material	Plate thick-ness mm	Steel C_{eq} <0.3 < 180 HB °C	Low alloy C_{eq} 0.3–0.6 200–300 HB °C	Tool steel C_{eq} 0.6–0.8 300–400 HB °C	Chromium steel 5–12% Cr 300–500 HB °C	Chromium steel >12% Cr 200–300 HB °C	Stainless steel 18/8 Cr/Ni ~200 HB °C	Manganese steel 14%Mn 250–500 HB °C
Low–alloy	≤20	–	100	150	150	100	–	–
200–300 HB	>20 ≤60	–	150	200	250	200	–	–
	>60	100	180	250	300	200	–	–
Tool steel	≤20	–	100	180	200	100	–	–
300–450 HB	>20 ≤60	–	125	250	250	200	–	o
	>60	125	180	300	350	250	–	o
12% Cr steel	≤20	–	150	200	200	150	–	x
300–500 HB	>20 ≤60	100	200	275	300	200	150	x
	>60	200	250	350	375	250	200	x
Stainless steel	≤20	–	–	–	–	–	–	–
18/8 25/12	>20 ≤60	–	100	125	150	200	–	–
200 HB	>60	–	150	200	250	200	100	–
Mn steel	≤20	–	–	–	x	x	–	–
200 HB	>20 ≤60	–	–	•100	x	x	–	–
	>60	–	–	•100	x	x	–	–
Co-based	≤20	100	200	250	200	200	100	x
type 6 40 HRC	>20 ≤60	300	400	•450	400	350	400	x
	>60	400	400	•500	•500	400	400	x
Carbide type (1)	≤20	–	o–	o–	o–	o–	o–	o–
55 HRC	>20 ≤60	–	100	200	•200	•200	o–	o–
	>60	o–	200	250	•200	•200	o–	o–

(1) Maximum two layers of weld metal. Relief cracking is normal.

– No preheating or preheating <100°C.

x Used very rarely or not at all.

o Preheating when large areas are surfaced.

• To prevent cracking, use a buffer layer of tough stainless weld metal.

Controlling weld metal dilution

Dilution is the inevitable mixture of the base material and the weld metal deposit when welding.

The objective is to keep the dilution as low as possible to obtain the optimun properties in the hard-facing deposit.

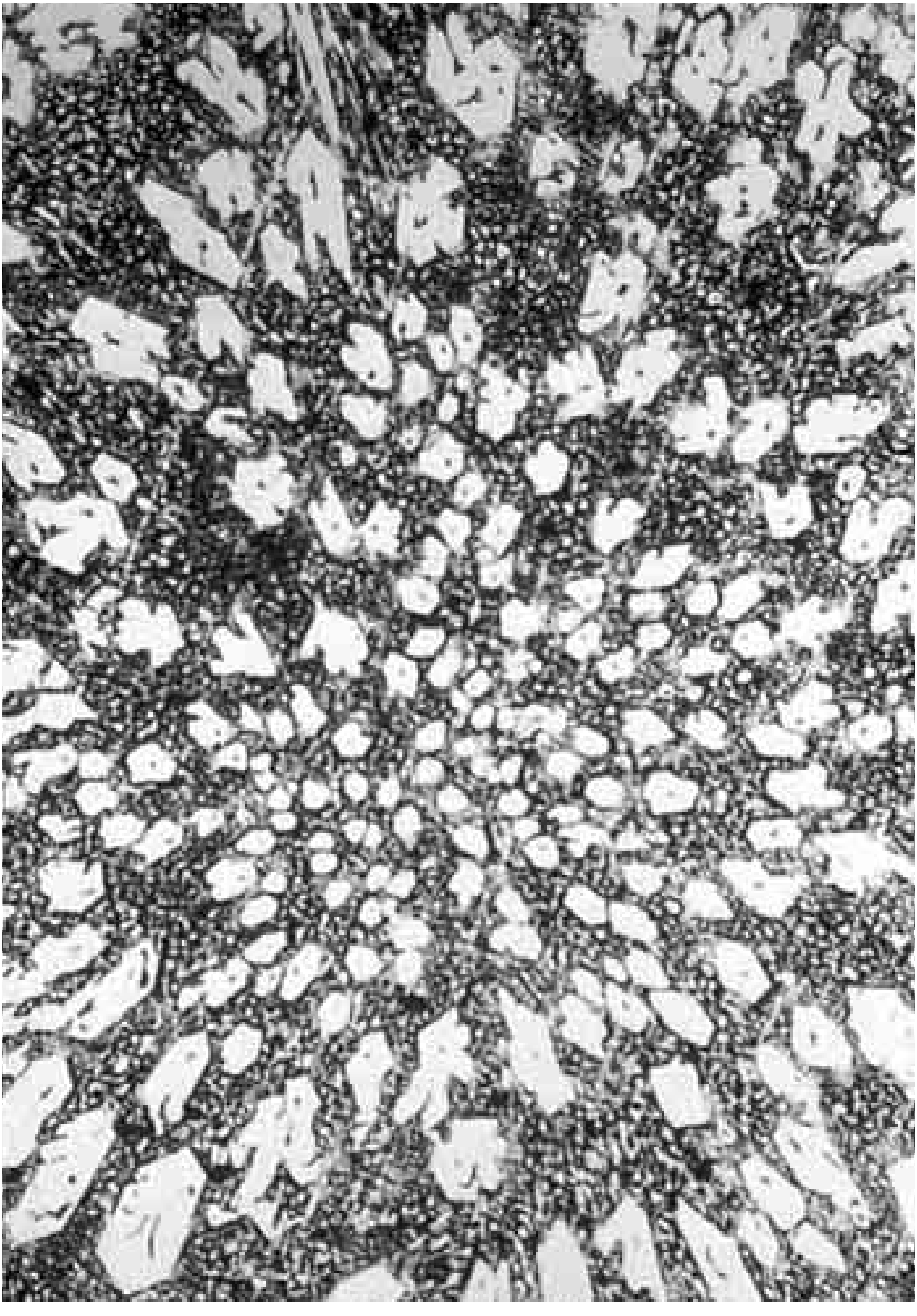
Softer hard-facing materials display an increase in hardness when deposited on higher alloyed materials. This is due to carbon and alloy pick-up from the base material.

The base material is, however, very often an unalloyed or low-alloy material and several layers may be needed to achieve the required hardness. In general, two or three layers are enough.

As the degree of dilution is a function not only of the welding process but also of the procedure, the latter must be carried out in such a way that the least possible dilution takes place.

Factors influencing dilution:

• Welding speed:	Slow speed – high dilution High speed – low dilution
• Welding polarity:	DC- low dilution AC intermediate dilution DC+ high dilution
• Heat input:	Low – low dilution High – high dilution
• Welding technique:	Stringer beads – low dilution Weaved beads – high dilution
• Welding position:	Vertical-up – high dilution Horizontal, flat, vertical down – low dilution
• Number of layers:	As more layers are deposited, the dilution decreases
• Type of weld metal:	Over alloyed weld metal – less sensitive to dilution
• Electrode stick-out: (wires)	Long stick-out – less dilution



Microstructure hard-facing weld metal: OK 84.78, chrome carbide.

The use of buffer layers and build-up layers

Buffer layers

Buffer layers are used as intermediate deposits between the base material and the actual hard-facing weld metal to:

- ensure good bonding with the base material
- avoid hydrogen-induced underbead cracking even on preheated workpieces
- minimize the consequences of stress
- limit the effect of dilution
- avoid spalling in subsequent hard layers
- prevent possible cracks in the hard-facing layer running into the base material

Austenitic consumables are widely used as ductile buffer layers in hard-facing. The choice of consumable depends on the base material and type of surfacing. See the table below.

Consumables for buffer layers

Base material	Application	SMAW	FCAW/GMAW
14% Mn-steel	Worn surface Crack repair	**OK 67.45** **OK 68.82**	**OK Tubrodur 14.71** **OK Autrod 16.75**
Low-alloyed	1 layer hard-facing, no impact wear	**No buffer layer**	
	2 layers hard-facing, impact wear	**OK 67.45**	**OK Tubrodur 14.71**
	2 layers Co and Ni alloys	**OK 67.45 or OK 68.82**	**OK Tubrodur 14.71 or OK Autrod 16.75**
Hardenable steels	1 layer hard-facing, no impact wear	**No buffer layer**	
	2 layers hard-facing, impact wear	**OK 67.45**	**OK Tubrodur 14.71**
	1–2 layers Co and Ni alloys	**OK 67.45 or OK 68.82**	**OK Tubrodur 14.71 or OK Autrod 16.75**
5–12%Cr steels	Co and Ni alloys, for cladding	**OK 67.45**	**OK Tubrodur 14.71**
2–17%Cr steels	Matching surfacing alloys	**No buffer layer** **Preheating, see Table 7 on page 108.**	
	1–2 layers hard-facing	**OK 67.45 or OK 68.82**	**OK Tubrodur 14.71 or OK Autrod 16.75**
Cast iron	Hard-facing	**OK 92.60**	**OK Tubrodur 15.66**

See table 2 on page 91 for further product data.

When harder surfacing materials are used on soft base material such as mild steel, there is a tendency for the hard-facing layer to sink under high load conditions, Figure A. This may result in the hard-facing material spalling off. To prevent this, a strong, tough material is deposited on the part prior to hard-facing, Figure B.

Figure A

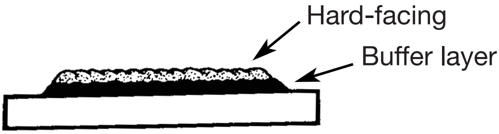


Figure B

OK 83.28 and OK Tubrodur 15.40 are suitable build-up/buffering materials. Depending on the base material, other types of buffer layer may be recommended.

When hard-facing with brittle alloys those containing chromium carbides and cobalt-based alloys, it is recommended first to buffer one or two layers with an austenitic consumable. This causes compression stress in subsequent layers during cooling and thus reduces the risk of cracks in the hard weld metal.

Many hard-facing deposits contain “relief cracks”. They are not harmful to the hard-facing, but there is a danger that, under heavy impact or flexing, the cracks will propagate into the base material, Figure C. This tendency is most pronounced where the base material is a high strength steel. The use of a tough bufferlayer will prevent this crack propagation, Figure D. Suitable consumables are OK 67.45 or OK 68.82 or OK Tubrodur 14.71 or OK Autrod 16.75, Figure B.

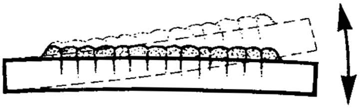


Figure C

Figure D

Build-up layers

If a workpiece is badly worn, one possible method is to rebuild it to its original form before hard-facing using the same type of alloy as the base material. Another method is to alternate hard and ductile deposits, see figure below.

Consumables for build up

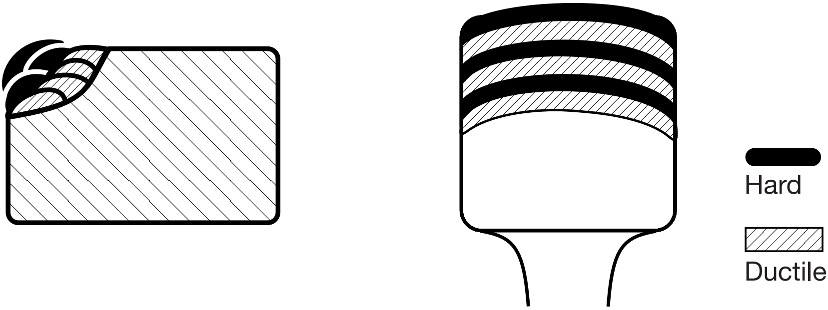
Alloy type	SMAW	FCAW	SAW	GMAW
Low carbon/ Low alloy	**OK 83.28** **OK 83.29**	**OK Tubrodur 15.40**	**OK Tubrodur 15.40/ OK Flux 10.71**	**OK Autrod 13.89**

Build-up alloys have good resistance to impact wear but, quite naturally, moderate resistance to abrasive wear.

Depending on the base material, other types may be recommended.

Typical applications are

- hammers
- crushers
- excavator teeth
- cold shearing tools



Engine block. Cast iron repair using OK 92.18 and OK 92.60.

Welding cast iron

General

Cast iron comprises alloys of iron with a carbon content of 2–5%, a silicon content of 1–3% and up to 1% manganese.

Cast iron exhibits low ductility, low hardness and low strength and is generally a very brittle material. To improve these properties, cast iron is very often alloyed or heat-treated.

The types of cast iron which are mainly used today are:
- grey iron
- nodular iron
- malleable iron
- compacted graphite iron
- white iron

The high carbon content affects its weldability considerably. Because of the range of properties of cast iron, weldability varies accordingly. Some types are casually welded, others are unweldable. All the iron grades above are successfully welded, apart from white irons because of their extreme brittleness.

Consumables for cast iron

Type	SMAW	FCAW
Pure nickel	**OK 92.18**	
Nickel-iron	**OK 92.58**	
Nickel-iron	**OK 92.60**	**OK Tubrodur 15.66**
Nickel-copper	**OK 92.78**	
Unalloyed steel	**OK 91.58**	

Pure nickel type

As a guideline, cast iron is welded with pure nickel electrodes. Nickel has a capability to absorb more carbon without changing its own properties. The co-expansion of Nickel and cast iron due to heat is comparable. Nickel is more ductile than other filler materials for cast iron welding and is very easy to machine. It is used for filling cavities, general repairs where a hardness of approx. 150HB is required. It is not recommneded for irons with a high sulphur and phosphorus content.

Nickel-iron type

To obtain still higher strength, nickel-iron electrodes can be used for joining cast iron and cast iron to steel. Due to the ferrous content of the weld metal, there is a slight increase in the hardness of the weld metal, compared with pure nickel weld metal. The weld metal is machinable.

The nickel-iron type is more tolerant of dilution with sulphur and phosphorus than the pure nickel type.

Nickel-copper type

When colour-matching weld metal is required, the nickel-copper type is suitable. The weld metal is easily machined.

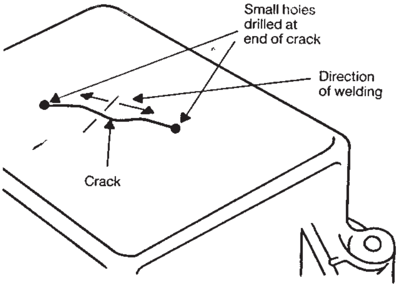
Unalloyed steel type

This type of electrode can be used for non-critical work and when no machining is required.

For further product data, see Table 1 on page 90.

Joint preparation for cast iron

- Joint angles should be wider than for mild steel
- All sharp edges must be rounded off
- U-grooves are generally preferred
- Cracks must be fully opened to permit accessibility
- For crack repair, drill a small hole at each end of the crack, see figure below.



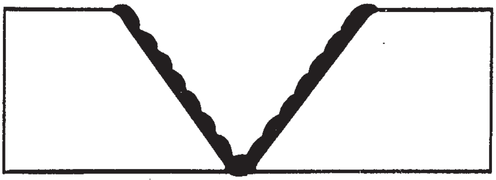
Procedure for repairing a crack

Since cast iron has a porous metallurgical structure, it absorbs oil and liquid which affect weldability and must thus be removed before welding. In order to burn out these liquids, heating is required. However, in most cases, this is impossible, due to the shape of the object or because of time limitations.

One way to get around this problem is to use the gouging electrode OK 21.03, page 5. It is excellent for the preparation of repairs in cast iron as it dries out and burns away impurities/graphite on the surface and thus reduces the risk of cracking and porosity when welding. With normal grinding, the impurities and graphite in the cast iron are smeared out along the groove and may cause problems when welding.

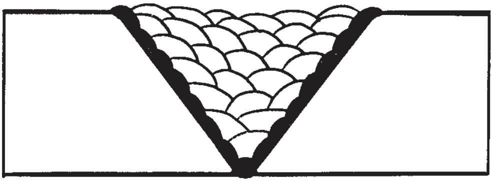
On some welds, it is beneficial to use the buttering technique. This means that one or both of the surfaces to be welded are clad prior to joining, Figures 1 and 2.

The technique is used to avoid the formation of brittle phases. The contractional stresses from the cooling weld metal in subsequent beads will have more effect on the ductile buttering layer than the brittle HAZ of the base material.



Buttering technique

Figure 1



Multilayer with
buttering technique

Figure 2

Cold welding cast iron

Most cast iron repairs are performed using SMAW and nowadays the cold welding technique is mainly used with the following procedure.

- Weld with short stringer beads (20–30 mm) depending on thickness
- Use small-diameter electrodes and weld with low amperage
- The intermediate temperature should be kept below 100°C at all times
- Peen the weld surface with a rounded tool directly after welding

Gear drive. Rebuilding using OK 68.82.

Welding
“difficult to weld steels”

There are many steels in the repair and maintenance field which can be regarded as difficult to weld due to their high hardenability.

These steels include:

- high carbon steels
- high strength steels
- tool steels
- spring steels
- heat-treated steels
- wear-resistant steels
- steels of unknown composition

Steels of unknown composition must be treated as having limited weldability in order to avoid failure when welding.

In principle, all these steels can be welded with matching ferritic consumables with the aid of preheating and postweld heat treatment to avoid hydrogen cracking in the heat affected zone (HAZ).

In the case of repair welding, it is, however, often not possible to preheat or to perform any postweld heat treatment.

So, in this case, welding with austenitic stainless or nickel-based consumables is considered to be one of the best methods. The risk of cracking is reduced by the higher solubility of hydrogen and the greater ductility of the weld metal.

The most common types are:

Type	SMAW	FCAW/GMAW
29Cr 9Ni	**OK 68.81, OK 68.82**	**OK Autrod 16.75**
18Cr 9Ni 6 Mn	**OK 67.42, OK 67.45, OK 67.52**	**OK Tubrodur 14.71** **OK Autrod 16.95**
Ni-based	**OK 92.26**	**OK Autrod 19.85**

OK 68.81/OK 68.82/OK Autrod 16.75

Have a great capacity for dilution and are chosen when high strength is needed. The ferrite level in undiluted weld metal is often >40%, which may promote embrittlement when used for applications at elevated temperatures.

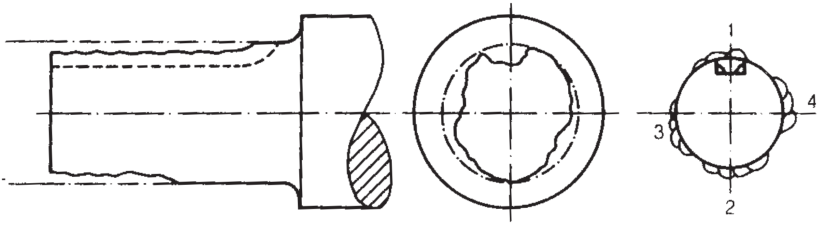
These types are the best choice when the material to be welded is of unknown composition.

OK 67.42/OK 67.45/OK 67.52/OK Tubrodur 14.71/OK Autrod 16.95
Deposit a fully austenitic weld metal of comparatively lower strength but with extremely good resistance to solidification cracking. This relatively soft weld metal reduces the stress on any martensite which may be present and thus reduces the risk of hydrogen cracking. This type of weld metal may therefore be a better choice when lower strength can be accepted.

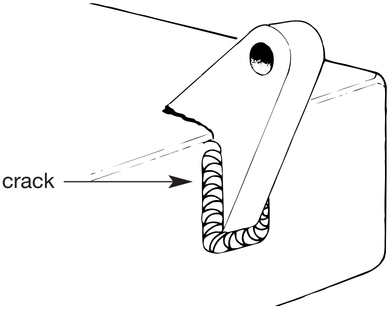
OK 92.26/OK Autrod 19.85
Are used for high-temperature, high-strength joints designed for service at over 200°C, such as creep-resistant Cr-Mo steel to stainless steel. These types are not sensitive to embrittlement in heat treatment and reduce the restraint in the joint due to their high elongation. These types are also very suitable when welding thick materials (>25 mm), i.e. multilayer welding.

See table 2 on page 91–92 for further product data.

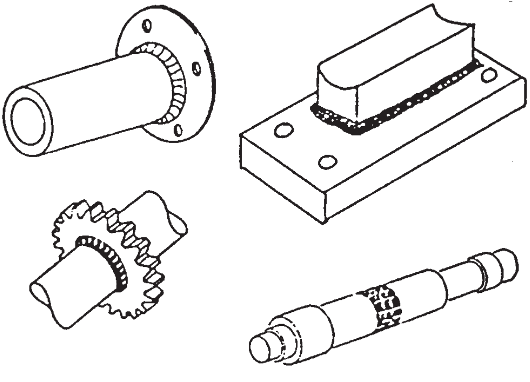
The following figures show typical applications in which OK 68.82 has been used successfully, for example.



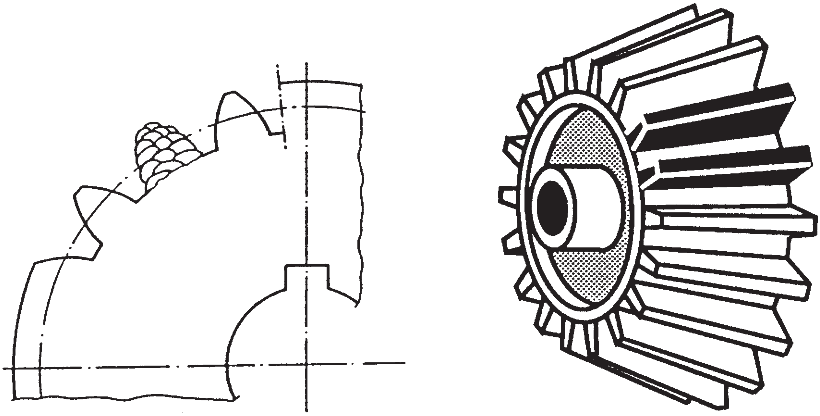
Repair of worn low-alloy steel shaft with OK 68.82.



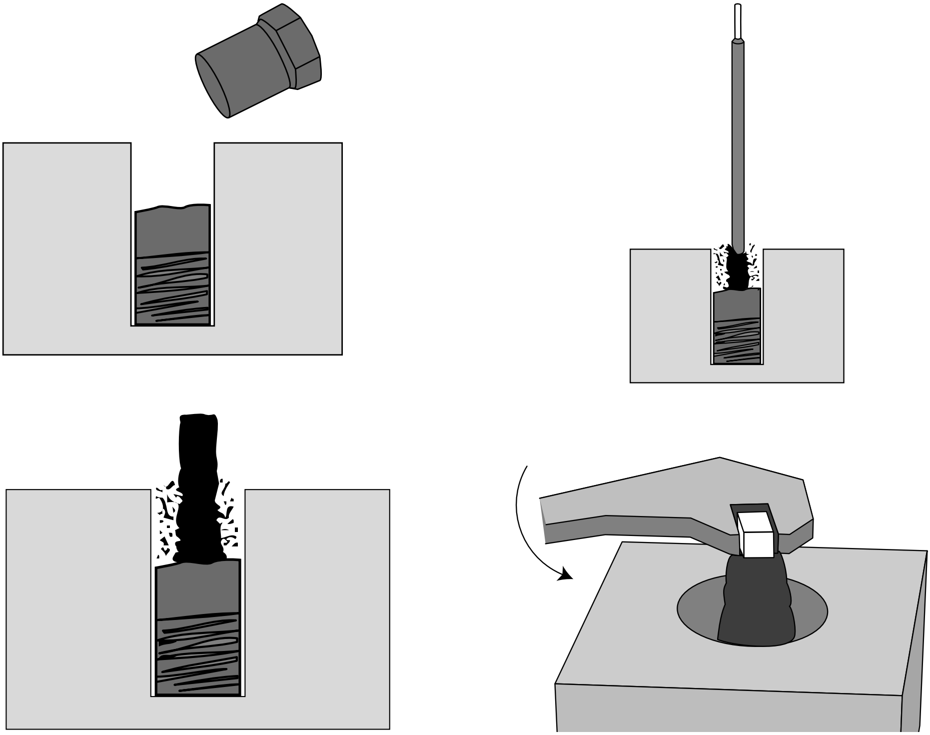
Repair of broken cast-steel support with OK 68.82.



Repaired machine parts using OK 68.82.



Repair of broken teeth in gear with OK 68.82.



Extraction of broken bolt using OK 68.82.

Joining stainless steel to unalloyed or low-alloy steels

Joining stainless to C/Mn or low-alloy steels is undoubtedly the most common and most important example of dissimilar metal welding. In particular, the joining of unalloyed or low-alloy steels to austenitic stainless steels (often referred to as ferritic/austenitic joints) for attachments or transitions is a common application.

The welding of stainless steel to unalloyed and low-alloy steel should normally be performed with over-alloyed stainless consumables i.e. more highly alloyed than the base material.

Two different methods can be used. The entire groove can be welded with the over-alloyed stainless steel or Ni-based consumable. Alternatively, the low-alloy or unalloyed groove surface can be buttered with over-alloyed stainless weld metal, after which the groove is filled with a consumable matching the stainless base material.

The welding can usually be performed without preheating. Follow the recommendations which apply to the particular steels in use, however.

For consumables for welding dissimilar materials, see Table 2 on page 96.

The most common types are:

Type	SMAW	FCAW/GMAW
29Cr 9Ni	**OK 68.81, OK 68.82**	**OK Autrod 16.75**
18Cr 9Ni 6 Mn	**OK 67.42, OK 67.45, OK 67.52**	**OK Tubrodur 14.71** **OK Autrod 16.95**
Ni-based	**OK 92.26**	**OK Autrod 19.85**

OK 68.81/OK 68.82/OK Autrod 16.75

Have a great capacity for dilution and are chosen when high strength is needed. The ferrite level in undiluted weld metal is often >40%, which may promote embrittlement when used for applications at elevated temperatures.

These types are the best choice when the material to be welded is of unknown composition.

OK 67.42/OK 67.45/OK 67.52/OK Tubrodur 14.71/OK Autrod 16.95
Deposit a fully austenitic weld metal of comparatively lower strength, but with extremely good resistance to solidification cracking. This relatively soft weld metal reduces the stress on any martensite which may be present and thus reduces the risk of hydrogen cracking. This type of weld metal may therefore be a better choice when lower strength can be accepted.

OK 92.26/OK Autrod 19.85
Are used for high-temperature, high-strength joints designed for service at over 200°C, such as creep-resistant Cr-Mo steel to stainless steel. These types are not sensitive to embrittlement in heat treatment and reduce the restraint in the joint due to their high elongation. These types are also very suitable when welding thick materials (>25 mm), i.e. multilayer welding.

Joining copper and copper alloys to steel/stainless steel

When joining copper alloys to steel/stainless steel, a buttering technique should be used.

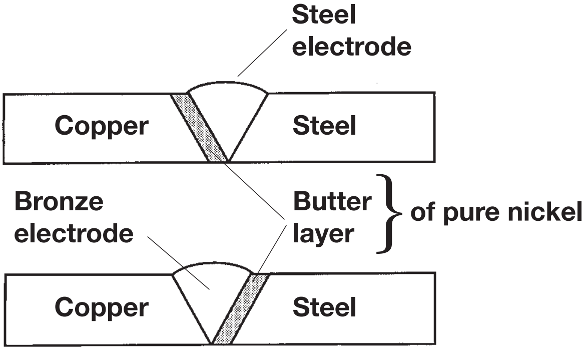
Liquid copper and, to a somewhat smaller extent, bronze migrate into the heat affected zone (HAZ) of the steel and precipitate in its grain boundaries. This phase has a melting point several hundred degrees lower than the steel. The penetration is fast and the penetration depth can be >1 mm. This phenomenon is encouraged by tensile stresses, which are always present in welding. It can also occur in nickel-based alloys apart from pure nickel and nickel-copper types. For this reason, pure nickel or nickel-copper can be used as a butter layer to avoid this copper penetration.

This copper penetration is not necessarily detrimental. It can be tolerated in many surfacing applications.

If however in joining, where the weld is exposed to heavy loads or particularly high temperatures, where the grain boundary will cause brittleness, copper penetration must be avoided. In these cases, a butter layer of nickel or nickel-copper must be used.

The butter layers can be made on either the copper side or the steel side. When welding the buttered joint, it is essential that physical contact between the weld metal and the metal beneath the buffer layer is avoided

In both cases, the pure nickel electrode **OK 92.05** can be used. For the final filling of the joint, electrodes of the steel/stainless type or bronze type are used, depending on which side the butter layer is applied. The figure on next page shows how this butter layer can be performed.



When buttering copper or bronze, preheating to 300–500°C should be applied. Thin material may be heated only around the starting area.

When the butter layer is on the non-copper side, the preheating temperature should be chosen according to this material.

When welding joints buttered on the non-copper side using Cu-based electrodes, the copper side should be preheated to 150–200°C (Al bronzes and Sn bronzes) and <100°C (Si bronzes) respectively.

Joints buttered on the copper side do not need to be preheated on this side since the insulating Ni layer effectively lowers the heat sink caused by the high thermal conductivity of copper.

For consumables for welding non-ferrous materials, see Table 6 on page 105–106.

Repointing of bucket tooth OK 67.45 or OK Tubrodur 14.71.

Dredger bucket. Joining new bucket lips using OK 68.82.

Welding manganese steels

Manganese steel, sometimes called austenitic-manganese steel, 14% manganese steel or Hadfield steel, typically contains 11–14% manganese and 1–1.4% carbon. Certain grades may also contain other minor alloying elements. This steel has an exceptional ability to work-harden during cold work, e. g. high impact and/or high surface pressure. This makes the steel ideal for severe conditions in the crushing and mining industry, in the wear parts of crusher hammers, tumblers, buckets, digger teeth and rail points, for example.

Manganese steel lasts for a long time, but it eventually gets worn. Reconditioning normally takes the form of repairing cracks or breakages, rebuilding metal which has worn away and depositing hard-facing layers to extend the service life of the part.

The weldability of manganese steel is restricted by its tendency to become brittle upon reheating and slow cooling. One rule of thumb is that the interpass temperature must not exceed 200°C. For this reason, very careful control of the heating during welding is essential. These steels should therefore be welded:

- with the lowest possible heat input by using low current
- with stringer beads instead of weaved beads
- where practicable, working with several components at the same time
- the component can be put in cooling water

Welding manganese steel can involve

- joining manganese steel to unalloyed, low-alloy steel
- joining manganese steel to manganese steel
- rebuilding worn surfaces
- hard-facing to secure initial hardness of the surface

Joining

To join manganese steels and manganese steels to steels, austenitic stainless consumables should be used to produce a full-strength, tough joint.

Consumables for joining

Alloy type	SMAW	FCAW	GMAW
18/8/6	**OK 67.42** **OK 67.45** **OK 67.52**	**OK Tubrodur 14.71** self shielding	**OK Autrod 16.95**
29/9	**OK 68.81** **OK 68.82**		**OK Autrod 16.75**

For further product data, see Table 2 on page 91–92.

Surfacing:

Before surfacing heavily worn parts, it is advisable to buffer with the austenitic consumable OK 67.XX. Surfacing is then carried out with one of the 13%Mn types below.

Consumables for surfacing

Alloy type	SMAW	FCAW
13Mn	**OK 86.08**	
13Mn 4Cr 3Ni	**OK 86.20**	**OK Tubrodur 15.60** self shielding
14Mn3Ni	**OK 86.28**	
14Mn18Cr	**OK 86.30**	**OK Tubrodur 15.65** self shielding

These consumables correspond to the most common austenitic-manganese steels available. For further product data, see Table 3 on page 93–94.

High initial hardness

To increase the initial hardness of the as-welded manganese weld metal and to improve the initial resistance to abrasion, hard-facing with chromium-alloyed consumables can be used. This can also be done on new parts for preventive purposes.

Consumables for initial hardness

HRC	SMAW	FCAW	GMAW
55–60	**OK 84.58**	**OK Tubrodur 15.52**	**OK Autrod 13.91**

In extremely abrasive conditions, high chromium-iron or complex carbide types may be used in a checker net or dot pattern.

HRC	SMAW	FCAW
60–63	**OK 84.78**	**OK Tubrodur 14.70**
~62*	**OK 84.84**	**OK Tubrodur 15.80**

* 1 layer

For further product data see table 5 on page 99–100.

Repairing of 14% Mn steel crusher using OK 86.08.

Crusher. Teeth: OK 86.20 buffer layer, OK 84.78 hardsurfacing.
Check pattern: OK Tubrodur 14.70.

Hammer crusher: OK Tubrodur 15.65.

Welding tool steels and steels for high-temperature applications

In comparison with structural steels, tool steels have a much higher carbon content. They are frequently alloyed with chromium, nickel, molybdenum and heat-treated to obtain specific properties, such as hardness, toughness, dimensional stability and so on.

The repair welding of tool steels without changing the inherent properties can be very difficult. This calls for heat treatment at high temperatures and the use of consumables which produce a weld metal with matching composition and properties. In practical terms, this is very complicated because of scaling and dimensional change problems. It also requires a great deal of time.

Simplified welding

The repair welding of tools can be carried out by preheating to 200–500°C (depending on the type of steel) and welding at this temperature, followed by annealing. This will not result in a completely even structure and hardness across the weld, but it may be adequate for the purpose of saving the expense of making a new tool.

The preheating and post-heat temperatures to be applied can be found in different standards, e.g. SAE/AISI, or are available from tool steel manufacturers.

Electrodes for tool steels

These electrodes are developed for the manufacture of composite tools and for repair welding.

Principal types

OK 84.52	Martensitic 13 Cr
OK 85.58	Martensitic+fine carbide
OK 85.65	“High-speed steel”
OK 93.06	Cobalt-based type – Co Cr W
OK 92.35	Nickel-based type – Ni Cr Mo W

One important aspect of tool steel weld metal is its hardness at elevated temperatures, since tools are often used at high temperatures or heat is generated during the cutting or forming operation. The hardness of low-alloy weld metal quickly drops at temperatures above 400°C, whereas high-speed steel types can retain their hardness up to 600°C.

Cobalt-based alloys are used primarily to withstand wear at elevated temperatures, where good hot hardness is required together with good resistance to oxidation, corrosion and scaling. Typical examples are valve seats, extrusion guides, engine valves and so on.

Cobalt-based alloys can be applied to parent materials such as carbon, low-alloy and cast steels or stainless steels.

Preheating is often required to obtain a crack-free deposit when welding more than two layers.

OK 93.06 is known for its excellent wear resistance at high temperatures and the weld metal is used in cutting and shearing operations at temperatures exceeding 600°C. For lower temperatures, however, “the high-speed steel” type electrodes like OK 85.65 may produce equally good or better results and superior toughness.

OK 92.35 is not very hard, but the drop in strength and hardness is very gradual. Even at 800°C, its tensile strength is in excess of 400 MPa. The alloy is highly resistant to thermal shock and cyclic stresses as well as oxidation.

Preparation, practical advice

To ensure even and correct temperatures, preheating should be carried out in a furnace. However, it may also be done with a torch. It is essential to increase the temperature slowly, especially on tools with a complicated design. It is also important to reduce the heat input to a minimum when welding and to use a skip welding technique.

The joints can be prepared by grinding. Sharp corners must be avoided and a sufficient corner radius is necessary.

For the very difficult to weld type of tool steels, the application of one or two passes of a buffer layer, using OK 67.45 or OK 68.82, for example, is recommended.

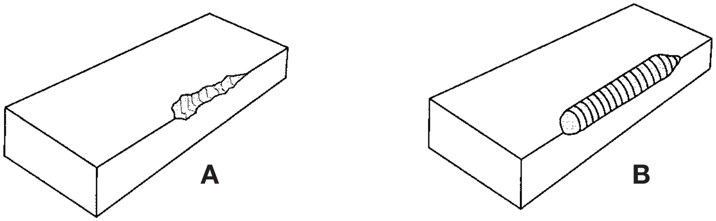
Less critical parts and low-alloy tool steels can be built up with OK 83.28 before hard-facing.

All working and cutting edges as well as surfaces require at least two weld deposit passes with the tool steel electrode.

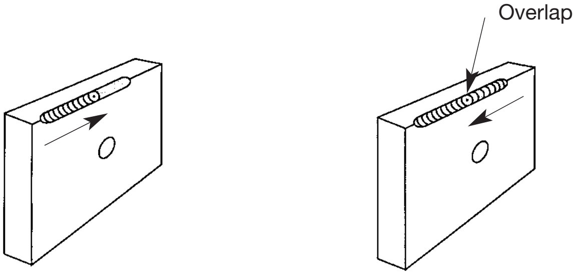
Consequently, a deposition of sufficient thickness must remain to permit machining to the correct size.

Tempering is carried out at approximately the same temperature as the preheating temperature. However, neither tempering nor pre-heating must exceed the annealing temperature.

Preparation for full repair: (A) damaged edge, (B) grooved for welding.



Preparation for partial repair: (A) damaged edge, (B) grooved for welding.



Techniques to avoid craters or edge damage during repair welding.

Selection of electrodes for different tools

Type of tool	Desired properties	Consumable
Cold-working dies Cold-forming tools	Toughness strength. Shock resistance. Abrasion resistance.	**OK 84.52**
Die-casting dies Plastic dies Hot forging dies Hot punches Extrusion dies	High hot strength and resistance to abrasion and shock at elevated temperatures.	**OK 85.58**
Hot blanking dies Hot piercing dies Hot shearing blades Planer tools Milling cutters	Cutting edge retention at high temperatures. High impact toughness.	**OK 85.65**
Forging dies Extrusion dies	Toughness under repeated cyclic stress. Oxidation resistance up to 1000°C.	**OK 92 35**
Stamping dies Trimming cutters Trimming punches	High shock resistance. High hardness at elevated temperature. Scaling resistance.	**OK 93.06**

For further product data see table 4 on page 95–97.

Hard-facing

General

Hard-facing involves protecting parts exposed to different types of wear in order to obtain a certain specific wear resistance or properties.

Although hard-facing is primarily used to restore worn parts to usable condition in order to extend their service life, it is worthwhile using this technique in new production as well. The component itself can thus be made from a cheaper material and the surface properties are obtained by an overlay with the properties required for good wear resistance.

hard-facing alloys can be applied using almost any welding process.

Increased hardness does not always mean better wear resistance or longer service life. A number of alloys can have the same level of hardness but may vary considerably in their ability to resist wear.

Experience has proven that, to select the best hard-facing alloy, you need to know the working conditions in which the component operates.

So, in order to choose the appropriate hardsurfacing alloy for a special application, the following information is needed:

- what are the wear factors
- what is the base material
- what process is preferred
- what surface finish is required

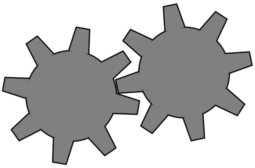
Wear factors

A large number of different wear factors exist, working alone or in combination. Consequently, in order to ensure efficiency and safety, weld metals with suitable properties must be carefully selected.

A hard-facing alloy should then be chosen as a compromise between each wear factor. For example; when examining a worn metal part, it is determined that the primary wear factor is abrasion and the second is moderate impact. The hard-facing alloy that is chosen should therefore have very good abrasion resistance but also a fair amount of impact resistance.

To simplify the concept of wear factors, they can be arranged in separate classes with highly different characteristics.

Metal-to-metal wear, frictional or adhesive wear



Wear from metal parts that roll or slide against one another, such as shafts against bearing surfaces, chain links against a roll, sprockets, steel mill rolls.

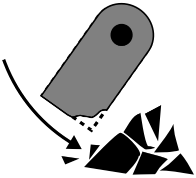
Martensitic hard-facing alloys are a good choice for metal-to-metal wear.

Austenitic-manganese and cobalt alloys are also good types for this kind of wear.

Cobalt alloys are used in high-temperature and oxidation environments.

Generally, contact between surface materials of the same hardness will result in excessive wear. So make a habit of selecting different material hardnesses for the shaft and the bushing, for example.

Impact



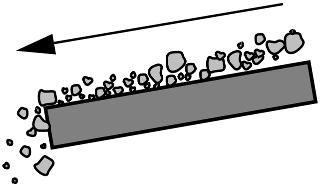
The surface of the material will become deformed or locally fractured and even break away when exposed to impact and/or high pressure conditions.

However, impact wear is also encountered in crushing and milling operations where fine particle abrasion occurs simultaneously, thereby necessitating a wear-resistant, hard surface.

Austenitic-manganese steel deposits offer the best resistance to pure impact wear as they work-harden. This results in a hard surface and a tough material underneath. Although not as good as the austenitic-manganese alloys, the martensitic alloys also offer moderate impact wear resistance.

Typical components are crusher rolls, impact hammers, railroad points.

Fine-particle mineral abrasion

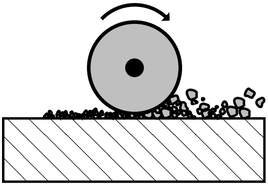


This type of wear is caused by sharp particles sliding or flowing across a metal surface at varying speeds and pressure, thereby grinding away material like small cutting tools. The harder the particle and the more sharp its shape, the more severe the abrasion.

Typical applications are found within dredging operations, the transportation of minerals and agricultural components.

Due to the absence of impact wear, the relatively brittle high carbon-chromium steel alloys, such as carbide-containing alloys, are used successfully to resist this type of wear.

Grinding abrasion. Abrasion + pressure

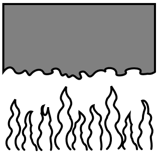


This type of wear occurs when small, hard, abrasive particles are forced between two metal parts and crushed in a grinding mode.

Typical components are pulverizers, roll crushers, mixing paddles and scraper blades.

The weld metals which are used include austenitic-manganese, martensitic and some carbide-containing alloys. Carbide alloys usually contain small, evenly-distributed titanium carbides.

High-temperature wear. Heat, oxidation, corrosion



When metals are exposed to high temperatures for long periods, they generally lose their durability. High-temperature service often results in thermal fatigue cracking. For instance, thermal shock brought about by cyclic thermal stresses will occur in tools and dies designed for forging and hot working operations.

When working in an oxidizing atmosphere, the metal surface builds up an oxide layer, which may break due to expansion and the entire oxidation operation is repeated.

Martensitic steels, 5–12% chromium are very resistant to thermal fatigue wear. Chromium carbide alloys have excellent wear resistance up to temperatures of around 600°C.

For elevated temperatures, either a nickel-based or cobalt-based alloy is used.

Typical parts exposed to high temperature are concast rollers, hot forging dies, extrusion dies, stamping dies, gripper tongs and sinter crushing equipment.

Base material

There are two main groups of base materials for hard-facing:
- carbon or low-alloy steels
- austenitic-manganese steels

To distinguish between these materials, a magnet can be used.
The carbon and low-alloy steels are strongly magnetic.
The austenitic-manganese types are not. These types become magnetic after work-hardening, however.

The recommendations for welding these alloys are completely different.

As the carbon and alloying elements within the carbon and low-alloy steels vary, preheating, post-heat treatment, slow cooling and so on may be needed. See preheating temperatures, Table 7 on page 108.

The austenitic-manganese steels, on the other hand, should be welded without any preheating or post-heat treatment at all. The interpass temperature should be kept as low as possible (≤ 200°C), as these materials become brittle when overheated.

Welding processes

The most common processes for hard-facing are:

Shielded Metal Arc Welding, SMAW

Also known as Manual Metal Arc Welding (MMA)

- covers the widest range of weld metals
- is inexpensive
- is a versatile process used outdoors and for out-of-position work

Flux-Cored Arc Welding, FCAW

- alloy availability almost the same as covered electrodes
- high deposition rate
- can be used on site due to open arc operation
- self-shielding, no extra gas is needed

Submerged Arc Welding, SAW

- limited range of products
- high deposition rate – to rebuild large worn parts
- no arc flash or spatter

Surface finish requirements

The required surface finish must be determined prior to the choice of weld metal, as hard-facing alloys range from easily machinable to non-machinable.

Furthermore, many of the high-alloy hard-facing deposits contain “relief cracking”. This means that small cracks are formed across the weld bead so as to break up and reduce the amount of stress or pull the cooling weld metal exerts on the base material.

The following questions should therefore be answered before selecting an alloy:

- Is machining after welding required or is grinding sufficient?
- Is relief cracking acceptable?

As a rule of thumb, weld metal hardness of <40 HRC can be machined. Hardnesses of >40 HRC can, however, be machined using special tools, such as cemented carbide tools.

This relief cracking is often not harmful to the performance of the hard-facing deposit and does not cause spalling or flaking. If, however, the component is subjected to heavy impact or flexing, a ductile buffer layer will prevent this cracking propagating into the base material.

Relief cracking is increased by low welding currents and high travel speeds.

Types of hard-facing weld metal

hard-facing weld metals can be divided into groups according to their characteristics, properties and resistance to wear.

They can be grouped as:

iron-based:

- martensitic alloys
- austenitic alloys
- carbide-rich alloys

non-iron-based:

- cobalt-based alloys
- nickel-based alloys

Their properties relating to wear:

martensitic:

These types are used for both building up and surfacing:

- good metal-to-metal resistance
- good impact resistance
- fair abrasion resistance

austenitic:

- excellent impact resistance
- good build-up alloy
- fair abrasion resistance

carbide-rich:

- excellent abrasion resistance
- good heat resistance
- fair corrosion resistance
- poor impact resistance

cobalt- & nickel-based

These alloys resist most types of wear, but, due to their higher cost, they are mainly used in applications in which their properties can be economically justified, such as high-temperature applications in which carbide-rich, iron-based alloys have a low resistance. Nickel alloys are the cheaper alternative.

Guide to classification of consumables for hard-facing acc. to DIN 8555 T1 (1983)

DIN 8555 | E | 8 | UM | 200 | KP |

Welding process	
G	gas welding
E	manual-arc welding
MF	metal-arc welding using cored-wire electrodes
TIG	tungsten inert gas welding
MSG	metal shielding gas welding
UP	submerged-arc welding

Alloy group	Type of filler metal or weld metal
1	Unalloyed up to 0.4% C or low-alloy up to 0.4% C and up to a maximum of 5% of the alloying elements Cr, Mn, Mo, Ni in total.
2	Unalloyed with up to more than 0.4% C or low-alloy with more than 0.4% C and up to a maximum of 5% of the alloying elements Cr, Mn, Mo, Ni in total.
3	Alloyed, with the properties of hot working steels.
4	Alloyed, with the proporties of high-speed steels.
5	Alloyed with more than 5% Cr, with a low C content (up to about 0.2%)
6	Alloyed with more than 5% Cr, with a higher C content (about 0.2 to 2.0%).
7	Mn austenites with 11 to 18% Mn, more than 0.5% C and up to 3% Ni.
8	Cr-Ni-Mn austenites.
9	Cr-Ni steels (resistant to rusting, acid and heat).
10	With a high C content and high Cr alloying content and without additional carbide-forming agents.
20	Co-based, Cr-W-alloyed, with or without Ni and Mo.
21	Carbide-based (sintered, cast or cored).
22	Ni-based, Cr-alloyed, Cr-B-alloyed.
23	Ni-based, Mo-alloyed, with or without Cr.
30	Cu-based, Sn-alloyed.
31	Cu-based, Al-alloyed.
32	Cu-based, Ni-alloyed.

Production	Method
GW	rolled
GO	cast
GZ	drawn
GS	sintered
GF	cored
UM	covered

Hardness level	Hardness range		
150	125≤	HB	≤175
200	175≤	HB	≤225
250	225≤	HB	≤275
300	275≤	HB	≤325
350	325≤	HB	≤375
400	375≤	HB	≤450
40	37≤	HRC	≤42
45	42≤	HRC	≤47
50	47≤	HRC	≤52
55	52≤	HRC	≤57
60	57≤	HRC	≤62
65	62≤	HRC	≤67
70		HRC	>67

Weld metal properties

C = corrosion-resistant
G = resistant to abrasive wear
K = capable of work hardening
N = non-magnetizable
P = impact-resistant
R = rust-resistant
S = cutting ability (high-speed steels etc.)
T = high-temperature strength as for high-temperature tool steels
Z = heat-resistant (non-scaling), i.e. for temperatures over about 600°C

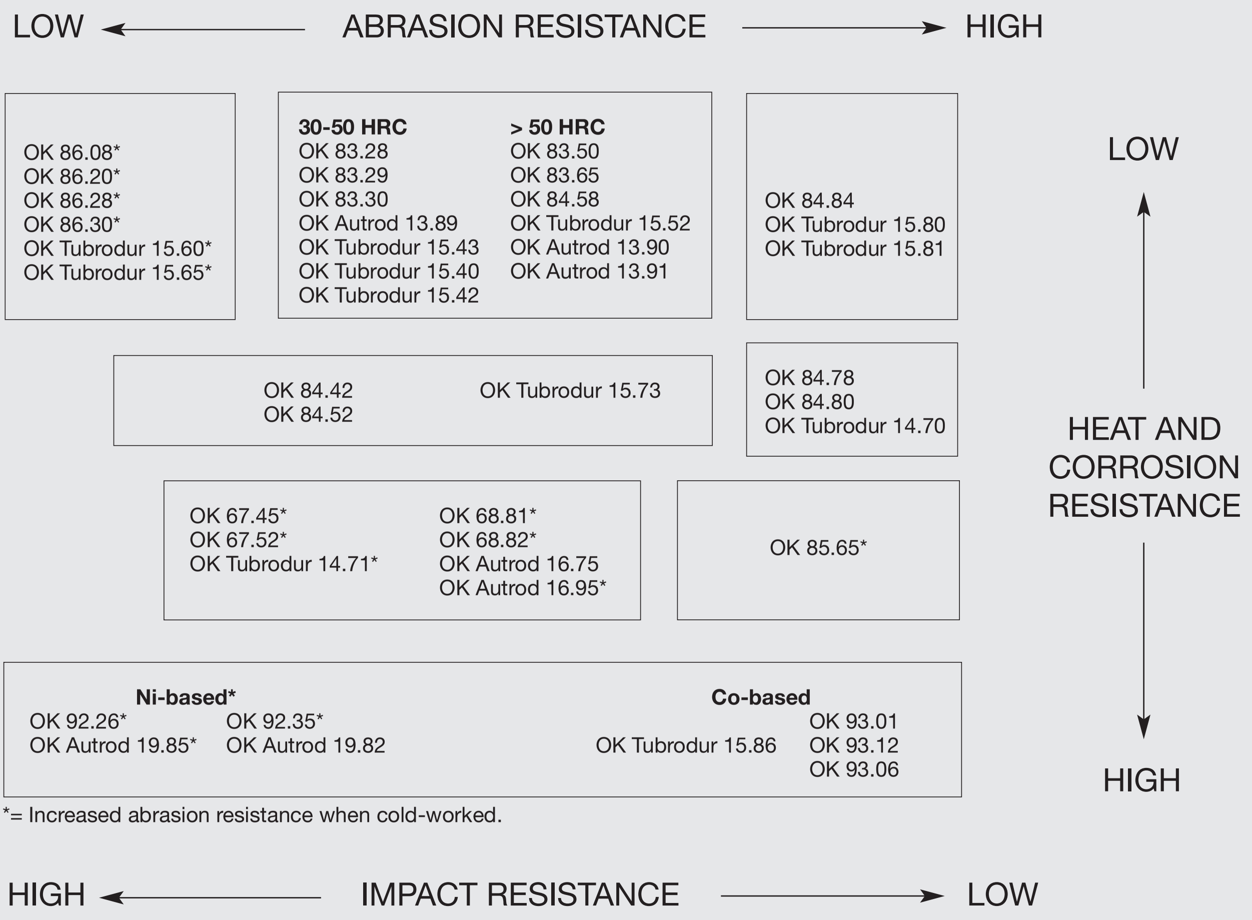
Esab hard-facing products

The materials are divided into groups according to their characteristics and their suitability for specific wear.

Type of wear	Alloy type	Product	DIN 8555
Metal-to-metal	Low-alloy, low carbon, build-up alloy	OK 83.27	E1-UM-350
		OK 83.28	E1-UM-300
		OK 83.29	E1-UM-300
		OK 83.30	E1-UM-300
		OK Tubrodur 15.39	MF1-GF-300P
		OK Tubrodur 15.40*	MF1-GF-350P
		OK Tubrodur 15.41	MF1-GF-300P
		OK Tubrodur 15.42*	
		OK Tubrodur 15.43	
		OK Autrod 13.89	MSG2-GZ-350-P
Metal-to-metal corrosion	13% chromium martensitic	OK 84.42	E5-UM-45-R
		OK 84.52	E6-UM-55-R
		OK Tubrodur 15.73*	MF5-GF-45-RTZ
		OK Autrod 13.89	MSG-2-GZ-C-350
Impact	14% manganese	OK 86.08	E7-UM-200-KP
		OK 86.20	E7-UM-200-KP
		OK 86.28	E7-UM-200-KP
		OK 86.30	E7-UM-200-KP
		OK Tubrodur 15.60	
		OK Tubrodur 15.65*	MF8-GF-200-GKPR
Abrasion + pressure	Complex carbides	OK 83.53	E-UM-60
		OK 84.84	
		OK Tubrodur 15.80	MF10-GF-60-GP
Fine-particle mineral abrasion	Chromium carbides	OK 84.78	E10-UM-60GZ
		OK 84.80	
		OK Tubrodur 14.70	MF10-GF-55-GPTZ
		OK Tubrodur 15.81	
		OK Tubrodur 15.82	MF10-GF-65-GTZ
Abrasion + impact	Low-alloy, high carbon, martensitic	OK 83.50	E6-UM-55-G
		OK 83.65	E4-UM-60-GZ
		OK Tubrodur 15.50	
		OK Tubrodur 15.52*	
		OK Autrod 13.90	MSG-2-GZ-C-5OG
		OK Autrod 13.91	MSG-6-GZ-C-6OG
	10% chromium high carbon martensitic	OK 84.58	E6-UM-55-G
Heat, oxidation, corrosion	Tool steel	OK 85.58	E3-UM-50-ST
		OK 85.65	E4-UM-60-ST
		OK 92.35	E23-200-CKT
		OK Tubrodur 15.84	MF3-50-ST
	Cobalt alloys	OK 93.01	E20-55-CTZ
		OK 93.06	E20-40-CTZ
		OK 93.07	E20-300-CTZ
		OK 93.12	E20-50-CTZ
		OK Tubrodur 15.86	MF20-GF-40-CTZ

*= available as a SAW product

Quick guide – selection of consumables



LOW ← ABRASION RESISTANCE → HIGH

OK 86.08*
OK 86.20*
OK 86.28*
OK 86.30*
OK Tubrodur 15.60*
OK Tubrodur 15.65*

30-50 HRC
OK 83.28
OK 83.29
OK 83.30
OK Autrod 13.89
OK Tubrodur 15.43
OK Tubrodur 15.40
OK Tubrodur 15.42

> 50 HRC
OK 83.50
OK 83.65
OK 84.58
OK Tubrodur 15.52
OK Autrod 13.90
OK Autrod 13.91

OK 84.84
OK Tubrodur 15.80
OK Tubrodur 15.81

OK 84.42
OK 84.52

OK Tubrodur 15.73

OK 84.78
OK 84.80
OK Tubrodur 14.70

OK 67.45*
OK 67.52*
OK Tubrodur 14.71*

OK 68.81*
OK 68.82*
OK Autrod 16.75
OK Autrod 16.95*

OK 85.65*

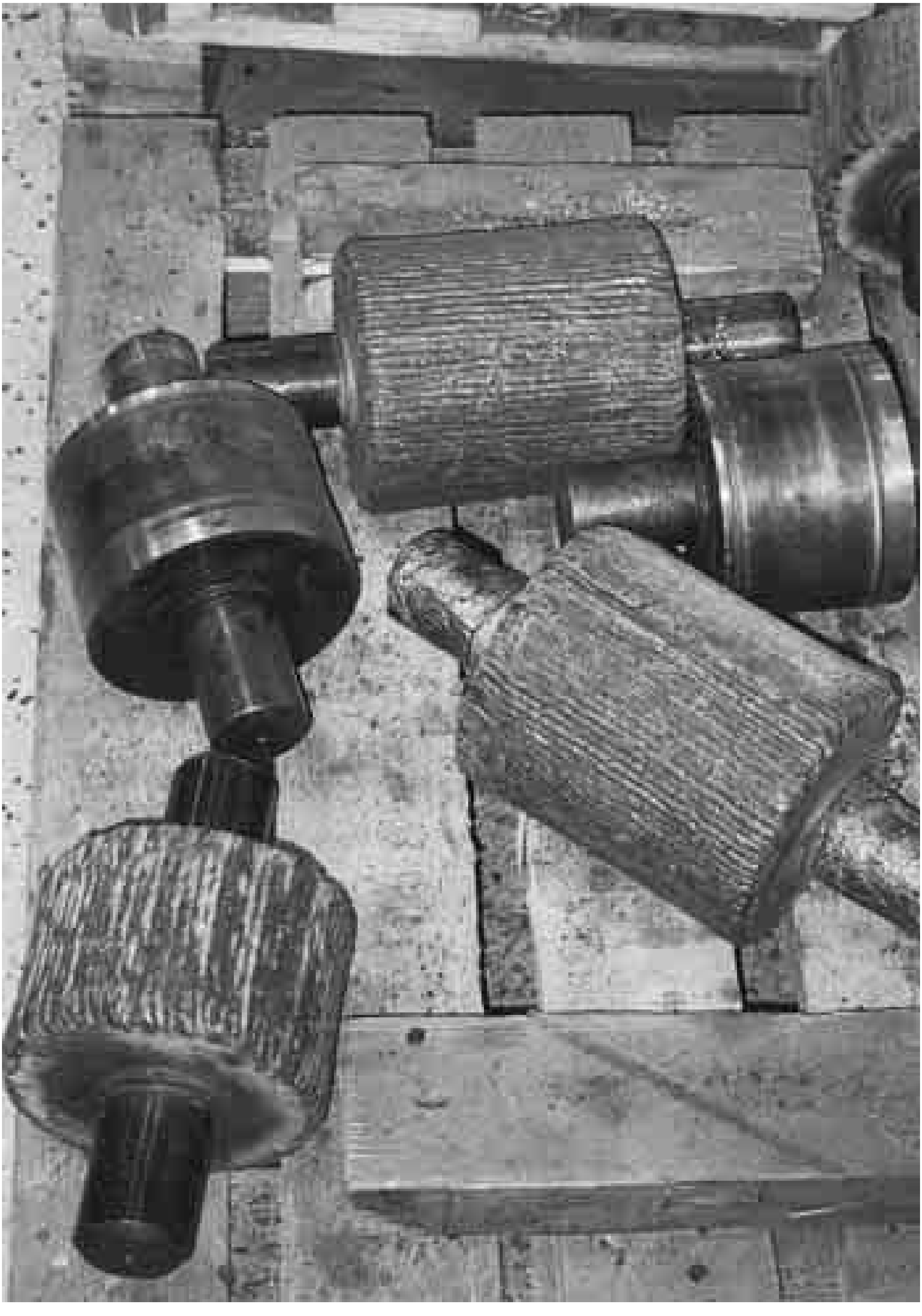
Ni-based*
OK 92.26*
OK Autrod 19.85*
OK 92.35*
OK Autrod 19.82

Co-based
OK Tubrodur 15.86
OK 93.01
OK 93.12
OK 93.06

*= Increased abrasion resistance when cold-worked.

LOW ↑ HEAT AND CORROSION RESISTANCE ↓ HIGH

HIGH ← IMPACT RESISTANCE → LOW



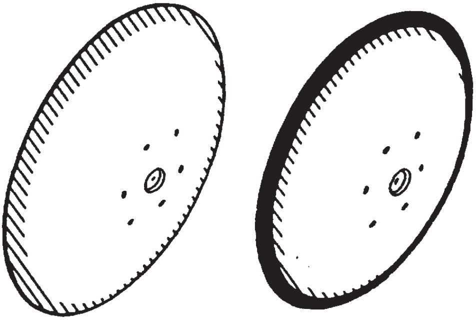
Hardsurfacing of support rollers OK 84.52 and OK 93.06.

Preventive hard-facing OK 84.58.

Hard-facing of tumbler OK 84.84. Build-up OK 83.28.

Illustrated application examples
Applications index

Agricultural tools – grain discs



Recommended procedure

The surfacing is performed on the concave side of the disc and profile grinding is done on the convex side if necessary.

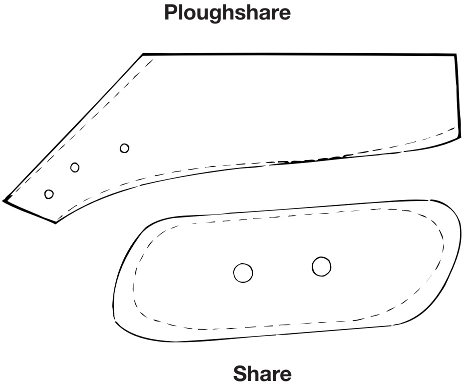
As the discs may be made of hardenable steel, it is recommended to preheat to 350–400°C. Grind the convex side of the disc and hardface approx. 20–30 mm back from the edge with OK 84.78, OK 83.50, OK 83.53 or OK 83.65. Weld on the edge and weave inwards.

Deposits should be as thin and smooth as possible. Slow cooling.

Consumables

OK 84.78 for dry–wet conditions
OK 84.58 for dry–wet conditions
OK 83.65 for dry conditions
OK 83.50 for dry conditions
OK 83.53 for wet–dry conditions

Agricultural tools – plough mouldboards



Recommended procedure

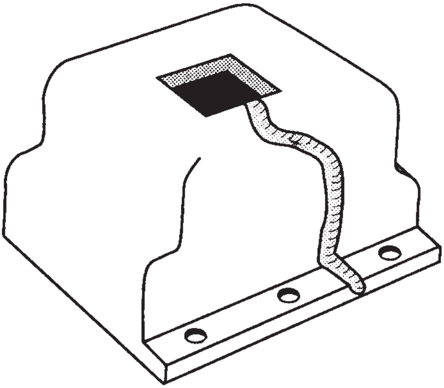
Ploughshares are worn mainly in the areas indicated in the figures.

Practice has revealed a great difference between the wear of different soils and the fact that the wear varies as the soil is wet or dry. Because of this it may be necessary to carry out trials to establish the best type of consumable.

Consumables

OK 84.78 for dry–wet conditions
OK 84.58 for dry–wet conditions
OK 83.65 for dry conditions
OK 83.50 for dry conditions
OK 83.53 for wet–dry conditions

Aluminium casting – repair



Recommended procedure

Grind the damaged area to produce a clean, even surface.

Make sure the electrodes to be used are dry.

Preheating heavy sections simplifies the welding and lower currents can be used.

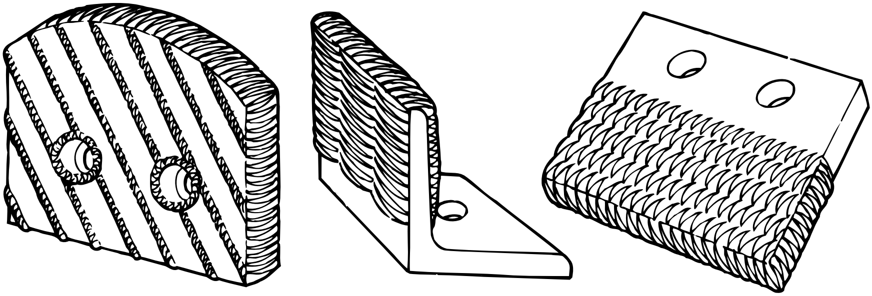
Complicated sections should be preheated to 100–150°C.

Weld with OK 96.50. Use stringer beads. If possible, the joint should be made in one pass. When multi-pass welding is necessary, make sure all slag is removed between passes.

Consumables

OK 96.50
OK Autrod 18.05

Asphalt mixer paddles



Recommended procedure

Before welding, remove defective material by gouging with OK 21.03 or by grinding. The working edges are hardfaced with wear-resistant electrodes OK 84.84 or OK 84.78, or flux-cored wires OK Tubrodur 14.70 or 15.80.

With OK 84.84 and OK Tubrodur 15.80, maximum hardness is obtained from the first layer. Perform no more than two layers with these consumables. OK 84.84 should preferably be welded using a checker net or dot pattern, while the others can be applied all over the surface to provide protection from abrasive wear.

OK 84.78 and OK Tubrodur 14.70 may contain relief cracking, but this does not influence the wear properties.

The edges and corners can be rebuilt using copper plates to hold the weld pool.

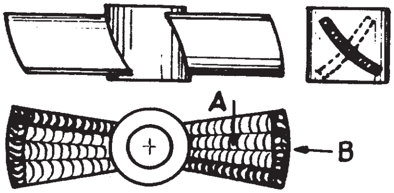
The weld metals can only be machined by grinding.

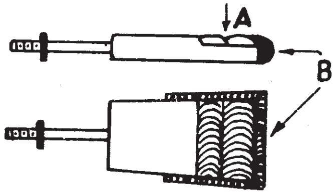
Consumables

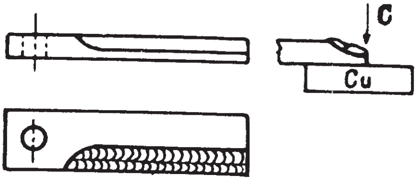
Gouging
OK 21.03

hard-facing
OK 84.84
OK Tubrodur 15.80
OK 84.78
OK Tubrodur 14.70

Brick and cement mixer paddles and knives







Recommended procedure

Grind off all defective material or previously hardfaced weld metal.

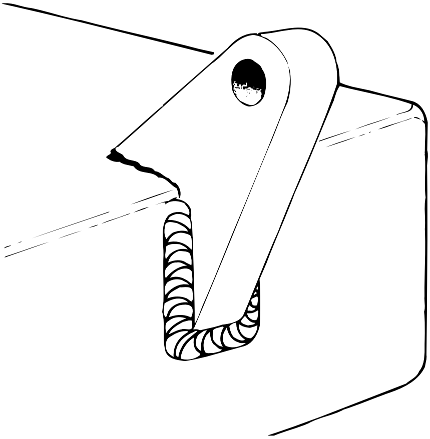
If the edges are very thin, a copper plate (C) can be used to control the weld pool. If necessary, some light final grinding may be performed.

These parts are hardfaced with:
OK 84.78 or OK Tubrodur 14.70 (A)
OK 84.84 is deposited on the edges in stringer bead form only (B) or on Tubrodur 15:80.

Consumables

OK 84.78
OK 84.84
OK Tubrodur 14.70
OK Tubrodur 15.80

Cast steel – repair of cracks, holes and so on



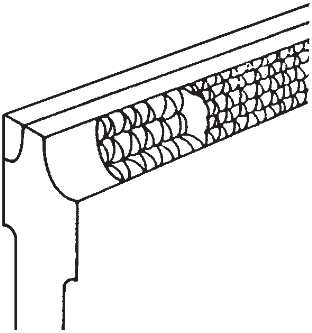
Recommended procedure

Cracks, holes and defects are gouged away with OK 21.03 – if possible from both sides to obtain an U or X joint. Carefully check that no defects remain and make sure that the joint ends are rounded smoothly to avoid crack propagation. OK 68.82 can be used without preheating. However, preheating is necessary for thicker materials. Weld on alternate sides to balance shrinkage stresses.

Consumables

OK 68.82
OK Autrod 16.75

Cutting and shearing tools – cold shear blades



Recommended procedure

Shear blades are made of hardened alloy steel. They should be hardfaced with a weld metal of similar hardness.

- Worn blades are prepared as shown above. Make sure all sharp edges are rounded in the area to be welded.
- Pre-heating should be to 200–300°C, depending on the base material.
- Weld with OK 85.65.
- Slow-cool in heat-insulating material.

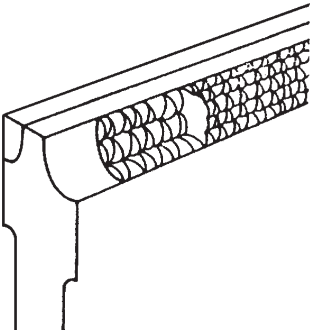
New shear blades can be made by using less expensive steel and hardfacing the cutting edges.

The weld metal hardness of OK 85.65 is 60HRC. The weld metal can, however, be double-tempered at about 550°C for one hour to increase the hardness to approx. 65 HRC.

Consumables

OK 85.65

Cutting and shearing tools – hot shear blades



Recommended procedure

Hot shear blades are usually made of heat-treatable steel.

Worn blades are prepared for welding as shown above.

Ensure that all sharp edges are rounded prior to welding.

Pre-heating to about 200–300°C is recommended and a buffer layer welded with OK 68.82 is advisable before hard-facing with either cobalt-based OK 93.06 or Ni-based OK 92.35. OK 85.58, a high-speed steel type weld metal, can also be used.

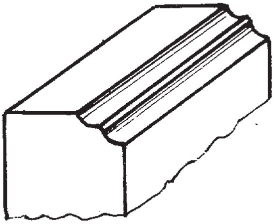
After welding, allow to cool slowly in insulating material. Sharpen cutting edges by grinding.

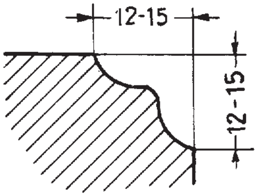
Consumables

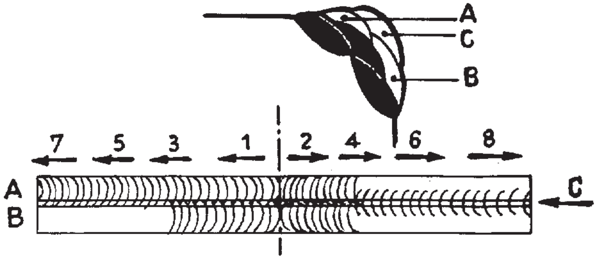
Buffer layer
OK 68.82

hard-facing
OK 93.06
OK 92.35
OK 85.58

Cutting dies, punches







Recommended procedure

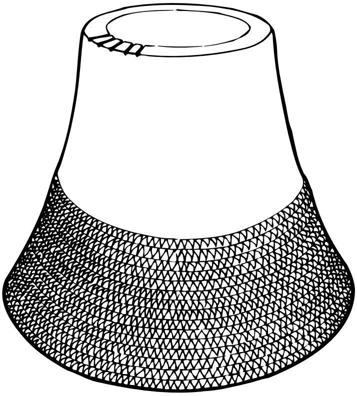
Prepare the groove as indicated in the figure.
Preheating should be to 200–250°C, depending on the carbon content of the base material.
A buffer layer approx. 4 mm thick is welded with OK 68.82.
Hardface a maximum of three layers with OK 93.06

Consumables

Buffer layer
OK 68.82

hard-facing
OK 93.06 hot and cold conditions
OK 85.58 cold conditions
OK 84.52 cold conditions

Crusher cones



Recommended procedure

Crusher cones are usually made of 14% manganese steel (non-magnetic) and should be welded cold. When welding, avoid heating the material to above 150–200°C.

Due to the size and thickness of the cones, heat dissipation normally prevents excessive heat build-up.

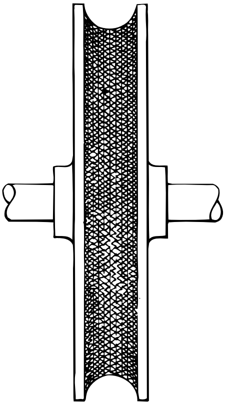
For build up, use OK 67.45 or OK Tubrodur 14.71. For hard-facing, use OK 84.58 or OK Tubrodur 15.80.

Consumables

Build-up
OK 67.45, OK 67.52
OK Tubrodur 14.71

hard-facing
OK 84.58
OK Tubrodur 15.80

Crane wheels



Recommended procedure

Most wheels are made of steels with a high carbon content. It is therefore advisable to pre-heat to 200–300°C and allow for slow cooling. If possible, automatic or semi-automatic welding should be used with the wheel positioned in a rotating jig. Rebuild to allow for machining to the correct size.
OK Autorod 13:89 is a solid wire in dimensions suitable for smaller semi-automatics. It is necessary to use a shielding gas. CO_2 or a mix of 80% Ar and 20% CO_2

As the wear is caused by metal-to-metal wear, a tough deposit producing a hardness of 30–35HRC is recommended.

Consumables

OK 83.28, OK 83.29
OK Tubrodur 15.40
OK Tubrodur 15.40/OK Flux 10.71

Disposers (hammers)

Recommended procedure

The hammers are made of low-alloy cast steel (magnetic) or manganese steel (non-magnetic). To avoid the risk of cracking in the hammer itself, it is advisable to apply a tough buffer layer before hard-facing low-alloy steel.

For this purpose, one layer of OK 67.45, OK 68.81 or OK Tubrodur 14.71 is applied.

Hard-facing is then carried out with two to three wear-resistant weld metal layers of according to the following list.

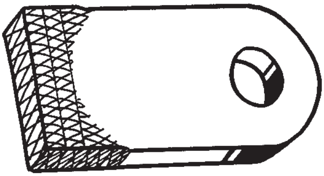
Build up on manganese steel with OK 86.28 and hardface as for low-alloy steel. OK 86.30 combines abrasion and impact resistance.

Consumables

Alloy cast-steel hammers

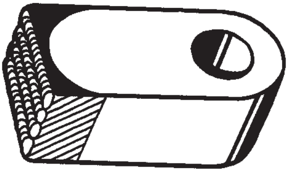
Buffer layer
OK 68.81
OK Autrod 16.75
or
OK 67.45
OK Tubrodur 14.71

Hard-facing
Impact+abrasion
OK 83.50
OK 83.53
OK Autrod 13.91
OK Tubrodur 15.52

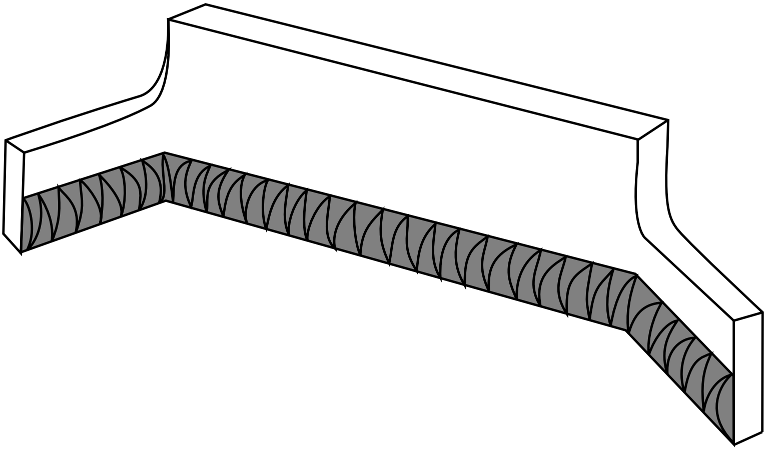


Abrasion+moderate impact
OK 84.78
OK Tubrodur 14.70

Manganese-steel hammers
Build-up layers
OK 86.28+OK 86.30
OK Tubrodur 15.60+OK Tubrodor 15.65
Hard-facing as for cast-steel hammers



Dragline blades



Recommended procedure

Leading edges and each side of the blade are hardfaced. To increase efficiency and service life, new blades should be hardfaced before use.

Consumables

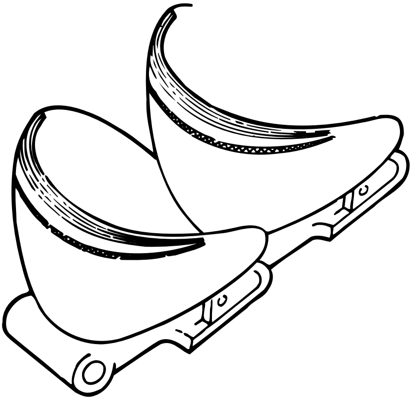
Extreme abrasive wear

OK 84.78
OK Tubrodur 14.70
OK Autrod 13.91

Moderate abrasive wear

OK 83.65
OK Tubrodur 15.52
OK Autrod 13.90

Dredger buckets



Recommended procedure

Manganese steel buckets and especially the bucket lips, are subject to abrasive wear.

Before new buckets are put into service, they should be hardfaced in order to increase efficiency and service life.

Buckets must be repair-welded before excessive wear takes place. Worn lips can be rebuilt with steel rims welded to the bucket with OK 67.52. The lips should be hardfaced on both sides.

New lips can be joined on the main bucket using OK 68.81, OK 68.82 or OK Tubrodur 14.71. Hard-facing the lips is carried out preventively using OK 84.78 or OK Tubrodur 14.70. To build up lips, use OK 67.45 or OK Tubrodur 14.71 and OK 84.78 or OK Tubrodur 14.70, OK Tubrodur 15.80 for hard-facing.

Consumables

Joining
OK 68.81 OK 68.82
Tubrodur 14.71

Build-up
OK 67.45 OK 67.52
OK Tubrodur 14.71

hard-facing
Abrasion+impact+pressure
OK 84.78
OK Tubrodur 14.70
OK Tubrodur 15.80

Earth drill bits

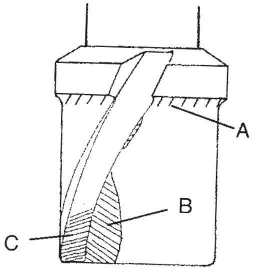


Fig. 1

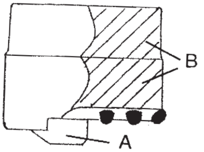


Fig. 2

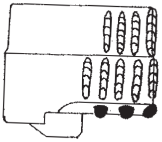


Fig. 3

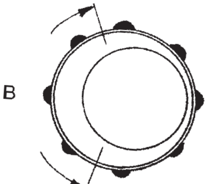


Fig. 4

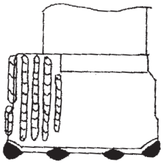


Fig. 5

Recommended procedure

The guide

The wear is normally in the areas indicated in Figure 1:

- the lower part of the “impact flange” (A)
- the lower part of the cylindrical surface (B)
- in the transport channel for the cuttings (C)

Welding is carried out using OK 83.28.

The reamer

Wear is found in the areas shown in Figure 2:

- at the stop head (A)
- on part of the cylinder face (B)

The stop head should be repaired as the surface is worn about 4 mm.

OK 83.28 is used for build-up before hard-facing with OK 84.84.

OK 84.84 is welded in the vertical-down position. If possible, keep the reamer in the 45° position The welding is performed with parallel stringer beads close to one another with a gap of 2 mm. They must not be in contact with one another, Figure 3.

The pilot crown

Wear is found in the areas indicated in Figures 4 and 5:

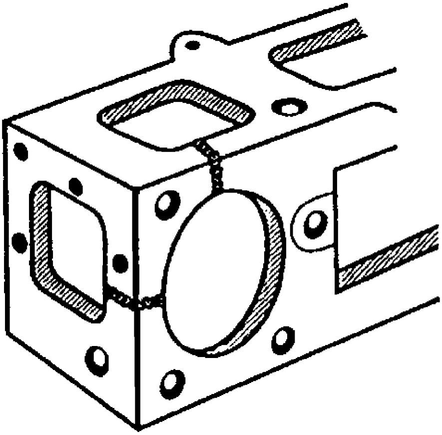
- in the groove for the stop head (A)
- on the outer part of the cylindrical face (B)

The groove should be repaired as the surface is worn down approx. 4 mm. Use OK 83.28. The face is repaired on the same way as the reamer.

Consumables

Build-up	*hard-facing*
OK 83.28	**OK 84.84**

Engine blocks – cast iron



Recommended procedure

Welding is carried out cold, i.e. without pre-heating.

- Weld short beads of maximum 25 mm, depending on thickness.
- Immediately after each run, peen weld with a hammer.
- Do not allow more heat build-up in the weld area than your hand can withstand.
  Keep the area cool with compressed air.
- Use the smallest diameter possible at low current.
- Weld in the direction towards corners and from thin material towards thicker material.
- Weld straight runs without weaving.

Drill holes at the ends of the crack to prevent propagation

A "U"-shaped preparation is preferable and is prepared by gouging out the crack with OK 21.03.

Gouging with OK 21.03 is very positive as it dries out oil and graphite from the groove surfaces.

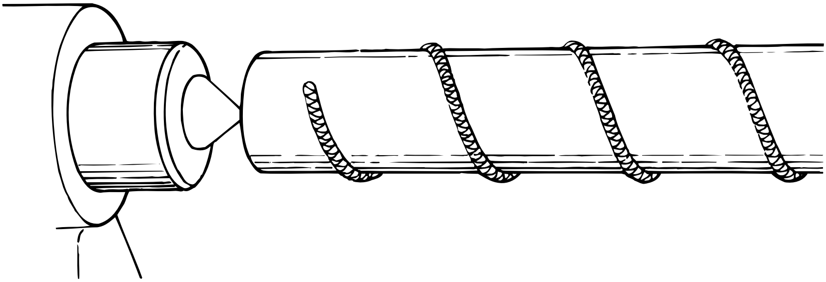
If possible, position the block to permit welding in the downhand position.

Consumables

Gouging
OK 21.03

Crack repair
OK 92.18
OK 92.60

Extrusion screws – plastics and rubber



Recommended procedure

Clean the surface carefully before welding.The extrusion screw positioned in a rotating jig should be preheated to 100–200°C when the thickness is >10 mm. The welding can be performed with OK 93.06 (cobalt-based) or OK Tubrodur 15.86 or OK 92.35 (Ni-based).

Allow for slow cooling in heat-insulating material and grind to size.

Consumables

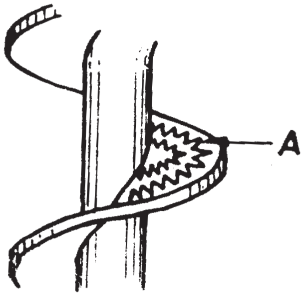
OK 93.06

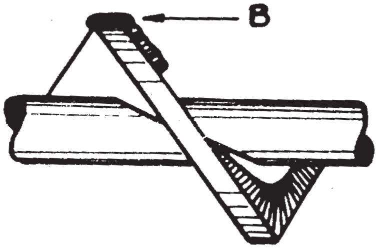
Is harder than OK 92.35 at all temperatures but less resistant to temperature variations.
Machinability: using cemented carbide tools.

OK 92.35

Is softer than OK 93.06 but has higher resistance to temperature variations.
Machinability: fair.

Feeder screws – brick press





Recommended procedure

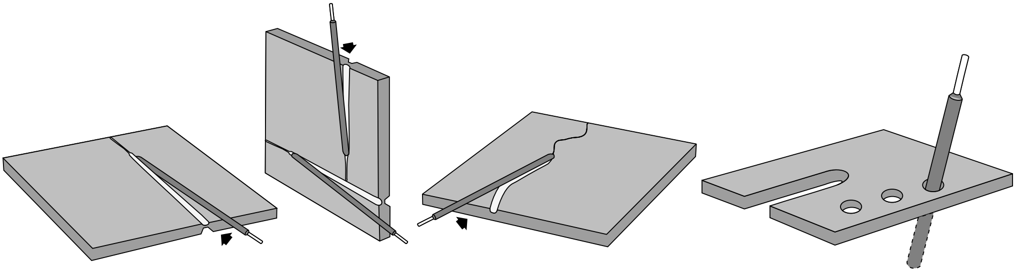
OK 84.84 or Tubrodor 15.80 is deposited using stringer beads on the periphery of the screw (B).

On the compression face (A), OK 84.78 or OK Tubrodur 14.70 are recommmended using weaved beads to cover the whole area.

Consumables

OK 84.84
OK 84.78
OK Tubrodur 14.70
OK Tubrodor 15.80

Gouging – Cutting – Piercing



Recommended procedure

OK 21.03 is an electrode for the gouging, cutting and joint preparation of steel, stainless steel, cast iron, manganese steels and non-ferrous metals like aluminium and copper alloys.

The electrode is used with ordinary transformers or rectifiers. No compressed air, gas or special electrode holder is necessary. Follow the recommended amperage on the packet.

A very clean cut is obtained with little or no final cleaning required before welding.

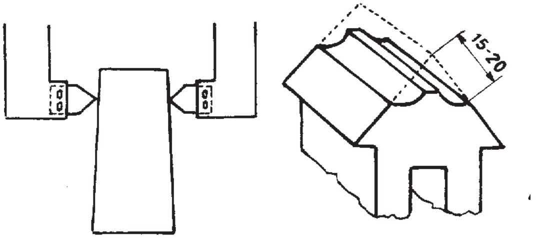
The arc is struck in the same way as an ordinary welding electrode, but it is then pushed forwards at a low angle (5–15°), using a saw-like motion. For deep cuts, the action is repeated.

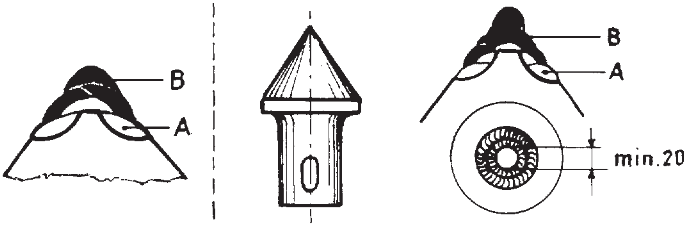
OK 21.03 can be used in all positions and is an AC/DC electrode.

Consumable

OK 21.03

Grab tongs – hot working





Recommended procedure

Prepare a groove as indicated in the figure. Low-alloy steel requires preheating to 150–200°C.

A buffer layer (A) is welded with OK 93.07.

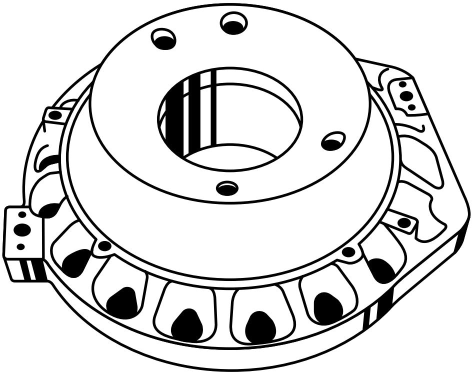
hard-facing (B) is performed with OK 93.06. If higher build up is needed, OK 93.07 can be used as the intermediate layer.

Consumables

Buffer layer
OK 93.07

hard-facing
OK 93.06

Grey cast iron – casting defects



Recommended procedure

Remove casting skin or sand inclusions by gouging with OK 21.03.

Round off all sharp edges prior to welding.

Weld with OK 92.18. Electrodes with a diameter of 2.5 or 3.2 mm are preferable for small cavities.

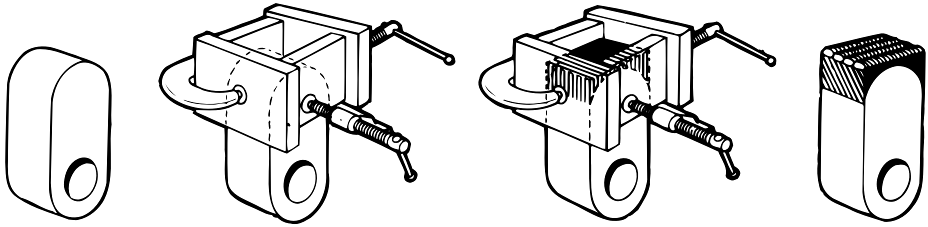
Weld towards the outer edges and avoid weaving. The welds should always be carried out in short runs. Whenever possible, peen the weld directly after each run.

Consumables

Gouging
OK 21.03

For repair
OK 92.18

Hammers



Recommended procedure

Hammers for crushing and grinding operations are normally made of manganese steel and sometimes of cast steel. To increase their service life, hard-facing should be carried out directly on new hammers.

Worn hammers frequently need to be built up before hard-facing. The build-up alloys are OK 83.28 for cast steel and OK 67.45 or OK 68.81 for manganese steel. When semi-automatic welding is required, use OK Tubrodur 15.40 for cast steel and OK Tubrodur 14.71 for manganese steel.

For heavy crushing, the tough weld metal from OK 84.58 or OK Tubrodur 15.52 offers the best resistance. For fine pulverizing, the very hard weld metal from OK 84.78 or OK Tubrodur 14.70 is superior.

To hold the weld pool and thus retain the correct form, edges and corners can be rebuilt with the aid of copper plates.

Consumables

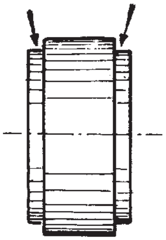
Build-up – cast steel
OK 83.28
OK Tubrodur 15.40

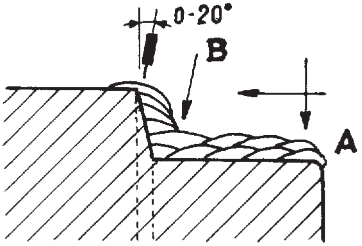
Build-up – manganese steel
OK 67.45
OK Tubrodur 14.71

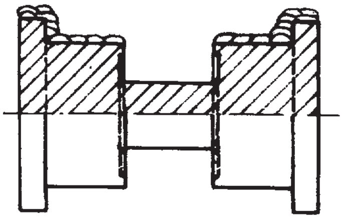
hard-facing
Abrasive wear
OK 84.78
OK Tubrodur 14.70

Abrasion+impact
OK 84.58
OK Tubrodur 15.52

Idlers – support rollers







Recommended procedure

The SAW or FCAW processes should preferably be used for rebuilding these parts.

One to three layers (A) are first applied, followed by layer (B), as indicated in the figure.

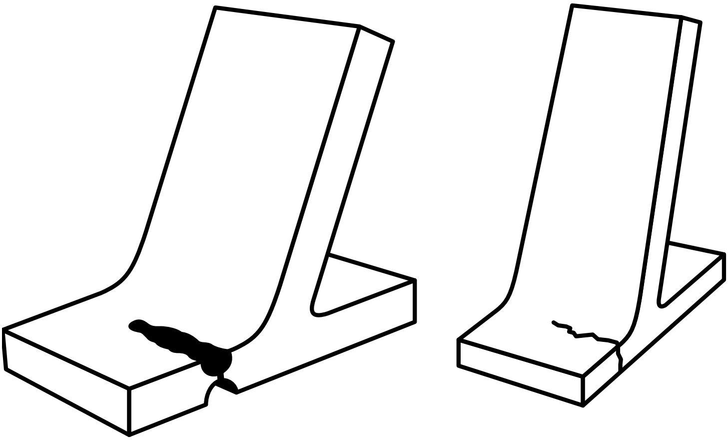
When using FCAW, the beads may be deposited by wide weaving.

If the welding (B) is performed with SMAW, deposit transverse beads.

Consumables

OK Tubrodur 15.40/OK Flux 10.71
OK Tubrodur 15.40/CO_2
OK 83.28
OK Autorod 13.89

Machine beds – repair of cracks in grey cast iron



Recommended procedure

Remove cracks by gouging with OK 21.03.

Prepare a U-joint or a double U-joint.

If possible, prevent the crack from propagating by drilling a hole at the two ends of the crack.

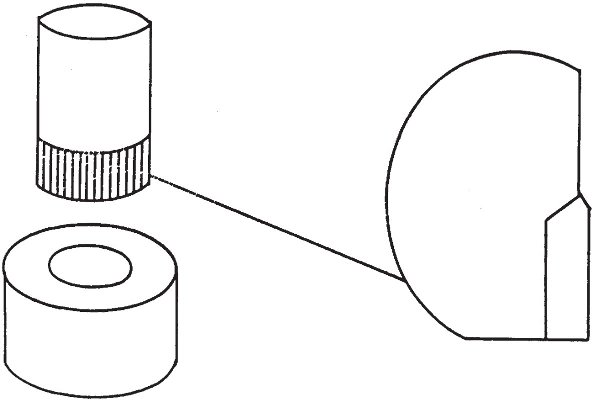
For maximum strength, use OK 92.60 or OK Tubrodur 15.66. Weld short beads using 2.5 or 3.2 mm electrodes. It is recommended to peen each bead immediately after deposition, to avoid cracking adjacent to the joint due to shrinkage of the weld during cooling.

Consumables

Gouging
OK 21.03

Crack repair
OK 92.60
OK Tubrodur 15.66

Metal stampings – Tools made from low-alloy steel



Recommended procedure

Machine recesses with rounded edges for the required operating length plus sufficient extension.

Remove all sharp edges before pre-heating and welding.

Depending upon the size of the tool, pre-heat to 150–200°C and apply a buffer layer of OK 68.82 to absorb welding stresses.

Apply two to three layers of high-speed steel electrode OK 85.65, according to the amount of build-up required. OK 85.65 produces approx. 60HRC.

Allow to cool slowly in a draught-free area and finish to exact tolerances by grinding.

Consumables

OK 85.65

Milling cutters for steel and metals

Recommended procedure

Grind damaged edges smooth and pre-heat cutters to 350–500°C depending upon size. If possible, apply one layer of OK 68.82 and peen while hot.

Deposit short stringer beads with OK 85.65 and peen each deposit while red-hot. Build up to allow for grinding back to size. The pre-heating temperature must be maintained during the welding operation, followed by slow cooling in heat-insulating material.

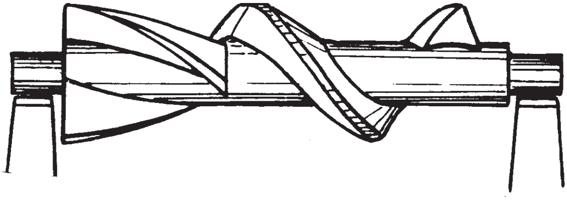
Machinability: grinding only

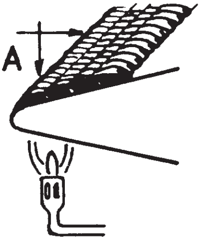
Consumables

Buffer layer
OK 68.82

hard-facing
OK 85.65

Mixing machines – kneading





Recommended procedure

Use a manipulator to permit rotation when preheating and welding.

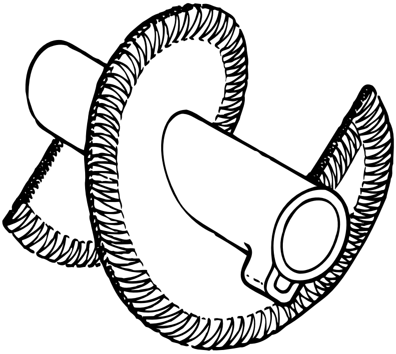
Hardface the flank area (A) with one layer. The top of the flank (B) is hardfaced with one or two layers. Longitudinal beads are welded on the shaft. Light final profile grinding of the edges.

Depending on the required hardness, OK 93.06 or OK 93.01 should be used.

Consumables

OK 93.06	approx. 42 HRC
OK 93.01	approx. 55 HRC

Paving screws – augers



Recommended procedure

Before welding, remove defective material by gouging with OK 21.03 or by grinding. Working edges are hardfaced with wear-resistant electrodes OK 83.65 or OK 84.78, or flux-cored wires OK Tubrodur 14.70 or OK Tubrodur 15.52.

Two or a maximum of three layers should be applied for maximum protection from abrasion.

The edges and corners can be rebuilt using copper plates to hold the weld pool.

The weld metal can only be machined by grinding.

Heavily worn screws can be rebuilt with OK 83.28 prior to hard-facing.

To reduce wear, the hard-facing welds should be applied in the same direction as the flow of material in use.

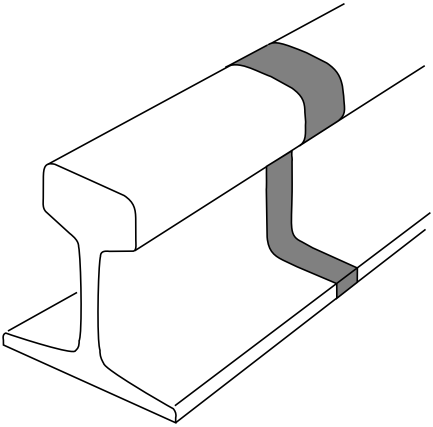
Consumables

Gouging
OK 21.03
Build-up
OK 83.28 OK 83.29

hard-facing
Severe abrasion
OK 84.78
OK Tubrodur 14.70
OK Tubrodur 15.80

Moderate abrasion
OK 83.65
OK Tubrodur 15.52

Railways – joining rails



Recommended procedure

For rail grades 700 and 900A, preheat to 350°C and 400°C.

As root support, use OK Backing 21.21.

The foot is welded with OK 74.78, stringer beads.

Copper shoes are mounted to mould-weld the web and the head using the same electrode. The top layer is welded with OK 83.28, weaved beads.

Rough grind when still hot. Allow for slow cooling by surrounding the area with mineral wool, for example. Once cool, final profiling can take place.

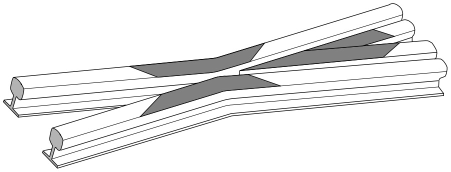
Consumables

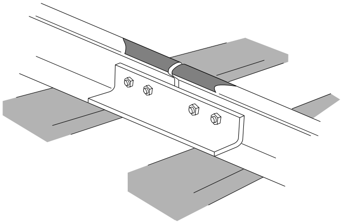
Backing
OK Backing 21.21

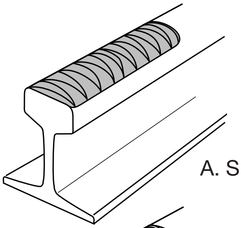
Joining
OK 74.78

Surfacing
OK 83.28

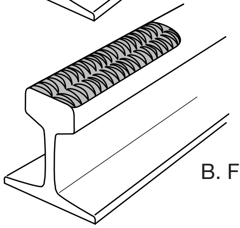
Railways – repair of rails – surfacing







A. SMAW



B. FCAW

Recommended procedure

Carbon-manganese grades

Rail grades	700 A	preheating	350°C
	900 A		400°C
	1100 A		450°C

Rail ends, plain rail defects and crossings

Stringer beads or weaved beads can be used. Weaved beads are deposited and the figures A and B illustrates the weld pattern for the different welding processes.

Sometimes it is advisable to weld a support bead along the edge or edges of the rail before building up the head.

FCAW wires are very suitable for mechanized welding.

Consumables

OK 83.27 or **OK Tubrodur 15.43**	approx.	35HRC
OK 83.28 or **OK Tubrodur 15.41**	approx.	30HRC

Austentic-manganese grades

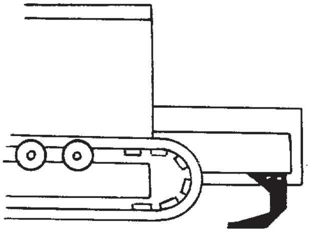
Weld as cool as possible and use stringer beads.

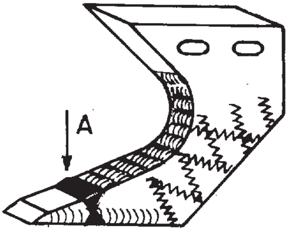
If more than three layers are needed, the build-up should be performed with a tough stainless weld metal, OK 67.45 or OK Tubrodur 14.71, before the final surfacing.

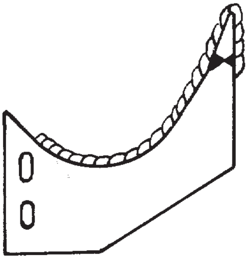
Consumables

For build-up	*hard-facing*
OK 67.45	**OK 86.28**
OK Tubrodur 14.71	**OK Tubrodur 15.65**

Ripper teeth







Recommended procedure

Worn tips can be replaced by new tips. OK 67.45 or OK 68.82 are used for joining. The whole tip and the inner side of the teeth are hardfaced with OK 84.78 or OK 84.84 or OK Tubrodur 14.70 or OK Tubrodur 15.80. On the sides of the teeth, a protective “checker net” is welded.

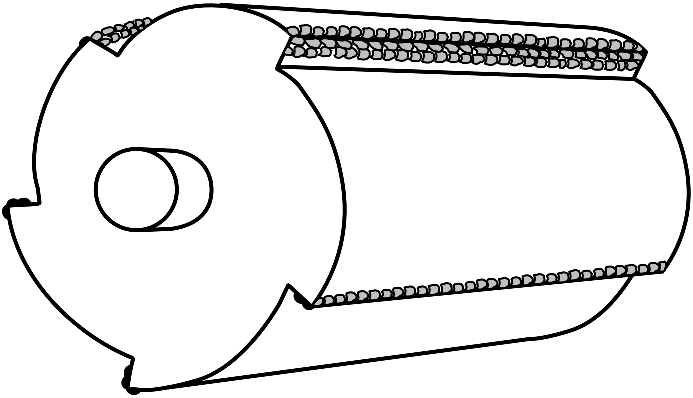
Consumables

Joining
OK 67.45
OK 68.82

hard-facing
Severe abrasion
OK 84.78
OK Tubrodur 14.70

Severe abrasion+impact
OK 84.84
OK Tubrodur 15.80

Roll crushers



Recommended procedure

The roll or the exchangeable crusher bars are made of manganese steel (non-magnetic). As with all manganese steel, the overheating of base material during welding must be avoided.

Before welding, the surface must be cleaned and checked for cracks. Cracks should be gouged out with OK 21.03 and repaired with OK 67.45 or OK Tubrodur 14.71.

OK 86.28 is used for manual metal arc surfacing and OK Tubrodur 15.60 for semi-automatic surfacing.

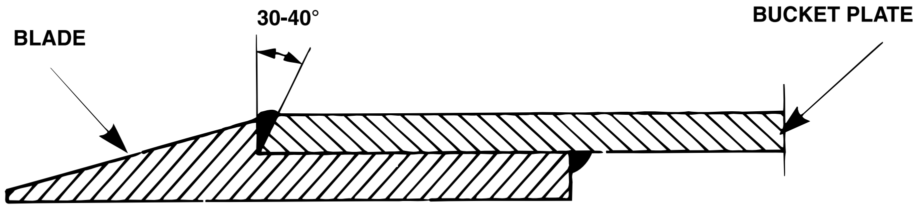
Consumables

Gouging
OK 21.03

Crack repair
OK 67.45
OK Autrod 16.95
OK Tubrodur 14.71

Surfacing
OK 86.28
OK Tubrodur 15.60

Scraper blades



Recommended procedure

In general, blades are made of low-alloy hardened steels.

Using OK 67.45 or OK 67.52, it is possible to perform joining without preheating. Preheating may be desirable when welding thicker materials. The weld is very ductile and can absorb high welding stresses. OK 68.82 is an alternative when higher strength is needed.

Consumables

OK 67.45, OK 67.52
OK Tubrodur 14.71
OK 68.82

Shafts

Recommended procedure

Rebuilding

Thoroughly clean components to check for cracks and damage and remove defective material by grinding or gouging. If subsequent machining is required, undercut to within 5 mm of finished size.

When low-alloy electrodes OK 83.28 or OK 74.78 or OK Tubrodur 15.40 are to be used, pre-heating may be necessary for large diameters and for shafts made of material with high levels of carbon and alloying elements.

C_{eq}>0.45-0.6 to about 200°C

C_{eq}>0.6 to about 350°C

Recommended preheating temperatures for different materials and thicknesses can be found in the table on page 7.

OK 68.82,OK 67.45 and OK Tubrodur 14.71 may be used without pre-heating, depending upon the diameter of the shaft.

In order to minimize distortion, the application of weld metal is balanced according to the figure. After welding, allow for slow cooling.

For semi-automatic or fully-automatic processes, use positioning fixtures to rotate the shaft to permit circumferential welding with OK Tubrodur 15.40/ OK Flux 10.71.

Broken shafts can be repaired with OK 74.78 or OK 68.82. The same rules apply to preheating as to rebuilding. Wherever possible, joint preparation should be the "U" formation.

Consumables

Surfacing with preheating

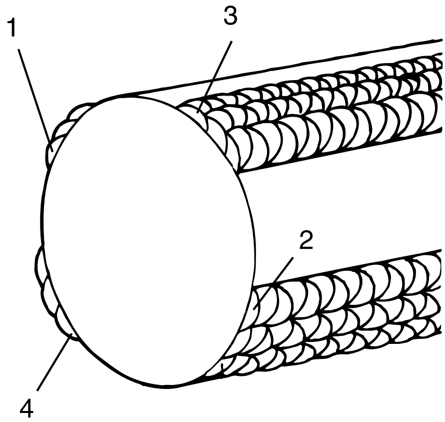
OK 83.28, OK 83.29
OK Tubrodur 15.40
OK Autrod 13.89
OK Tubrodur 15.40/OK Flux 10.71

Surfacing, preheating not necessary

OK 68.82
OK Autrod 16.95
OK 67.45, OK 67.52
OK Tubrodur 14.71

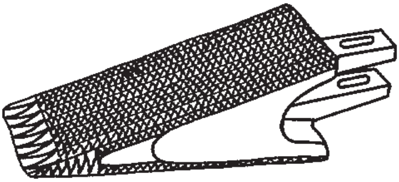
Joining

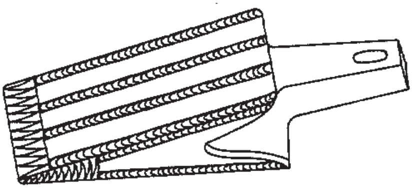
OK 74.78 preheating
OK 68.82 preheating not necessary



Shovel teeth

Type of wear: impact





Recommended procedure

Teeth which work where impact is the major type of wear are often made of austenitic-manganese steel. This material must be welded as cold as possible. For build-up, OK 86.08 or OK Tubrodur 15.60 are used. New or repaired teeth are hardfaced with OK 84.58 or OK Tubrodur 15.52 or OK 84.78 or OK Tubrodur 14.70.

For teeth working in coarse, rocky conditions, deposit the stringer beads so that they run parallel to the part of the material which is being handled, see figure. The large lumps of rock and so on will then ride along the top of the hard-facing bead without coming in contact with the base material.

Consumables

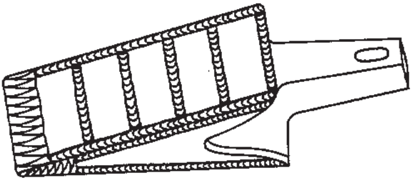
Build-up
OK 86.08
OK Tubrodur 15.60

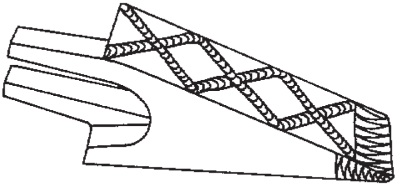
hard-facing
Abrasion+impact
OK 84.58
OK Tubrodur 15.52

Severe abrasion
OK 84.78
OK Tubrodur 14.70

Shovel teeth

Type of wear: abrasion – sand erosion





Recommended procedure

Teeth for working in abrasive enviroments like fine-grained soil are often made of low-alloy hardened steel, although manganese steel is also used and hardfaced with a wear pattern as shown in the figure. Low-alloy teeth are preheated to approx. 200°C. Manganese steel teeth are welded cold. The weld pattern and distances between the beads have a great influence on the wear properties.

Most earth-moving equipment is required to operate in conditions in which a mixture of coarse and fine abrasive material is in contact with the surface. A “checker or waffle pattern” is generally used.

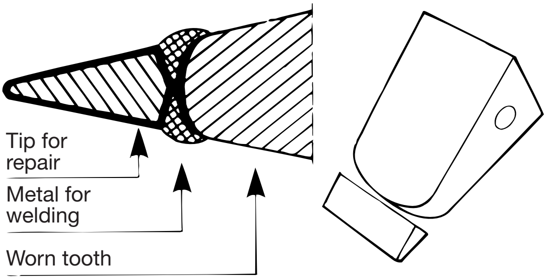
Consumables

Build-up
OK 83.28
OK Tubrodur 15.40

hard-facing
Abrasion+impact
OK 84.58
OK Tubrodur 15.52

Severe abrasion
OK 84.78
OK Tubrodur 14.70

Shovel teeth – repointing



Recommended procedure

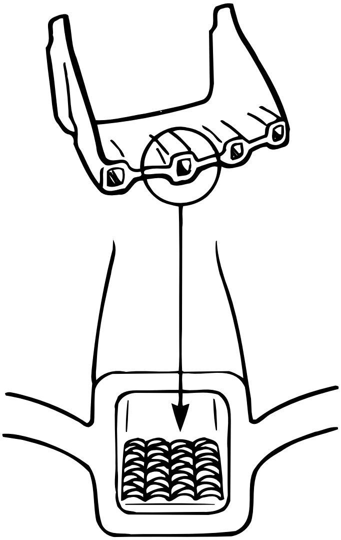
Spare tips are generally made of manganese steel but may also be made of hardenable steel. In both cases, the joining is carried out with over-alloyed stainless steel consumables

If hard-facing is required, see shovel teeth procedures.

Consumables

OK 67.45, OK 67.52
OK Tubrodur 14.71

Tooth holders



Recommended procedure

These holders are usually made of low-alloy, hardenable steel. The holder is joined to the bucket lip with OK 48.30, with pre-heating to 150–200°C, or OK 67.52, OK 68.82 without pre-heating.

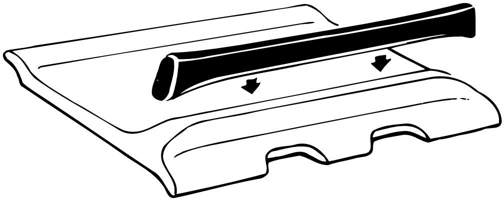
Rebuild and protect holders by surfacing with OK 83.28 or OK Tubrodur 15.40. If higher hardness is required, OK 83.50 or OK Tubrodur 15.52 can be used.

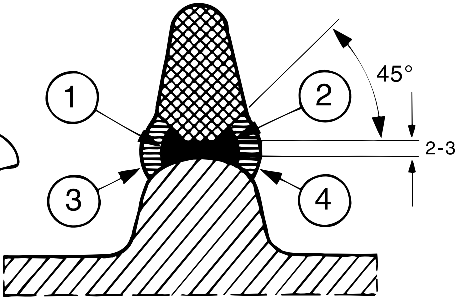
When the bucket lip is made of non-magnetic steel (manganese steel), the holders are joined to the bucket with OK 67.45, OK 67.52 or OK 68.82 without pre-heating.

Consumables

Joining	*Surfacing*
OK 48.30	*30–35HRC*
OK 67.45, OK 67.52	**OK 83.28**
OK 68.82	**OK Tubrodur 15.40**
	55–60HRC
	OK 83.50
	OK Tubrodur 15.52

Track links





Recommended procedure

The repair of track links is performed by welding profiles (bars) to the worn track.

Clean the track link. The bar is then joined to the track link leaving a gap of 2–3 mm. Welding sequence as indicated in the figure, starting from the centre and moving towards the edge.

If the track link is made of manganese steel instead of carbon steel, the same procedure is used.

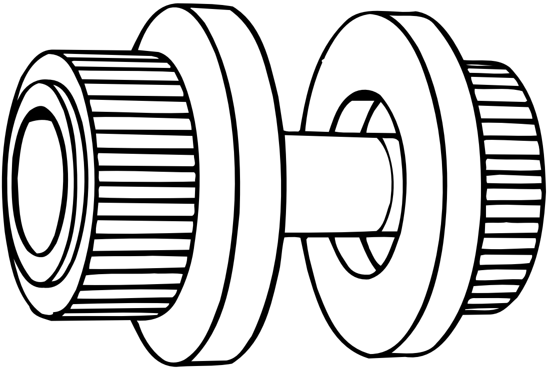
If a worn profile is only going to be repaired by hard-facing, the use of copper moulds is needed to obtain the right profile.

Consumables

Joining
OK Autrod 12.51
OK 68.82

hard-facing
OK Tubrodur 15.40
OK 83.50
OK 84.58
OK Tubrodur 15.52

Track rollers



Recommended procedure

Rebuilding should preferably be carried out using automatic circumferential bead welding, positioning the rollers in a rotating jig.

Manual or semi-automatic welding can be carried out by applying transverse weld beads.

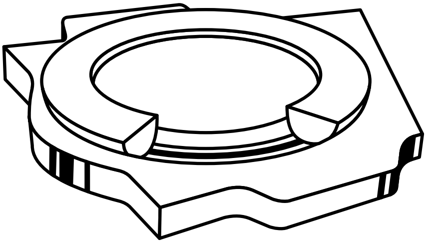
When using OK Tubrodur 15.40, a minimum of machining is needed as the surface is comparatively smooth as welded. The welding can also be carried out by SAW using the same type of wire, together with OK Flux 10.71.

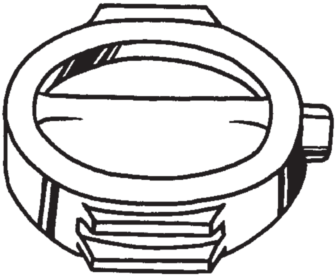
All weld metals are machinable.

Consumables

OK 83.28
OK 83.29
OK Tubrodur 15.40
OK Tubrodur 15.40/OK Flux 10.71

Valve seats





Recommended procedure

Valve seats are made of cast or forged steel. Depending upon size and composition, they should be pre-heated to between 100 and 200°C.

To obtain the best corrosion resistance and hardness, welding should be done in two or three layers.

The cooling must be very slow. Although they are very tough and wear-resistant, the weld metals can be machined by grinding.

OK 93.06 cobalt-based weld metal is used for temperatures above 500°C.

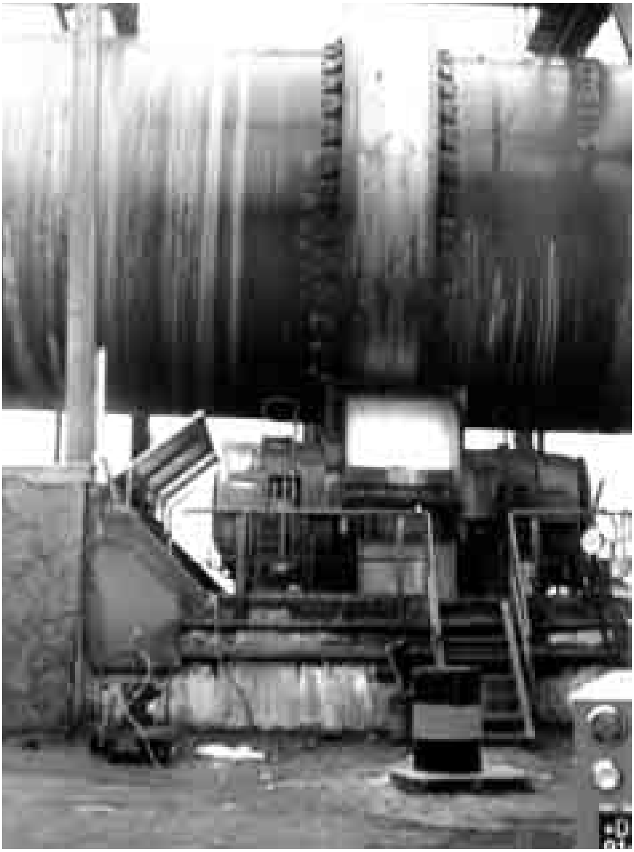
For temperatures below 500°C, OK 84.42 of the high chromium stainless type is recommended.

For gate valves made of bronze use OK 94.25.

Consumables

OK 93.06 HRC 40–45
OK 84.42 HRC 44–49
OK 94.25

Support Rollers and Tyre Bands



The ESAB OK 92.26 stick electrode is nickel based and is suitable for steels with limited weldability. Tyre bands and support rollers are always in need of maintenance due to spalling and cracking. The electrode is also suitable for Inconel 600, similar Inconel alloys and cryogenic steels. It´s heat resistant and appropriate for welding martensitic steels to austenetic steels.
Ball mills are also subjected to impact and stresses causing cracking in their end sections. If the defects on the tyre band, support rollers and ball mill are discovered in reasonable time they can be repaired in situ.

Consumable

OK 92.26

Hard-facing Wire and flux

Hard-facing method that uses unalloyed wires together with alloying fluxes to obtain different hardness levels.

Consumables:
Wire
OK Autrod 12.10

Fluxes:
OK Flux 10.98/OK Autrod 12.10 HRC 25-30
OK Flux 10.96/OK Autrod 12.10 HRC 30-35
OK Flux 10.97/OK Autrod 12.10 HRC 35-40

Hardness value depends on level of arc voltage, welding speed and electrode extension.

Turbine Buckets and Blades

Hard-facing Pelton and Francis wheels and other water turbine components in 13% Cr 4% Ni soft martensitic steels. The range covers the commonly applied stainless steel grades, X4CrNi 13 4 and X5NiMo 16 5 1, soft martensitic steels.

Consumables:

Filarc PZ 6156	13%Cr1.5%Ni alloyed martensitic stainless steel
Filarc PZ 6166	13%Cr4.0%Ni alloyed martensitic stainless steel
Filarc PZ 6176	16%Cr5.0%Ni alloyed martensitic stainless steel

Shielding Gas Ar/2%CO2
Polarity electrode positive
Wire diameter 1.2 mm Ø

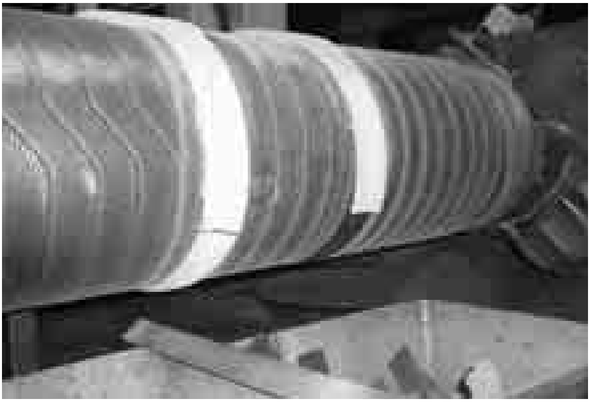
Spin Wheels

Hard-facing spin-wheels that are used in the manufacturing of mineral-wool. These wheels can be preventively maintained by adding several layers of Filarc 6166S or OK Tubrodur 15.85 or OK Tubrodur 15.91S.

Consumables
PZ 6166S metal powder cored wire Ø 1.6 mm and OK Tubrodur 15.85 are used with shielding gas Ar/2%CO_2

OK Tubrodur 15.91S Metal powder filled wire for SAW Ø 3.0 mm
OK Flux 10.92
GMAW
OK Tubrodor 15.85. Ø 1.6 mm

Continuous Casting Rolls



For recommended procedures please contact your nearest ESAB representative.

Consumables that yield a weld metal resisting thermal shock, abrasion, corrosion and erosion.

Consumables SAW

Wires

OK Tubrodur 15.71S for building up
OK Tubrodur 15.72S 13% Cr N_2 bearing wire Martensitic weld metal
OK Tubrodur 15.73S 13% Cr Martensitic weld metal
OK Tubrodur 15.79S 17% Cr
OK Band 11.82 17% Cr
OK Fluxes for wires
OK Flux 10.33

Flux for SAW Strip

OK Flux 10.07

Consumables GMAW

OK Tubrodor 15.73

Repairing earth drill bits: OK 83.28 for build-up OK 84.84 for hard-facing.

Before repair.

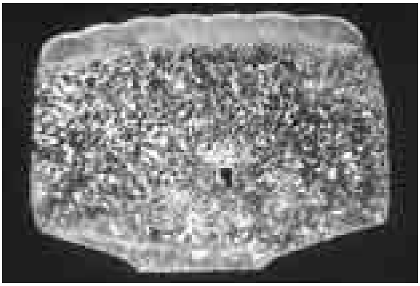
After repair.

Rail repair


Joining of rails by mould welding: OK 74.78.


Tram line repair: OK 67.52.


Wheel burn repair OK Tubrodur 15.43.


Manganese rail: OK Tubrodur 15.65.


Carbon-manganese rail: OK Tubrodur 15.43.


Mechanized welding: Railtrac BV/OK Tubrodur 15.43.

Consumables tables product data

Table 1. Consumables for cast iron

Product	**Classification**	**Applications**	**Typical all-weld metal composition %**	**Typical properties all-weld metal**	**Ø mm**
SMAW					
OK 91.58 Basic DC+, AC	DIN 8573 E Fe-B2	For non-critical repair of cast or surface defects and where machining is not required.	C 0.07 Mn 1.0	**Hardness** a w 50 HRC R_m=540MPa A 25% **Machinability** None	2.5 3.25 4.0
OK 92.18 Basic DC+, – AC	AWS A 5.15 ENi-CI DIN 8573 ENi-BG11	For the repair of cast-iron parts such as cracks in engine blocks, pump housings, gear boxes, frames, as well as foundry defects.	C 1.0 Fe 4.0 Ni 94.0	**Hardness** a w 130 – 170 HB R_m=300MPa A 6% **Machinability** Good	2.5 3.2 4.0 5.0
OK 92.58 DC+, – Basic	AWS A 5.15 ENiFe-CI DIN 8573 ENiFe-1-BG11	Joining and rebuilding cast-iron parts as well as cast iron to steel. Repair of pump bodies, heavy machine sections, gear teeth, flanges and pulleys. Can be used for malleable nodular cast iron and alloy cast irons.	C 1.7 Fe 46.0 Ni 50.0	**Hardness** a w 160 – 200 HB R_m=375MPa A 12% **Machinability** Good	2.5 3.2 4.0 5.0
OK 92.60 Basic High current carrying capacity DC+ AC	AWS A 5.15 ENiFe-CI DIN 8573 ENiFe-1-BG11		C 1.7 Fe 46.0 Ni 50.0	**Hardness** a w 180 – 200 HB R_m=540MPa A 12% **Machinability** Good	2.5 3.2 4.0 5.0
OK 92.78 Basic DC+ AC	DIN 8573 E NiCu-BG31	A nickel-copper type for the welding and repair of grey, malleable, nodular cast irons. Offers excellent colour match.	C 0.7 Fe 3.0 Cu 32.0 Ni bal.	**Hardness** a w 140 – 160 HB R_m=350MPa A 12% **Machinability** Good	2.5 3.2 4.0
FCAW					
OK Tubrodur 15.66 DC+ Shielding gas: Ar/2% O_2	AWS A5.15 E NiFe-CI	A flux-cored wire for rebuilding and joining cast-iron parts, as well as cast iron to steel. Repair of pumps, heavy machine sections and so on.	C 0.1 Fe bal. Cu 2.5 Ni 50.0	R_m=500MPa A 12% **Machinability** Good	1.2

Table 2. Consumables for buffer layers, difficult-to-weld steels and dissimilar metals

Product	Classification	Application	Type/Properties	Ø mm
SMAW				
OK 67.42 Rutile High recovery AC DC+	DIN 8555 E 8-200 CKZ AWS 5.4 (E307-26)	For joining manganese steels or hardenable steels and for buffer layers before hard-facing. Extremely tough and able to absorb stresses.	C=0.1 Mn=6 Cr=18 Ni=9 aw 200 HB wh 400 HB R_m=600 MPa A=45%	2.5 3.2 4.0 5.0 6.0
OK 67.45 Basic DC+	DIN 8555 E 8-200-CKZ AWS 5.4 (E307-15)		C=0.1 Mn=6 Cr=18 Ni=9 aw 200 HB wh 400 HB R_m=620 MPa A=40%	2.5 3.2 4.0 5.0
OK 67.52 Basic High recovery DC+, AC AC OCV 70	DIN 8555 E 8-200-CKZ AWS 5.4 (E307-26)	As above but high recovery	C=0.1 Mn=6 Cr=18 Ni=9 aw 200 HB wh 400 HB R_m=630 MPa A=45%	2.5 3.2 4.0 5.0
OK 68.81 DC+ AC Rutile	DIN 8555 E9-200-CTZ AWS E 312-17	High-strength electrode for welding high-carbon steels, tool steels and dissimilar steels.	C=0.1 Cr=29 Ni=10 aw 230 HB wh 450 HB R_m=790 MPa A=25%	2.5 3.25 4 5
OK 68.82 DC+ AC Rutile	DIN 8555 E9-200-CTZ		C=0.1 Cr=29 Ni=10 aw 240 HV wh 450 HV	2.5 3.25 4 5
OK 92.26 Basic DC+ AC	AWS 5.11 ENiCrFe-3 DIN 1736 EL-NiCr15FeMn	For joining and cladding as well as buffer layers on large and thick sections of difficult to weld steels. Also for joining nickel and nickel alloys. A typical application is tyre bands on the kilns in the cement industry.	C≤0.1 Mn=6 Cr=16 Ni=70 Nb=2 R_m=640 MPa A=40%	2.5 3.25 4 5
FCAW				
OK Tubrodur 14.71 Rutile Shielding gas: None	DIN 8555 MF8-200-CK NPZ	Stainless steel tubular wire for cladding and joining 14% Mn steel or hardenable steels and for buffer layers before hard-facing.	C=0.1 Mn=6 Cr=18 Ni=8 aw 200HB wh 400HB R_m=640 MPa A=35%	1.6

Table 2 cont. Consumables for buffer layers, difficult-to-weld steels and dissimilar metals

Product	Classification	Application	Type/Properties	Ø mm
GMAW				
OK Autrod 16.75 Shielding gas: Ar/1–3% O_2 Ar/1–3% CO_2	DIN 8555 MSG9-200-CTZ	Stainless steel wire for welding high carbon steels, tool steels and dissimilar steels.	C=0.1 Cr=29 Ni=9 aw 230 HB wh 450 HB R_m=770 MPa A=>20%	0.8 1.0 1.2 1.6
OK Autrod 16.95 Shielding gas: Ar/1–3% O_2 Ar/1% CO_2	DIN 8555 MSG8-GZ-200-CKNPZ	Stainless steel wire for welding and cladding 14% manganese steel, dissimilar steels.	C=0.1 Mn=6 Cr=18 Ni=10 aw 200 HB wh 400 HB R_m=640 MPa A=40%	0.8 1.0 1.2 1.6

Table 3. SMAW products, manganese steels

— impact wear applications

Product SMAW	Classification	Applications	Typical all-weld metal composition %	Typical properties all-weld metal	Ø mm
OK 86.08 Basic DC+, AC	DIN 8555 E 7-200-K	Surfacing and building up manganese steel parts exposed to high impact or battering such as jaws, hammers, cones and mantles of rotary crushers. The weld metal has high work-hardening properties. Interpass temperature < 200°C.	C 1.1 Mn 13.0	**Hardness** a w 180–200 HB **Hardness** w h 44–48 HRC **Machinability** Grinding **Impact resistance** Excellent	3.2 4.0 5.0
OK 86.20 Rutile-basic DC+, AC	DIN 8555 E 7-200-K	As for OK 86.08, but less work-hardening capacity. The resistance to abrasion is higher.	C 0.8 Mn 13.0 Cr 4.5 Ni 3.5	**Hardness** a w 200–220 HB **Hardness** w h 37–41 HRC **Machinability** Grinding **Impact resistance** Excellent	3.2 4.0 5.0 6.0
OK 86.28 Basic High recovery DC+, AC	AWS A5.13 EFeMn-A	As for OK 86.20, but more crack-resistant. Used for surfacing rail points.	C 0.8 Mn 14.0 Ni 3.5	**Hardness** a w 160–180 HB **Hardness** w h 42–46 HRC **Machinability** Grinding **Impact resistance** Excellent	3.2 4.0 5.0
OK 86.30 Rutile-basic High recovery DC+, AC		As OK 86.08, but corrosion-resistant. Suitable for multilayer welding and for joining manganese steels to carbon-manganese steels.	C 0.3 Mn 14.0 Cr 18.0 Ni 1.5	**Hardness** a w 190–210 HB **Hardness** w h 40–44 HRC **Machinability** Grinding **Abrasion resistance** Good **Impact resistance** Excellent **Corrosion resistance** Very good	3.2 4.0 5.0

Table 3 cont. FCAW products, manganese steels

— impact wear applications

Product FCAW	Classification	Applications	Shielding gas/ OK Flux 10.xx	Typical all-weld metal composition %	Typical properties all-weld metal	Ø mm
OK Tubrodur 15.60 Rutile DC+	DIN 8555 MF 7-200-KNP	Surfacing austenitic 13% Mn steels found in excavating and mining industries where maximum resistance to impact is required. Interpass temperature ≤ 200°C.	Self-shielding	C 0.9 Si 0.4 Mn 13.0 Ni 3.0	**Hardness** a w 200–250 HV w h 400–500 HV **Machinability** Grinding **Impact resistance** Excellent	1.6–2.4
OK Tubrodur 15.65 Rutile DC+	DIN 8555 MF 8-200-GKNPR	Rebuilding mild, low-alloy and 13Mn steels. The weld metal combines excellent abrasion and impact resistance. Crusher jaws and hammers, railway point frogs, ripper teeth and wear plates. Can also be used with OK Flux 10.61 for SAW. Interpass temperature ≤ 200°C .	Self-shielding, CO_2 OK Flux 10.61	C 0.3 Mn 13.5 Cr 14.5 Ni 1.5 Mo 0.8 V 0.4	**Hardness** a w 200–250 HV w h 400–500 HV **Machinability** Grinding **Impact resistance** Excellent **Abrasion resistance** Good **Corrosion resistance** Very good	1.6–2.4 3.2

Table 4. Consumables for tool steels and steels for high-temperature applications

Product **SMAW**	**Classification DIN 8555**	**Applications**	**Typical all-weld metal composition %**	**Typical properties all-weld metal**	**Ø mm**
OK 84.52 Basic DC+, AC	E 6-55-R	Repair of worn dies with similar material. Manufacture composite tools from carbon and alloyed steel for extrusion dies, blanking dies, cold cutting and shearing tools.	C 0.25 Cr 13.0	**Hardness** a w 50–56 HRC **Machinability** Grinding only **Abrasion resistance** Very good **High temp. wear resistance** Very good **Corrosion resistance** Very good	2.5 3.2 4 5
OK 85.58 Basic DC+, AC	E 3-50-TS	Repair of damaged or worn hotworking punches, trimming dies and forging dies.	C 0.35 Cr 1.8 W 8 Co 2	**Hardness** a w 46–52 HRC **Machinability** Grinding only **Abrasion resistance** Good **High temp. wear resistance** Very good	2.5 3.2 4 5
OK 85.65 Basic DC+, AC	E 4-60-S	Repair of high-speed steel tools and for manufacturing composite tools for cutting, piercing and shearing.	C 0.9 Cr 4.5 Mo 7.5 W 1.8 V 1.5	**Hardness** a w 56–62 HRC **Machinability** Grinding only **Abrasion resistance** Very good **High temp. wear resistance** Very good	2.5 3.2 4
OK 92.35 Basic DC+, AC	E 23-250-CKT	For extremely high-temperature wear applications, such as hot forging dies, hot extrusion dies and hot shear blades. Also for welding and joining Nimonic and Inconel alloys.	C 0.1 Cr 16 Mo 17 Fe 6.0 Ni bal.	**Hardness** a w 240–260 HV w h 40–45 HRC **Machinability** Fair **High temp. wear resistance** Excellent **Corrosion resistance** Very good	2.5 3.2 4 5

cont'd

Table 4 cont. Consumables for tool steels and steels for high-temperature applications

Product SMAW	Classification DIN 8555	Applications	Typical all-weld metal composition %	Typical properties all-weld metal	Ø mm
OK 93.01 Rutile High recovery DC+, AC	E 20-55-CTZ AWS 5.13 ECoCr-C	Surfacing dies, valves, glass cutters, burner nozzles, drawing valves and so on.	C 2.2 Cr 30 W 12.5 Fe 3.0 Co bal.	**Weld metal hardness** a w 55HRC **Hot hardness** 600°C 800°C ~ 44 HRC ~ 34 HRC **Machinability** Grinding only **Abrasion resistance** Excellent **High temp. wear resistance** Excellent **Corrosion resistance** Excellent	3.2 4 5
OK 93.06 Rutile High recovery DC+, AC	E 20-40-CTZ AWS 5.13 ECoCr-A	Surfacing hot shear blades, steam nozzles, bushings, blanking dies, exhaust valves.	C 1.0 Si 0.9 Mn 1.0 Cr 28.0 W 4.5 Fe 3.0 Co bal.	**Hardness** a w ~ 42 HRC **Hot hardness** 300°C 600°C ~ 35HRC ~ 29HRC **Machinability** Using cemented carbide tools **Abrasion resistance** Very good **High temp. wear resistance** Excellent **Corrosion resistance** Excellent	2.5 3.2 4 5
OK 93.07 Rutile High recovery DC+AC	E 20-300-CTZ	Surfacing hot working tools, dies, shear blades, exhaust valves, sliding surfaces. Can be used as bufferlayer prior to hard-facing with OK 93.01, OK 93.06, OK 93.12.	C 0.3 Cr 28.0 Ni 3.5 Mo 5.5 Fe 2.0 Co bal.	**Hardness** a w ~ 30 HRC w h ~ 45 HRC **Hot hardness** 300°C, 280 HB **Machinability** Using cemented carbide tools **Impact resistance** Good **Abrasion resistance** Very good **Corrosion resistance** Excellent	3.25 4 5

cont'd

The cobalt-based products are also available as GTAW products.

Table 4 cont. Consumables for tool steels and steels for high-temperature applications

Product	Classification DIN 8555	Applications	Typical all-weld metal composition %	Typical properties all-weld metal	Ø mm
OK 93.12 Rutile High recovery DC+, AC	E 20-50-CTZ AWS 5.13 ECoCr-B	Surfacing hot rolls, kneading rolls, press screws, band saws, feeder screws, wood-working tools.	C 1.4 Cr 28.0 W 8.5 Fe 3.0 Co bal.	**Hardness** a w ~ 46 HRC **Hot hardness** 300°C, 600°C ~ 37, ~ 32HRC **Machinability** Using cemented carbide tools **Abrasion resistance** Very good **High temp. wear resistance** Excellent **Corrosion resistance** Excellent	3.2 4 5
FCAW					
OK Tubrodur 15.84 Metal-cored DC+ Shielding gas CO_2		Repair of hot working punches, trimming dies and forging dies.	C 0.4 Cr 1.8 Mo 0.4 V 0.4 Co 2.0 W 8.0	**Hardness** a w 49–55 HRC **Machinability** Grinding only **Abrasion resistance** Good **High temp. wear resistance** Very good	1.6
OK Tubrodur 15.86 Metal-cored DC+ Shielding gas $Ar/2\%O_2$	MF20-GF-40 CTZ	It is suitable for exhaust valves, chemical valves, forging dies and a host of components in the power generation, plastic, paper and rubber industries.	C 1.0 Cr 27.0 Ni 2.5 W 4.0 Fe ≤ 5.0 Co bal.	**Hardness** a w ~ 40 HRC **Machinability** Using cemented carbide tools **Impact resistance** Fair **Metal-to-metal wear resistance** Good **Abrasion resistance** Excellent **High temp. wear resistance** Very good **Corrosion resistance** Excellent	1.2 1.6

Table 5. SMAW products, hard-facing and build-up

Product	Classification DIN 8555	Applications	Typical all-weld metal composition %	Typical properties all-weld metal	Ø mm
OK 83.27 Basic DC+, AC	E 1-350	Specially developed for rails and rail points.	C 0.2 Cr 3.2	**Hardness** a w ≈ 35 HRC **Machinability** Good **Impact resistance** Very good **Metal-to-metal wear resistance** Very good	4.0 5.0
OK 83.28 Basic DC+, AC	E 1-300	For build-up and support layer for harder deposits. Parts in rolling mills, grooved rolls and clutches, rails, rail points, cog wheels, links and rollers for tractors and bearing journals.	C 0.1 Cr 3.2	**Hardness** a w ≈ 30 HRC **Machinability** Good **Impact resistance** Very good **Metal-to-metal wear resistance** Very good	2.5 3.2 4.0 5.0 6.0
OK 83.29 Basic High recovery DC+, AC	E 1-300	As OK 83.28.	C 0.1 Cr 3.2	**Hardness** a w ≈ 30 HRC **Machinability** Good **Impact resistance** Very good **Metal-to-metal wear resistance** Very good	3.2 4.0 4.5 5.0 5.6
OK 83.30 Rutile DC+, AC	E 1-300	As OK 83.28.	C 0.1 Cr 3.2	**Hardness** a w ≈ 30 HRC **Machinability** Good **Impact resistance** Very good **Metal-to-metal wear resistance** Very good	3.25 4.0 5.0
OK 83.50 Rutile DC+, AC AC OCV 40	E 6-55-G	Special electrode for welding with small hobby transformers with low open circuit voltage. Suitable for worn farming equipment and forestry tools.	C 0.4 Cr 6.0 Mo 0.6	**Hardness** a w 50–60 HRC **Machinability** Grinding only **Abrasion resistance** Very good	2.0 2.5 3.2 4.0 5.0
OK 83.53 Basic DC+, AC 65	E6 UM 60	Electrode with EWR properties against abrasion combined with impact. Rock crushing machinery parts and drilling equipment.	C 0.5 Cr 7.5 Mo 1.2 Nb 0.5	**Hardness** a w 50–60 HRC **Impact resistance** Excellent **Abrasion resistance** Excellent **Machinability** Grinding only	cont'd

Table 5 cont. SMAW products, hard-facing and build-up

Product	Classification DIN 8555	Applications	Typical all-weld metal composition %		Typical properties all-weld metal	Ø mm
OK 83.65 Basic DC+, AC	E 2-60-G	For parts subjected to extreme abrasive wear by stone, coal, minerals and soil. Conveyor screws, rollers, dredger buckets, mixing parts, excavator buckets and crushing mills.	C Si Cr	0.75 4.0 2.0	**Hardness** a w 58–63 HRC **Machinability** Grinding only **Abrasion resistance** Very good	3.2 4.0 5.0 6.0
OK 84.42 Rutile DC+, AC	E 5-45-R	For valve seats, cog wheels, shafts and knives. Retains hardness to about 500°C.	C Cr	0.12 13.0	**Hardness** a w 40–46 HRC **Machinability** Cemented carbide tools can be used **Metal-to-metal wear** Very good **High temp. wear resistance** Very good **Corrosion resistance** Very good	2.5 3.2 3.2 4.0 5.0
OK 84.52 Rutile DC+, AC	E6-55-R	As OK 84.42, but produces higher hardness	C Cr	0.25 13.0	**Hardness** a w 50–56 HRC **Machinability** Grinding only **Metal-to-metal wear** Good **High temp. wear resistance** Very good **Corrosion resistance** Very good	2.5 3.2 3.2 4.0 5.0
OK 84.58 Basic DC+, AC	E 6-55-G	Hard-facing, farming equipment, forestry tools, loading machines and mixers. Suitable as top layer on work-hardening deposits. Checker net and edge welding.	C Si Mn Cr	0.7 0.6 0.7 10.0	**Hardness** a w 53–58 HRC **Machinability** Grinding only **Abrasion resistance** Very good **High temp. wear resistance** Good **Corrosion resistance** Fair	2.5 3.2 3.2 4.0 5.0 6.0

cont'd

Table 5 cont. SMAW products, hard-facing and build-up

Product	Classification DIN 8555	Applications	Typical all-weld metal composition %		Typical properties all-weld metal	Ø mm
OK 84.78 Rutile High recovery DC+, AC	E10-60-GZ	Parts mainly exposed to abrasion, but also in corrosive and/or moderate temperature environments. Earth-moving machines, mixers, feeder screws, dust extractors and crushers.	C Cr	4.5 33.0	**Hardness** a w 59–63 HRC **Machinability** Grinding only **Abrasion resistance** Excellent **High temp. wear resistance** Good **Corrosion resistance** Excellent	2.5 3.2 4.0 5.0
OK 84.80 Acid High recovery DC+, AC	E10-65-GZ	Especially for applications where heat is involved, such as ash ploughs, conveyor screws and sinter plant components. Good resistance up to 700°C.	C Si Cr Mo Nb W V	5.0 2.0 23.0 7.0 7.0 2.0 1.0	**Hardness** a w 62–66 HRC **Machinability** Grinding only **Abrasion resistance** Excellent **High temp. wear resistance** Very good **Corrosion resistance** Excellent	3.2 4.0 5.0
OK 84.84 Basic DC+, AC	E10-60-GP	For parts exposed to extreme abrasion, such as earth-drilling equipment, hammers, scraper knives, conveyor screws. Especially suitable for surfacing edges. High hardness in the very first layer.	C Si Cr V Ti	3.0 2.0 8.0 6.0 6.0	**Hardness** a w 62 HRC **Machinability** Grinding only **Abrasion resistance** Excellent	2.5 3.2 4.0

cont'd

Table 5 cont. SAW products for hard-facing

Product	Classification DIN 8555	Application	OK Flux 10.XX	Typical all-weld metal-composition %		Ø
OK Tubrodur 15.71S Metal powder cored	N/A	For building up continuous casting rolls	OK Flux 10.33	C Cr Mn Mo Nb	0.03 4.9 0.6 1.3 1.8	4.0 mm
OK Tubrodur 15.72S Metal powder cored	N/A	For hard-facing continuous casting rolls	OK Flux 10.33	C Cr Mn Mo N_2 Nb V	0.03 13.0 0.6 1.3 Ni 0.009 0.12 0.12	2.4 mm 3.2 mm
OK Tubrodur 15.73S Metal powder cored	N/A	For hard-facing continuous casting rolls	OK Flux 10.33	C Cr Mn Mo Ni Nb V	0.03 13.0 0.6 1.3 4.5 0.12 0.12	2.4 mm 3.2 mm
OK Tubrodur 15.79S Metal powder cored	N/A	17% Cr wire for hard-facing continuous casting rolls	OK Flux 10.33	C Si Cr Ni Mo Mn	0.06 1.10 17.0 5.5 1.1 1.2	
OK Tubrodur 15.91S	N/A	Hard-facing spin wheels used in the making of mineral wool	OK 10.92	C Si Mn Cr Mo Ni	0.04 1.0 0.2 22.0 1.2 4.0	3.0 mm

Table 5 cont. SAW products for hard-facing

Product	Classification EN 760: SA CS 3 Cr DC	Application	Typical all-weld metal composition %
OK Autrod 12.10/ OK Flux 10.98		OK Autrod 12.10/ OK Flux 10.98 achieves~30 HRC	**C** 0.08, **Si** 1.4, **Mn** 1.1, **Cr** 5.0
OK Autrod 12.10/ OK Flux 10.96		OK Autrod 12.10/ OK Flux 10.98 achieves~35 HRC	**C** 0.08, **Si** 1.4, **Mn** 1.1, **Cr** 5.0
OK Autrod 12.10/ OK Flux 10.97 Basicity 0.7 Neutral		OK Autrod 12.10/ OK Flux 10.98 achieves~40 HRC	**C** 0.08, **Si** 1.4, **Mn** 1.1, **Cr** 5.0

These fluxes ar Cr alloying, agglomerated and are intended for hard-facing together with OK Autrod 12.10 non alloyed solid wire. The consumption of flux and the chromium alloy increase and decrease with the arc voltage. Notice must also be taken on the electrode extension and the travel speed of the object in question.
These flux and wire combinations work well on both AC and DC welding current.
Positive electrode gives higher heat input and the deposition rate is reduced.
Negative electrode increases the deposition rate as does an increased length of the electrode extension.

Table 5 cont. FCAW/SAW products, hard-facing and build-up

Product	Classification DIN 8555	Applications	Shielding gas/ OK Flux 10.xx	Typical all-weld metal composition %		Typical properties all-weld metal	Ø mm
OK Tubrodur 14.70 Basic DC+	MF 10-GF-55-GTZ	Mixer and scraper blades, bucket lips, augers and a multiplicity of earth-moving machinery and mining components where exceptional abrasion resistance is required.	Self-shielding	C Cr Mo V	3.5 21.0 3.5 0.4	**Hardness** a w 50–60 HRC **Machinability** Grinding only **Abrasion resistance** Excellent **High temp. wear resistance** Very good **Corrosion resistance** Good	1.6 2.4
OK Tubrodur 15.39 Metal-cored DC+	MF 1-GF-300P	For repairing worn off parts and building up intermediate layers for harder final deposits Shafts, wheel runners sprockets, tractor rollers and links.	CO_2	C Cr	0.2 2.0	**Hardness** a w 27–36 HRC **Machinability** Good **Impact resistance** Good **Metal-to-metal wear resistance** Very good	1.6 2.4
OK Tubrodur 15.40 Rutile DC+	MF 1-GF-350P	Wheel runners, tractor rollers and links, shafts. Ideal for components subjected to compressive stresses.	CO_2 OK Flux 10.71	C Cr	0.2 1.4	**Hardness** a w 32–40 HRC **Machinability** Good **Impact resistance** Good **Metal-to-metal wear resistance** Very good	1.6 2.0 2.4 3.0 4.0
OK Tubrodur 15.41 Basic DC+	MF 1-GF-300P	C-Mn rails, point frogs, rollers, shafts, pins and intermediate build-up for harder final deposit.	Self-shielding	C Cr	0.15 3.5	**Hardness** a w 28–36 HRC **Machinability** Good **Impact resistance** Good **Metal-to-metal wear resistance** Very good	1.2 1.6 2.4
OK Tubrodur 15.42 Basic DC+		Track rolls, idler wheels and links, mine car wheels, crane wheels. Compressive loads with mild abrasion.	Self-shielding CO_2 OK Flux 10.71	C Cr Ni Mo	0.15 4.5 0.5 0.5	**Hardness** a w 35–45 HRC **Machinability** Fair **Impact resistance** Good **Metal-to-metal wear resistance** Good **Abrasion resistance** Good	1.6 2.0 2.4 3.0 4.0

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Table 5 cont. FCAW/SAW products, hard-facing and build-up

Product	Classification DIN 8555	Applications	Shielding gas/ OK Flux 10.xx	Typical all-weld metal composition %	Typical properties all-weld metal	Ø mm
OK Tubrodur 15.43 Basic DC+		Especially developed for the on-site repair of CMn railway and tramway tracks. Excellent compresssive strength and ideal for mechanized applications.	Self-shielding	C 0.15 Cr 1.0 Ni 2.3 Mo 0.5	**Hardness** a w 30–40 HRC **Machinability** Good **Impact resistance** Good **Metal-to-metal wear resistance** Very good	1.2 1.6
OK Tubrodur 15.50 Metal-cored DC+		Suitable for worn farming equipment forestry tools, grinders and mill hammers.	CO_2 Ar/CO_2	C 0.65 Cr 5.0 Mo 1.0	**Hardness** a w 55–60 HRC **Machinability** Grinding only **Impact resistance** Good **Abrasion resistance** Very good	1.2 1.6
OK Tubrodur 15.52 Rutile DC+		For conveyor screws, bucket teeth and tips, bulldozer blades and mixing components.	Self-shielding, OK Flux 10.71	C 0.4 Mn 1.3 Cr 5.0 Mo 1.2	**Hardness** a w 55–60 HRC **Machinability** Grinding only **Impact resistance** Fair **Abrasion resistance** Very good	1.6 2.4 3.0 4.0
OK Tubrodur 15.73S Metal-cored DC+(–)	MF 5-45-GF-RTZ	Suitable for applications at high temperatures, such as shafts, valve seats and rolls.	OK Flux 10.33	C 0.18 Mn 1.2 Cr 13.0 Ni 2.5 Mo 1.5 V 0.25 Nb 0.25	**Hardness** a w 45–50 HRC **Machinability** Using cemented carbide tools **Abrasion resistance** Good **High temp. wear resistance** Very good **Corrosion resistance** Very good	2.4 3.0

cont'd

Table 5 cont. FCAW products, hard-facing and build-up

Product	Classification DIN 8555	Applications	Shielding gas/ OK Flux 10.xx	Typical all-weld metal composition %		Typical properties all-weld metal	Ø mm
OK Tubrodur 15.80 Basic DC+	MF 10-GF-60-GP	Suitable for parts subjected to high abrasive wear by fine-grained materials under pressure. Examples include augers, mixers, transport screws, earth-moving and quarrying components.	Self-shielding	C Cr Mo Ti	1.6 6.5 1.5 5.0	**Hardness** a w 56–60 HRC **Machinability** Grinding **Impact resistance** Good **Abrasion resistance** Excellent	1.6
OK Tubrodur 15.81 Metal-cored DC+		Coal pulverizer equipment and caolin mills.	CO_2, Ar/CO_2	C Cr Nb	1.2 5.5 6.0	**Hardness** a w 55–62 HRC **Machinability** Grinding only **Impact resistance** Good **Abrasion resistance** Excellent	1.6
OK Tubrodur 15.82 Metal-cored DC+	MF 10-GF-65-GTE	Blast furnace bells and brick manufacturing plants.	CO_2, Ar/CO_2	C Cr Mo Nb V W	4.5 17.5 1.0 5.0 1.0 1.0	**Hardness** a w 62–64 **Abrasion resistance** Excellent **High temp. wear resistance** Very good	1.6

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Table 5 cont. GMAW products, hard-facing and build-up

Product	Classification DIN 8555	Applications	Shielding gas/	Typical all-weld metal composition %	Typical properties all-weld metal	Ø mm
OK Autrod 13.89	MSG-2-GZ-C-350	Building up and hard-facing wheels, rolls, shafts, shovel teeth, parts of dredging equipment.	Ar/20%CO_2, CO_2	C 0.6 Mn 1.0 Cr 1.0	**Hardness** a w 35–40 HRC **Machinability** Fair **Impact resistance** Good **Abrasion resistance** Good	0.8 1.0 1.2 1.6
OK Autrod 13.90	MSG-2-GZ-C-50G	Hard-facing wear-resistant layers on shafts, feeder screws, cutting tools and dies.	Ar/20%CO_2, CO_2	C 1 Mn 2 Cr 2	**Hardness** a w 58–60 HRC **Machinability** Grinding only **Abrasion resistance** Very good **Impact resistance** Very good	0.8 1.0 1.2 1.6
OK Autrod 13.91	MSG-6-GZ-C-60G	For loading machines, mixers, shovel teeth, different tools and wear parts. Resistant to softening up to about 550°C.	Ar/20%CO_2, CO_2	C 0.45 Si 3.0 Mn 0.4 Cr 9	**Hardness** a w 50–60 HRC **Machinability** Grinding only **Abrasion resistance** Very good **High temp. wear resistance** Very good	0.8 1.0 1.2 1.6
PZ 6156	DIN 8556 SG 13 1	Francis and Pelton turbines	CO_2 Ar/2%CO_2	C 0.05 Cr 13.00 Ni 1.7 Mn 0.9 Mo 0.45	**Corrosion resistance** Excellent **Cavitation resistance** Excellent	
				M_S	~400° C	
PZ 6166	DIN 8556 SG 13 4 Werkst Nr 1,008	Francis and Pelton turbines	CO_2 Ar/2%CO_2	C 0.03 Cr 13.00 Ni 4.5 Mn 1.25 Mo 0.45	**Corrosion resistance** Excellent **Cavitation resistance** Excellent	
				M_S	~245° C	
PZ 6176	DIN 8556 SG 13 4 Werkst Nr 1.4351	Francis and Pelton turbines	CO_2 Ar/2%CO_2	C 0.03 Cr 16.00 Ni 4.5 Mn 1.25 Mo 0.45	**Corrosion resistance** Excellent **Cavitation resistance** Excellent	
				M_S	~155° C	

Table 5 cont. GMAW products for hard-facing

Product	Classification DIN 8555	Application	Shielding gas	Typical all-weld metal-composition %		Ø
OK Tubrodur 15.73 Metal powder cored	N/A	For hard-facing continuous casting rolls.	Ar/20%CO_2 CO_2	C Si Cr Mn Mo Ni Nb V	0.12 0.35 13.0 1.4 1.6 2.5 0.25 0.25	1.6 mm
OK Tubrodur 15.85 Metal powder cored	N/A	For hard-facing spin wheels for mineral wool manufacturing	Ar/20%CO_2 CO_2	C Si Cr Mn Mo Ni	0.08 0.85 26.0 0.85 1.6 5.0	1.6 mm

Table 6. SMAW products, non-ferrous metals

Nickel alloys – Copper alloys – Aluminium – Aluminium alloys

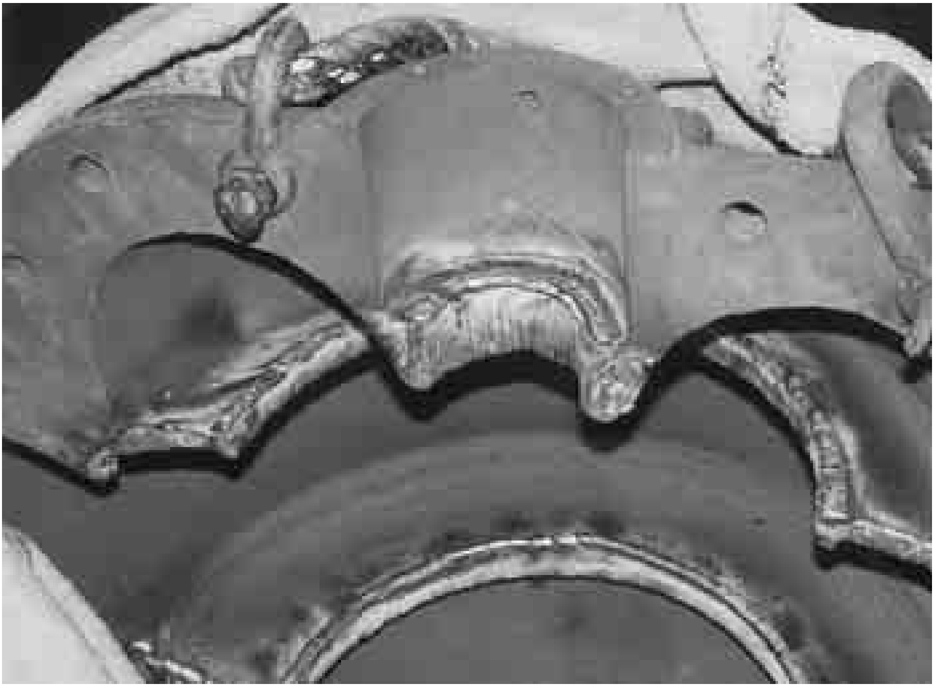
SMAW	Classification	Application	Type/Properties	Ø mm
OK 92.05 DC+ Basic	DIN 1736 EL-NiTi 3	Joining nickel alloys, dissimilar metals such as nickel to steel, nickel to copper, copper to steel and surfacing steel.	Nickel alloy C=0.02 Ni=97 Ti=2 R_m=500 MPa A=28%	2.5 3.25 4.0
OK 92.26 DC+ Basic	AWS 5.11 ENiCr Fe-3 DIN 1736 EL-NiCr15FeMn	Welding nickel alloys such as “Inconel” and the like and welding low-temperature steels and high-temperature resistant-castings.	Nickel alloy C=0.5 Mn=7.5 Cr=15 Nb=2.5 Fe max=10 R_m=640MPa A=40%	2.5 3.25 4 5
OK 92.86 DC+ Basic	DIN 1736 EL-NiCu30Mn	Welding nickel-copper alloys to themselves and to mild and low-alloy steel.	Nickel alloy C=0.06 Mn=5 Cu=30 Nb=1.5 R_m=640MPa A=40%	2.5 3.25 4
OK 94.35 DC+ Basic	DIN 1733 EL-CuNi30Mn AWS A5.6 ECuNi	Cupro-Ni welding electrode used for chemical process equipment, desalination equipment, desalination plants and offshore applications. Suitable for cladding and joining, matching or dissimilar alloys.	C=0.05 Si=0.5 Mn=1.5 Ni=30.0 Ti=0.5 Fe=0.6	2.5 3.25 4.0
OK 94.25 DC+ Basic	DIN 1733 EL-CuSn7	Welding copper and copper alloys and steel to bronze. For ordinary bronzes, red brass castings, phosphor-bronze and manganese-bronze. Also for overlaying bearing surfaces and for corrosion-resistant surfacing on steel.	Copper alloy Sn=7.5 HB120 R_m=330-390MPa A=25%	2.5 3.25 4 5
OK 94.55 DC+ Basic	DIN 1733 EL-CuSi3		Copper alloy HB120 Si=3	2.5 3.25 4 5
OK 96.10 DC+ Special	DIN 1732 EL-Al99.5	For welding pure aluminium.	Pure aluminium	2.5 3.25 4
OK 96.20 DC+ Special	DIN 1732 EL-AlMn1	Welding sheets and plates such as containers in dairies and breweries made of Al, AlMn and AlMg alloys.	Aluminium alloy Mn=1	2.5 3.25 4
OK 96.40 DC+ Special	DIN 1732 EL-AlSi5	For welding AlMgSi alloys.	Aluminium alloy Si=5	2.5 3.25 4
OK 96.50 DC+ Special	DIN 1732 EL-AlSi12	Joining and repairing cast alloys, aluminium-silicon alloys, such as engine blocks, cylinder heads, fans, base plates and frames.	Aluminium alloy Si=12	2.5 3.25 4

Table 6 cont. GMAW/TIG Products, non-ferrous metals

Aluminium & aluminium alloys – Copper & copper alloys – Nickel alloys

GMAW	Classification	Application	Type/Properties	Ø mm
OK Autrod 18.01 Shielding gas: Argon	DIN 1732 SG-Al99.5 AWS A5.10 ER 1100 BS 2901 1050A	Welding pure aluminium and wrought alumium alloys.	Aluminium Al=99.5 R_m=75MPa A=33%	0.8 1.0 1.2 1.6 2.4
OK Autrod 18.04 Shielding gas: Argon	DIN 1732 SG-AlSi5 AWS A5.10 ER 4043 BS 2901 4043A	Welding Al-Si or Al-Mg-Si alloys. Repair of engine blocks, base plates, frames.	Aluminium alloy Si=5 R_m=165MPa A=18	0.8 1.0 1.2 1.6 2.4
OK Autrod 18.05 Shielding gas: Argon	DIN 1732 SG-AlSi12 AWS A5.10 ER 4047 BS 2901 4047A	Joining and repairing cast alloys – aluminium silicon alloys, such as cylinder heads, engine blocks and base plates.	Aluminium alloy Si=13 R_m=170	0.8 1.0 1.2 1.6 2.4
OK Autrod 18.15 Shielding gas: Argon	DIN 1732 SG-AlMg5 AWS A5.10 ER 5356 BS 2901 5056A	Welding AlMg-alloys containing ≤ 5% Mg. Suit-able for saltwater-resistant alloys.	Aluminium alloy Mg=5 R_m=265MPa	0.8 1.0 1.2 1.6 2.4
OK Autrod 19.12 Shielding gas: Argon	DIN 1733 SG-CuSn AWS A5.7-77 ERCu	Welding pure and low-alloy copper.	Copper alloy Sn=0.7 R_m=220MPa A=23%	0.8 1.0 1.2 1.6
OK Autrod 19.30 Shielding gas: Argon	DIN 1733 SG-CuSi3 AWS A5.7-77 ERCuSi-A BS 2901C9	Welding copper-silicon and copper-zinc metals. Can also be used for cladding of steels.	Copper alloy Si=3 Mn=1 R_m=300MPa A=23%	0.8 1.0 1.2 1.6
OK Autrod 19.40 Shielding gas: Argon	DIN 1733 SG-CuAl8 AWS A5.7-77 ERCuAl-Al BS 2901C28	Welding rolled and cast aluminium-bronze alloys. High strength, good wear resistance and very good corrosion resistance, particulary in salt water.	Aluminium bronze Al=8 R_m=420MPa	0.8 1.0 1.2 1.6
OK Autrod 19.85 Shielding gas: Ar, Ar/He, He	DIN 1736 SG-NiCr20Nb AWS 5.14 ERNiCr-3	For joining and surfacing Ni alloys. Especially suit-able for joints designed for service at < 200°C.	Nickel alloy C=0.05 Mn=3 Cr=20 Mo=1 Nb 2.5 R_m=600	0.8 1.0 1.2 1.6

The GMAW products are also available as GTAW products.



Pump housing: OK 94.25.

Feeder screw: OK Tubrodur 14.70 hard-facing.

Table 7. Recommended preheating temperatures

Base material Filler material	Plate thick-ness mm	Steel C_{eq} <0.3 < 180 HB °C	Low alloy C_{eq} 0.3–0.6 200–300 HB °C	Tool steel C_{eq} 0.6–0.8 300–400 HB °C	Chromium steel 5–12% Cr 300–500 HB °C	Chromium steel >12% Cr 200–300 HB °C	Stainless steel 18/8 Cr/Ni ~200 HB °C	Manganese steel 14%Mn 250–500 HB °C
Low–alloy 200–300 HB	≤20	–	100	150	150	100	–	–
	>20 ≤60	–	150	200	250	200	–	–
	>60	100	180	250	300	200	–	–
Tool steel 300–450 HB	≤20	–	100	180	200	100	–	–
	>20 ≤60	–	125	250	250	200	–	o
	>60	125	180	300	350	250	–	o
12% Cr Steel 300–500 HB	≤20	–	150	200	200	150	–	x
	>20 ≤60	100	200	275	300	200	150	x
	>60	200	250	350	375	250	200	x
Stainless Steel 18/8 25/12 200 HB	≤20	–	–	–	–	–	–	–
	>20 ≤60	–	100	125	150	200	–	–
	>60	–	150	200	250	200	100	–
Mn Steel 200 HB	≤20	–	–	–	x	x	–	–
	>20 ≤60	–	–	•100	x	x	–	–
	>60	–	–	•100	x	x	–	–
Co-Based Type 6 40 HRC	≤20	100	200	250	200	200	100	x
	>20 ≤60	300	400	•450	400	350	400	x
	>60	400	400	•500	•500	400	400	x
Carbide type (1) 55 HRC	≤20	–	o–	o–	o–	o–	o–	o–
	>20 ≤60	–	100	200	•200	•200	o–	o–
	>60	o–	200	250	•200	•200	o–	o–

(1) Maximum 2 layers of weld metal. Relief cracking is normal.

– No preheating or preheating <100°C.

x Used very rarely or not at all.

o Preheating when large areas are surfaced.

• To prevent cracking, use a buffer layer of tough stainless weld metal

Table 8. Comparative hardness scales

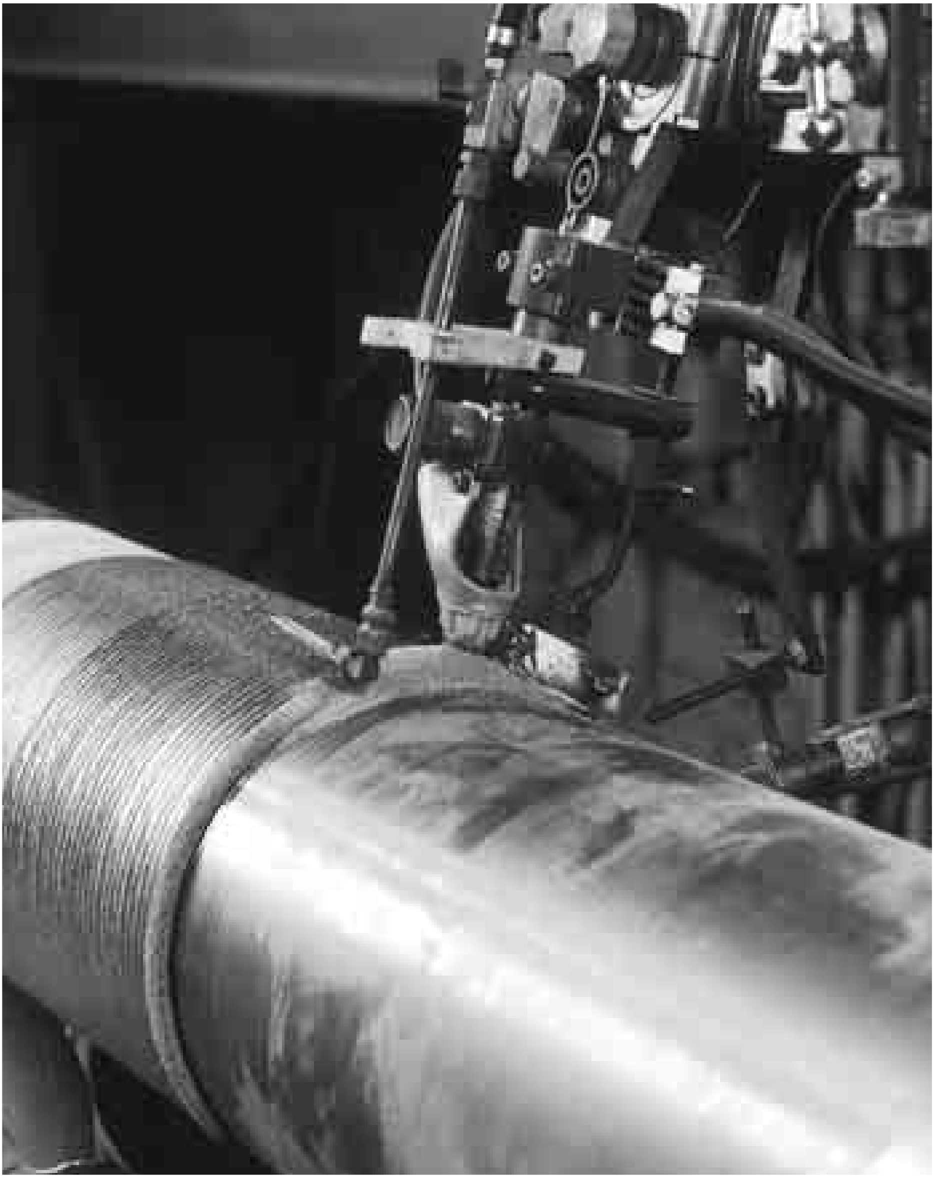
Vickers	Brinell	Rockwell	
HV	HB	HRB	HRC
80	76,0		
85	80,7	41,0	
90	85,5	48,0	
95	90,2	52,0	
100	95,0	56,2	
105	99,8		
110	105	62,3	
115	109		
120	114	66,7	
125	119		
130	124	71,2	
135	128		
140	133	75,0	
145	138		
150	143	78,7	
155	147		
160	152	81,7	
165	156		
170	162	85,0	
175	166		
180	171	87,1	
185	176		
190	181	89,5	
195	185		
200	190	91,5	
205	195	92,5	
210	199	93,5	
215	204	94,0	
220	209	95,0	
225	214	96,0	
230	219	96,7	
235	223		
240	228	98,1	20,3
245	233		21,3
250	238	99,5	22,2
255	242		23,1
260	247	(101)	24,0
265	252		24,8
270	257	(102)	25,6
275	261		26,4
280	266	(104)	27,1
285	271		27,8
290	276	(105)	28,5
295	280		29,2
300	285		29,8
310	295		31,0
320	304		32,2
330	314		33,3
340	323		34,4
350	333		35,5
360	342		36.6
370	352		37,7
380	361		38,8
390	371		39,9
400	380		40,8
410	390		41,8
420	399		42,7
430	409		43,6
440	418		44,5
450	428		45,3
460	437		46,1
470	447		46,9
480	(456)		47,7
490	(466)		48,4
500	(475)		49,1
510	(485)		49,8
520	(494)		50,5
530	(504)		51,1
540	(513)		51,7
550	(523)		52,3
560	(532)		53,0
570	(542)		53,6
580	(551)		54,1
590	(561)		54,7
600	(570)		55,2
610	(580)		55,7
620	(589)		56,3
630	(599)		56,8
640	(608)		57,3
650	(618)		57,8
660			58,3
670			58,8
680			59,2
690			59,7
700			60,1
720			61,0
740			61,8
760			62,5
780			63,3
800			64,0
820			64,7
840			65,3
860			65,9
880			66,4
900			67,0
920			67,5
940			68,0

The information given in this table should only be used as a guide.

Table 9. Metal identification guide chart

Magnet	**File**	**Surface colour**	**Grinding sparks**	**Metal type**	**Comment**
Magnetic	Soft	Dark grey	Long yellow lines	Low carbon steel* Cast steel	–
	Hard	Dark grey	Long yellowish-white lines plus stars	High carbon steel Low-alloy steel	Pre-heat heavy materials to 150°C
	Soft	Matt grey, cast-iron colour	Red feather-like lines	Cast iron	May be pre-heated Peening useful Slow cooling
	Hard	Shiny grey	Yellowish-red coarse lines	13% Cr steel	May be pre-heated
Non-magnetic	Hard	Matt grey, cast-iron colour	Yellowish-white lines and sparks	14% Mn steel	Low interpass temperature
	Soft	Bright silver-grey	Yellowish-red coarse lines	Austenitic stainless steel	Low interpass temperature
	Soft	Reddish-yellow shiny	No visible sparks	Cu alloys	Pre-heat coarse materials to 200–300°C
	Soft	Shiny, very light	No visible sparks	Al alloys	Pre-heat coarse materials to 150–200°C

*N.B. Cast iron is a high carbon material susceptible to cracking, while cast steel has characteristics similar to those of ordinary steel.



Reconditioning of concast rollers.
Consumables: OK Tubrodur 15.72S/OK Flux 10.33.
Equipment: ESAB A6 HD SAW.

13860:325.52/5

Application index-alphabetical order

In the application index and the illustrated applications, you will find two to three possible choices of consumables. To make it clear, there are no comments on the individual consumable in the index. The comments can be found with the illustrated applications and/or in the product data tables.

With these illustrations, comments, index and data tables for the individual consumables and our Welding Handbook, we hope you will be helped to make the right choice.

Should you require any further detailed information, please contact your nearest ESAB representative or call ESAB directly.

Drive sprocket: Preventive maintenance OK 83.28.

001-218-461

Application index – in alphabetical order

		Products	
Application	**SMAW**	**FCAW**	**GMAW**
	OK	**OK Tubrodur**	**OK Autrod**
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Aluminium	96.20 96.10		18.01 18.04 18.15
Aluminium cast alloys	96.50		18.04 18.05
Asphalt mixer	84.78 83.65	15.52 14.70	
Asphalt pawing screw	84.78 83.65	15.52 14.70	
Brake shoe	83.28 83.50	15.40 15.52	
Briquette press	83.65 84.78 84.84	15.40 15.52	13.90
Bronze to steel	94.25 94.55		19.30
Carbon steel to stainless	68.81 68.82 67.45		16.75 16.95
Cast iron (grey)	92.18 92.58 92.60	15.66	
Cast iron (nodular)	92.58 92.60	15.66	
Cast steel	68.81 68.82		
Chain saw (guide plate)	93.06		
Chisels	84.52 85.65		
Clutch housing	92.18 92.60	15.66	
Concast rollers		15.73 15.72S	
Concrete feeder	84.58 84.78 84.84	15.52 14.70 15.80	
Concrete mixer	84.78 84.84	15.52 14.70 15.80	
Cone crusher	86.08 86.28 84.78	15.60 15.65 15.80	
Conveyor chains	83.65 83.50 84.58	15.52 15.80	
Copper alloys	94.25 94.55		
Copper to steel	94.25 92.86		
Crane wheel	83.27 83.28 83.29	15.40 15.41 15.42	13.89
Crusher (abrasion)	83.65 83.50 84.78	15.52 14.70	
Crusher (impact)	86.28 68.82 84.58	15.60 15.65 15.40	
Crusher rolls (abrasion)	83.65 83.50 84.78	15.52 14.70 15.80	
Crusher rolls (impact)	86.08 86.28 84.58	15.60 15.65 15.52	
Cultivator teeth	68.81		16.75
Cutting	21.03		
Cutting tools (cold)	85.65 84.52		
Cutting tools (hot)	85.58 93.06 92.35		
Dissimilar materials (joining)	68.81 68.82		16.75
Dredger bucket (abrasion)	84.78 83.65	14.70 15.52	13.90 13.91
Drills, metal	85.65		
Drills, wood	84.52 85.65		
Drop forging tools	85.58 92.35		
Earth & rock drills	83.65 84.78 84.84		
Earth drills	84.84 83.28		
Eccentric rolls	84.52 84.58 85.65	15.52 15.73	13.90 13.91
Engine block, aluminium	96.50		18.05
Engine block, cast iron	92.18 92.60	15.66	
Excavator bucket	84.78 83.65 83.50	14.70 15.52	13.91
Extruder dies	85.58 92.35		
Extruder screws	93.06 92.35	15.86	

Application	Products SMAW OK	FCAW OK Tubrodur	GMAW OK Autrod
Feeder screws	83.50 83.53 84.58 84.84	15.52 15.80	13.90 13.91
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Gear housing, cast iron	92.18 92.60	15.66	
Gears, alloyed steel	68.81 68.82	15.40	13.89 16.75
Gears, unalloyed steel	83.28 68.81	15.17 15.40	12.51 13.89 16.75
Gouging	21.03		
Hammer (abrasion)	83.50 83.53 83.65 84.78	15.52 15.80	13.91 13.90
Hammer (impact)	86.28 86.08	15.60 15.65	
Impellers	83.50 84.58 84.78	15.52 14.70 15.80	13.90 13.91
Manganese steel (Hadfield)	86.08 67.45 68.81	15.60 14.71	16.95 16.75
Metal stamping (cold)	85.65		
Metal stamping (hot)	92.35 93.06	15.86	
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Shovel teeth (abrasion)	84.78 83.65 83.50	15.52 14.70 15.80	13.91
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