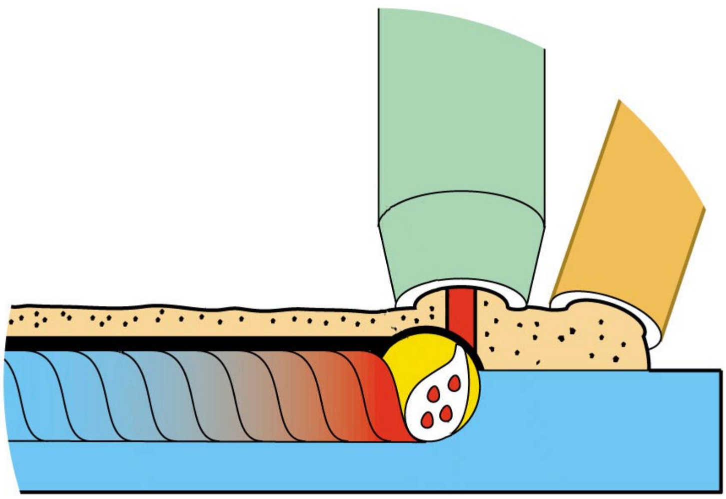
Submerged Arc Welding



XA00109620

Contents

1 Submerged Arc Welding

Submerged arc welding can be employed for an extremely wide range of workpieces. The method is suitable for butt welding and fillet welding of such applications as structural members in ships, manufacture of pressure vessels, bridge beams, massive water pipes, thin sheet shells and so on. In addition, the process is particularly effective for cladding applications, e.g. when surfacing mild carbon steel with stainless steel materials, or when depositing hard materials on a softer substrate.

Submerged arc welding is generally performed indoors in fabrication shops. Working outdoors always carries the risk of undesirable levels of moisture finding their way into the joint or flux and resulting in porosity of the weld. If submerged arc welding must be carried out outdoors, special precautions should be taken, such as the construction of a roof over the work area.

Submerged arc welding is most efficient if the joint can be filled with as few passes as possible. If, when working in mild steel, the workpiece can be turned over, and if the material is not too thick, a bead is often applied from each side of the joint. If the basic material is alloyed steel, a multi-pass procedure is normally necessary. Admittedly, this results in an increase in process costs, but for many workpieces the economics of the process are still sufficiently attractive for submerged arc welding to be more cost-effective than, say, manual welding using coated electrodes. In addition, there will be fewer weld defects with automatic welding.

1.1 The principle of submerged arc welding

The diagram below indicates, in schematic form, the main principles of submerged arc welding. The filler material is an uncoated, continuous wire electrode, applied to the joint together with a flow of fine-grained flux, which is supplied from a flux hopper via a tube. The electrical resistance of the electrode should be as low as possible to facilitate welding at a high current, and so the welding current is supplied to the electrode through contacts very close to the arc and immediately above it. The arc burns in a cavity which, apart from the arc itself, is filled with gas and metal vapour. The size of the cavity in front of the arc is delineated by unmelted basic material, and behind it by the molten weld. The top of the cavity is formed by molten flux. The diagram also shows the solidified weld and the solidified flux, which covers the weld in a thin layer and which must subsequently be removed. Not all of the flux supplied is used up: the excess flux can be sucked up and used again.

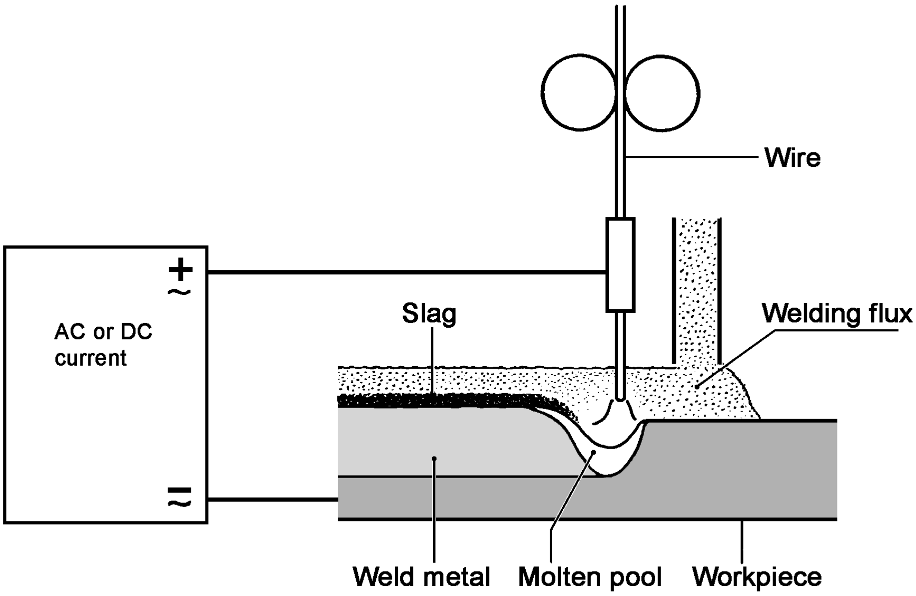


Figure 1. The principle of submerged arc welding.

The flux also has a thermal insulating effect, and thus reduces heat losses from the arc. As a result, more of the input energy is available for the actual welding process itself than is the case with processes involving an exposed arc. The thermal efficiency is greater and the rate of welding is faster. It has been found that submerged arc welding has a thermal efficiency of about 90 %, as against an approximate value of about 75 % for MMA welding.

Submerged arc welding can be performed using either DC or AC.

1.2 Applications

Submerged arc welding can be employed for an extremely wide range of workpieces. The method is suitable for butt welding and fillet welding of such applications as structural members in ships, manufacture of pressure vessels, bridge beams, massive water pipes, thin sheet shells and so on. In addition, the process is particularly effective for cladding applications, e.g. when coating mild carbon steel with stainless steel materials, or when depositing hard materials on softer substrates.

Submerged arc welding is generally performed indoors in fabrication shops. Working outdoors always carries the risk of undesirable levels of moisture finding their way into the joint or flux and resulting in porosity in the weld. If submerged arc welding cannot be avoided outdoors, special measures should be taken, such as the construction of a roof over the work area.

Submerged arc welding is most efficient if the joint can be filled with as few passes as possible. If, when working in mild steel, the workpiece can be turned over and if the material is not too thick, a bead is often applied from each side of the joint. If the basic material is an alloy steel, a multi-pass procedure is normally necessary. Admittedly, this results in an increase in process costs, but for many workpieces the economics of the process are still sufficiently attractive for submerged arc welding to be more cost-effective than, say, manual welding using coated electrodes. In addition, there will be fewer weld defects with automatic welding.

2 PARAMETERS

2.1 Selection of welding data

Welding data depends on the size of the workpiece, and must be selected to ensure satisfactory penetration and correct shape of the weld. Starting from this basic requirement, we select the appropriate values of filler wire size, arc voltage, welding current and welding speed. The tables of welding data at the end of this binder give a number of guidelines for selection of correct welding data. It is recommended that the selections made should be first tested by trial welds, thus avoiding the risk of an unsuccessful weld when working with the workpiece itself.

Arc voltage

The arc voltage is decisive in determining the shape and width of the arc and, to some degree, also in determining its penetration. Too high an arc voltage in an I-joint in flat sheet will produce a wider weld, while in a V-joint, X-joint and fillet radii it will result in a concave weld, with a risk of undercutting and slag that is difficult to remove. On the other hand, too low an arc voltage will result in a high, round weld in I-joints and V-joints, while in X-joints and fillet radii it will result in a convex weld, and which is also hard to de-slag.

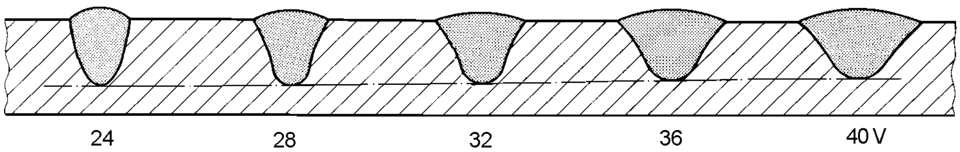


Figure 2. How a change in arc voltage affects the shape of weld. Welding current is constant.

Welding current

Welding current is the parameter that is of greatest importance for penetration. The current setting depends on the thickness of the metal and the type of joint. The current has no effect on the width of the bead, but too high a current can result in burn-through, while too low a current can result in insufficient penetration with resulting root defects.

This means that the welding current, which is proportional to the wire feed speed, affects the deposition rate (the quantity of electrode material melted into the weld per unit of time), so that as the welding current increases, the rate of melting of the filler wire also increases. For a given welding current, the deposition rate will be higher if the filler wire is negative with respect to the workpiece than if the wire is positive, but the penetration will be reduced.

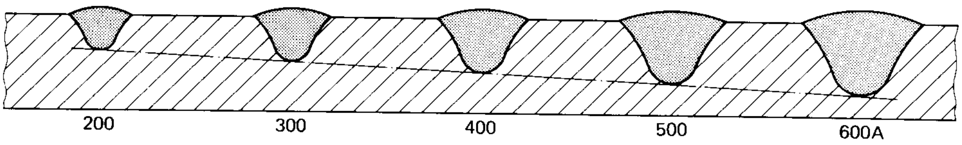


Figure 3. Increasing welding current results in deeper penetration.

Welding speed

The welding speed (the linear speed along the line of the weld) also affects the penetration. If the speed is increased relative to the original value, penetration will be decreased and the weld will be narrower. Reducing the speed increases penetration and results in a wider weld (cf. manual welding). However, reducing the welding speed to about 20–25 cm/min (depending on the actual value of the current) can have the opposite effect, i.e. a reduction in penetration, as the arc is prevented from transferring thermal energy to the parent metal by the excessive size of the weld pool. If the welding speed is to be changed while penetration is kept constant, it is necessary to compensate by adjustment of the welding current, i.e. to increase or decrease it.

Wire diameter

For a given current, a change in wire size will result in a change in current density. Greater wire diameter results in a reduction in penetration and, to some extent, also the risk of burning through at the bottom of the weld. In addition, the arc will become more difficult to strike and arc stability will be adversely affected. There is a risk of root defects if too large an electrode is used in V-joints.

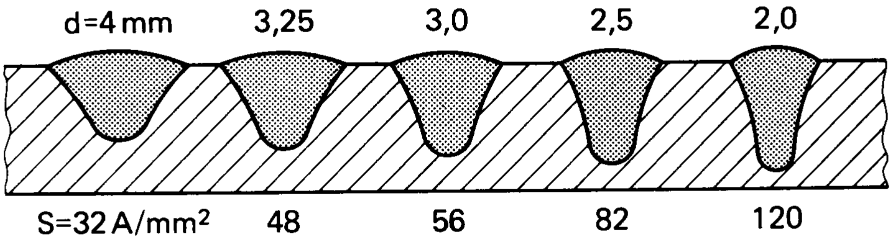


Figure 4. The effect of different wire diameters at constant welding current.

Stick-out

The electrical stick-out of the wire is the distance from the contact tip to the surface of the workpiece.

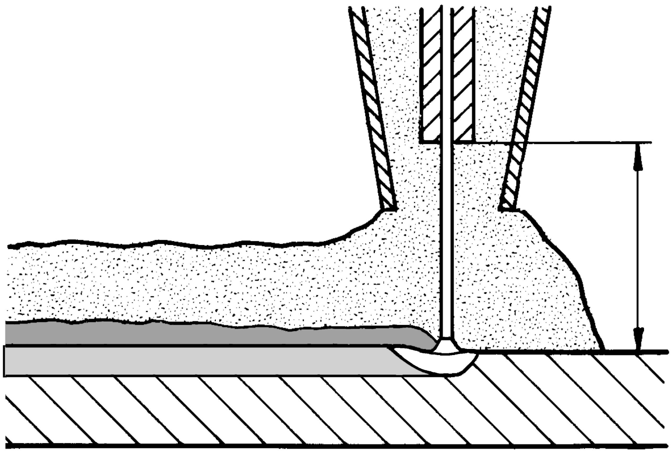


Figure 5. Stick-out distance.

This distance is an important parameter, affecting the resistive heating of the tip of the wire. If the stick-out is short, little heat will be developed in the wire and penetration will be greater. As the stick-out length is increased, so the temperature of the wire increases and penetration is reduced, while the rate of deposition is increased.

Extra long electrical stick-out is employed particularly for deposition and cladding (application of a stainless steel or wear-resistant layer). It is possible to increase the rate of deposition by up to 50% with a long stick-out. When welding in normal structural steels, a normal value of stick-out is 25–30 mm, with a somewhat shorter stick-out of about 20–25 mm being used for stainless steels, as stainless steel filler wires have higher resistance.

It is desirable to be able to adjust the flux depth, depending on the amount of molten metal in the bead.

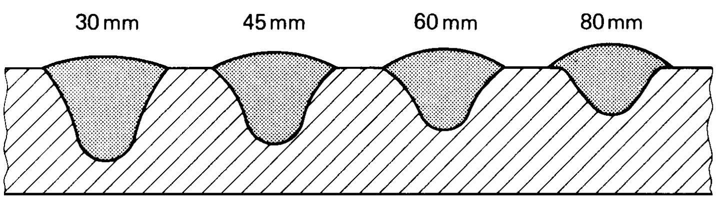


Figure 6. Penetration is reduced as electrical stick-out increases.

Wire angle

The angle between the filler wire and the workpiece determines the position of the weld, its appearance and its penetration.

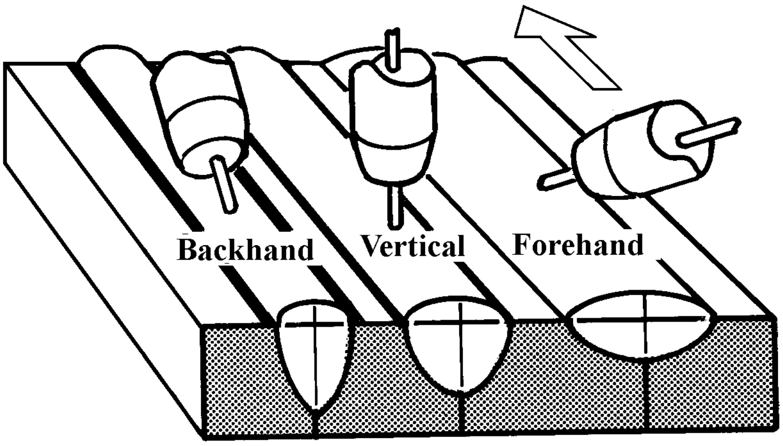


Figure 7. Effect of wire angle on weld penetration and width.

Electrode angle	Backhand	Vertical	Forehand
Penetration	High	Normal	Low
Weld convexity	Narrow (high)	Normal	Wide (low)
Tendency to undercut-ting	High	Normal	Slight

Vertical filler wire angle is most commonly used, but when tandem and multi-wire systems are used both forehand and backhand wire angles are used in order to achieve the welding performance.

2.2 Formulas

$$Q = \frac{U \cdot I \cdot 60}{V} \cdot \eta$$

Heat input

where Q = Input energy, kJ/mm
U = Voltage, V
I = Current, A
V = Linear welding speed, mm/min
η = Efficiency (for submerged arc = 0.9 or 1.0)

Carbon equivalent

$$E_c = Cev = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

The parent metal should/must be preheated if $E_c > 0.40$ %

Form factor

$$F = \frac{B}{D}$$

where F = Width/height ratio
B = Width of weld
D = Height/depth of weld

F should not be less than 1–1.5, as there will otherwise be a risk of cracking.

Deposit rate

An approximation of the deposit rate is given by the formulas

Dep. rate (kg/h) = Amp / (50 x $Diam^{0.3}$) Single wire DC+

Dep. rate (kg/h) = Amp / (40 x $Diam^{0.3}$) Single wire AC

Somewhat more accurate value on wire feed speed (m/min) for DC+:

$$WFS = \left(\frac{AMP + 22}{44.7 \cdot DIAM^{1,79}} \right)^{1,41}$$

3 SUBMERGED ARC WELDING METHODS

3.1 Single-wire welding

Filler wires with diameters from 1.2 mm to 6 mm can be used with welding currents of 120–1500 A. Submerged arc welding processes have developed from single-wire welding to higher productivity processes.

3.2 Twin-arc welding

Submerged arc welding with two parallel wires differs more from twin-wire welding with separate welding heads than it does from conventional submerged arc welding having one wire and one welding head.

An automatic twin-arc welding machine can be easily produced by fitting a single-wire machine with feed rollers and contact tips for two wires, together with an extra carrier for a second wire bobbin. Double wires have become increasingly common in the interests of higher productivity. Without very much higher capital costs, it is possible to increase the deposition rate by 30–40% in comparison with that of a single-wire machine, as a result of the higher current density that can be carried by two filler wires in parallel.

As the equipment uses only a single wire feed unit, the welding current will be shared equally between the two wires.

Wire sizes and types of current

Wire sizes normally used for butt welding are 2.0, 2.5 and 3.0 mm, with wire separations of about 8 mm.

DC welding, with the wire positive relative to the workpiece, is preferable, as this results in the best arc stability and least risk of porosity.

When hardfacing using tubular wires, it is generally preferable for the wire to be negative, resulting in minimum penetration and highest deposition rate. Commonly used tubular wire diameters are 2.4, 3.0 and 4.0 mm.

Wire angles and positions: advantages and drawbacks

- By varying the angle of the contact tip, the wire angle relative to the joint can be varied.
- With the wires in line with the joint, penetration will be highest and risk of undercutting will be least. This position ensures the least risk of porosity, as the molten weld metal has longer to cool, allowing more time for gas to escape from the weld.
- With the wires perpendicular to the joint, penetration is minimum. This arrangement is preferred in welds in which ordinary root faces for submerged arc welding cannot be used, e.g. corner/fillet welds, and also where wide joint widths need to be covered with one pass or where the edges of the joint are uneven. There is some risk of undercutting at high welding speeds. As, with the wires in this position, very little of the parent metal is melted relative to the amount normally melted in the submerged arc process, resulting in an improved form factor of the weld. This arrangement is also used for welding materials in which there is a risk of thermal cracking.
- A pair of wires arranged diagonally to the weld can be used as a compromise position to obtain the benefits of the two basic positions described above.

Comparison between single-wire and twin-wire welding

The performance parameters shown in the table below are based on the performance of the A6 wire feed motor, and not on basic welding characteristics.

TYPE OF WIRE	DIAMETER mm	AREA mm²	WELDING CURRENT A max	DEPOSITION RATE kg/h
SINGLE WIRE	3.0	7.06	650	8.0
	4.0	12.56	850	11.5
	5.0	19.62	1100	14.5
TWIN WIRE	2.0	6.28	1000	14.0
	2.5	9.81	1200	17.0
	3.0	14.13	1500	21.0

3.3 Tandem welding

When the wires are connected to separate power units, and the welding heads work on the same joint, the process is referred to as tandem welding. Tandem welding uses thicker wires (3–4 mm). The method is used when welding thick plate, where substantial cross-sectional areas have to be filled with weld metal.

Tandem welding partly offsets the metallurgical structure drawbacks that can result from a large, slowly solidifying, weld pool.

3.4 Strip welding

The same equipment can be used for strip welding as for single-wire welding, but the wire is now in the form of a strip of metal, either 0.5 x 60 mm or 0.5 x 100 mm. The welding head and flux feed arrangements are modified to suit. As a result of the rectangular cross-section, penetration is exceptionally low, producing a smooth and wide weld. The process is used for such applications as cladding carbon steel with stainless steel, where the dilution from the parent metal must be low in order not to affect the corrosion resistance of the surface layer. The method is also used for repair of worn parts.

3.5 Narrow gap welding

ESAB's NGSA method has been developed for the welding of thick-wall pressure vessels in very narrow gaps. The joint sides are almost parallel, inclined at an angle of only 3. Conventional welded joints use either double V-joints or U-joints, so it can be easily appreciated that both welding time and the amount of filler material can be reduced when using narrow-gap welding methods.

Instead of applying a substantial pass in the middle of the joint, the method is based on applying passes to the left and right sides alternately. In order to ensure good release of the slag, the width of the slag must not be wider than the joint.

Narrow-gap welding can be used in metal thickness up to 350 mm, which can be welded from the root to the final pass without interruption.

Benefits of narrow-gap welding

- Short arc times
- Minimum of filler materials
- Low welding stresses
- Narrow heat-affected zone
- Low input power
- High quality.

3.6 Cold wire addition

ESAB has introduced a simple equipment for cold wire addition, a process called Synergic Cold Wire (A6 SCW). It offers the opportunity to increase the deposition rate by up to 100% compared with single-wire welding. The cold wire is fed in synergy (e.g. with the same wire-feed speed) with the normal arc wire into weld pool where it melts. Because the wire feed speeds are the same, the arc and cold wire ratio always remains constant. The proportion can be changed by the choice of the individual wire diameters.

3.7 Iron powder

Productivity can be increased by adding cold materials, such as iron powder, to the weld beads. The shipbuilding industry in particular now makes widespread use of welding with iron powder. In comparison with conventional submerged arc welding, productivity can be increased by almost 50%.

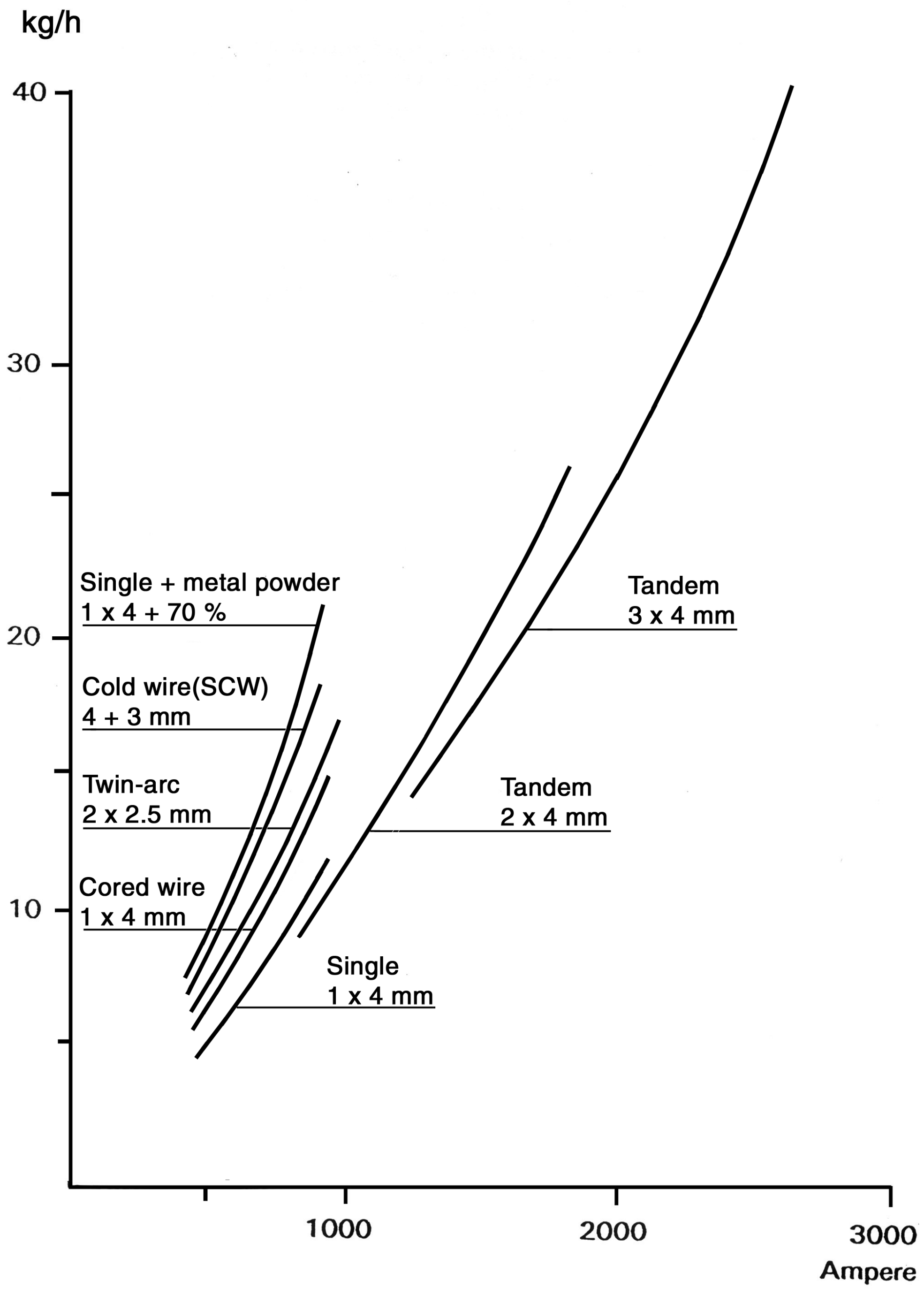


Figure 8. Deposition rates of various submerged arc welding methods. DC, electrode positive.

4 JOINT PREPARATION

4.1 General

In order to be able to obtain full benefit of the productivity of automatic welding, it is essential that joints are prepared with the greatest accuracy. The edges of sheets must be carefully machined to ensure optimum penetration. The root face on a V-joint or Y-joint must be sufficiently high to ensure production of the required root pass and to prevent burn-through. The edges of the sheet must be absolutely clean, i.e. with no traces of water, oil, paint, mill scale or rust, which would otherwise result in pores or crack formation. If the sheet has been plasma-cut, the edges must be ground.

Dimensional inaccuracies in joint preparation result in defective welds. They will also, in any case, make automatic welding more difficult. The results of poor matching of joints will be burn-through or incomplete penetration, i.e. root defects.

Submerged arc welding requires more expensive joint preparation than manual welding. However, the cost difference is so small that there is no justification for attempting to skimp the joint preparation work. A clean, properly prepared joint allows higher welding speeds, which more than offsets the expensive preparation.

4.2 Joint backing

The advantage of good joint backing is that it allows the use of welding currents sufficiently high to ensure adequate penetration, a high deposition rate and acceptable appearance of the root side of the weld.

Backing

This is defined as a root face, a manually welded bottom pass, a copper bar (common with stationary working positions) or some form of fireproof material that can be fitted to the workpiece.

Backing strips

Consists of a bar or section, generally of the same grade of material as the parent metal, tack-welded beneath the joint and intended to form part of the joint when finished.

Ceramic backing

Easily applicable root support in the form of ceramic tiles, intended to be used with workpieces that cannot be turned, e.g. the decks of vessels, fixed structures etc., and thereby avoiding arc-air gouging and post-welding.

5 FILLER MATERIALS

Two main items are generally used as filler materials for submerged arc welding: electrodes (filler wire) and flux. Recently, a third component has become increasingly commonly used: iron powder.

5.1 Filler wire

The filler wire is generally copper-plated in order to ensure good current transfer to it from the contact jaws, and to reduce wear of the jaws. The copper, in other words, is not intended as corrosion protection in the usual meaning, and coils of filler wire must be protected against moisture in the same way as must other filler materials.

The wire may be of various types, solid or tubular and, in the case of solid wire, be round or rectangular in cross-section. Solid filler wires of round section are used for fabrication welding and cladding, while rectangular section wires – known as strip electrodes – are generally used only for cladding. Tubular wire electrodes are also very suitable for cladding, as the alloying elements necessary can be contained in the hollow centre of the wire.

Both strip electrodes and tubular wire electrodes are an important part of the field of welding technology devoted to cladding.

5.2 Flux

As yet, there is no universal flux suitable for all purposes. A flux that has been developed, for example, for good mechanical properties in high-grade steel, generally has poorer characteristics in some other respect that is of importance for welding. It is therefore only natural that companies with a mixed range of manufactured products have to use two or more grades of flux.

Flux compositions are optimised for use in combination with filler wires of varying metallurgical characteristics. This combination can be provided in three ways: with all the necessary alloying elements in the filler wire, in the flux or in the filler wire and flux together.

Flux can be classified as a fused, sintered or agglomerating type.

A **fused flux** is homogeneous, i.e. the substances in the flux have been melted together to form a glass-like substance, which has then been crushed and ground before finally being classified to a suitable grain size.

The particles in an **agglomerated flux**, on the other hand, have been formed by 'rolling' the various constituents on a rotating dish, drum or cone, with waterglass as an additive. The resulting product has then been dried in a rotary kiln at a temperature of 800–900 °C. After drying, the flux is classified to give approximately the same grain size as that of a fused flux.

Sintered fluxes are produced by sintering the various components to produce blocks, which are then crushed and classified.

Fused fluxes are non-hygroscopic, and are therefore particularly suitable for outdoor welding and in high-humidity environments. Agglomerated fluxes, which may be hygroscopic, should be handled with the same care as recommended for electrodes for manual welding.

FLUX TYPE	BENEFITS	DRAWBACKS
Fused	Non-hygroscopic High grain strength	Alloying elements such as Cr and Ni cannot be incorporated in the flux High specific density (approx. 1.6 kg/l)
Sintered	Relatively low hygroscopicity Relatively low density (approx. 1.3 kg/l)	Alloying elements cannot usually be included in the flux Relatively low grain strength
Agglomerated	Alloying elements such as Cr and Ni can be included in the flux Low specific density (approx. 0.8 kg/l)	Hygroscopic Relatively low grain strength

5.3 ESAB fluxes and characteristic properties from a welding viewpoint

Introduction

From a chemical viewpoint, fluxes can generally be categorised as follows:

- Acidic and neutral fluxes (with basicity B =< 1.2)
- Basic fluxes (B = 1.2–2.0)
- High-basic fluxes (B => 2.0)
- Special fluxes

The special fluxes are defined not in chemical terms, but in terms of their applications, e.g. for welding stainless steel or for hardfacing.

A. Acidic and neutral fluxes

This group is characterised by:

- Excellent welding properties
- Moderate mechanical properties (Grade II approval, i.e. with impact strength requirements at 0 °C)
- The fluxes are alloyed, i.e. intended for use with unalloyed filler wire (OK Autrod 12.10)
- Suitable for use with both AC and DC welding current

Within this group, ESAB markets two fluxes: the acid OK Flux 10.81 and the neutral OK Flux 10.80.

OK Flux 10.81 has a basicity index of about 0.5 in accordance with the Boniczewski index, and can be classified chemically as being of the alumina type. It demonstrates excellent slag release, good weld formation, high welding speed, low risk of porosity and gas flats, together with good current tolerance. These characteristics have earned the flux wide application, particularly for welding of vertical and horizontal fillet joints with both single-wire and multi-wire systems.

Additional applications for the flux are the welding of thin sheet, various types of pipes and other structures having requirements up to Grade II approval. OK Flux 10.81 is equivalent to – and, in some cases, better than – competitive fluxes available on the market of this group, i.e. with basicity index up to 1.0.

OK Flux 10.80 has a basicity index of about 1.1, and can chemically be regarded as being of calcium/magnesium silicate type. It belongs to the older generation of fluxes, but is still widely used for butt welding of thicker materials, e.g. in the shipbuilding industry.

Its most characteristic feature is its excellent current tolerance, which allows welding with a large weld pool, i.e. at high current and low welding speed. The reason for this is to be found in the slag's relatively high SiO_2 content. However, in comparison with OK Flux 10.81, this high SiO_2 content does mean that its slag release characteristic is poorer, and that the flux is less suitable for welding fillet joints.

The drawback of this flux is its somewhat limited shelf life, due to the fact that absorbed moisture can be taken up as water of crystallisation.

B. Basic fluxes

This group, having a basicity index of 1.2 – 2.0, is generally characterised by:

- Good welding characteristics
- Good mechanical characteristics (Grade III approval, with impact requirements at -20 °C)
- The ability to supply alloyed fluxes, i.e. intended for use with unalloyed filler wire (OK Autrod 12.10), or unalloyed, i.e. intended for use with alloyed filler wire (e.g. OK Autrod 12.24).

Within this group, ESAB sells two fluxes: OK Flux 10.70 and OK Flux 10.71.

OK Flux 10.70 has a basicity index of about 1.7, and can chemically be regarded as being of the aluminate-basic type. It is of the alloying type, and one of its features is that its basicity is such that it is suitable for use with either AC or DC welding.

In addition, it features good slag release, good weld formation, low pore formation and good current tolerance. These characteristics have resulted in it being suitable not only for normal butt welding, but also for use with vertical and horizontal fillet welds with single-wire or multi-wire systems. Partly as a result of its good shelf life, it is intended that it will replace OK Flux 10.80 in the longer term.

OK Flux 10.71 has a basicity index of about 1.6 and can, in the same way as can OK Flux 10.70, be regarded chemically as of the aluminate-basic type. However, it differs from OK Flux 10.70 in being compensating or weakly alloying in respect of alloying elements, and must therefore be used in combination with alloying filler wire.

Its general welding characteristics are identical with those of OK Flux 10.70. The real difference is that, for metallurgical reasons, OK Flux 10.71 is more suitable for multi-pass welding in thicker materials, e.g. when welding steels with fine grain structure.

C. High basic fluxes

This group, which has a basicity index of 2.0–3.5, generally has the following characteristics:

- Reasonable welding characteristics (can usually be used only for DC + welding).
- Excellent mechanical characteristics. (This type of flux is used for welding LPG materials having impact strength requirements down to -55 °C.)
- The fluxes are unalloyed, i.e. intended for use with alloyed filler wires, e.g. OK Autrod 12.34.

Within this group, ESAB markets OK Flux 10.61 and OK Flux 10.62.

OK Flux 10.61 has a basicity index of about 2.8 and can be regarded as being chemically of the lime basic type. It is compensating, or produces a slight loss of alloying elements. Its welding characteristics are so good for this type of flux that tandem welding, with DC current, is possible.

The slag release, weld formation, risk of pore formation and current tolerance can be regarded as being of the very best for fluxes of this type.

OK Flux 10.62 has a higher basicity index than OK Flux 10.61, together with better welding characteristics for AC and DC.

D. Special fluxes

As stated at the beginning of this section, these fluxes are generally defined only in terms of their applications. ESAB markets the following fluxes in this category.

OK Flux 10.91 and 10.92 are both intended for welding stainless steel, and therefore include Cr for compensation of Cr loss during welding. Both are acid fluxes, having a basicity index of about 0.8. This is because they are intended for cladding applications using stainless steel strip and therefore require excellent welding characteristics.

OK Flux 10.91 is intended for use together with OK Autrod 16.10 and 16.30, while OK Flux 10.92 is intended for use with (stainless steel) strip electrodes.

OK Flux 10.96 is of the alloying type, intended for hardfacing. With an unalloyed filler wire (OK Autrod 12.10) it produces a hardness of about 36 HRC.

OK Flux 10.16 is intended for cladding with Inconel strip, and is also used for joint welding of duplex and wire electrodes. We are not aware of any third-party equivalent of this flux on the market at present.

Iron powder

In order to increase the productivity of welding materials over 20 mm thick, additives in the form of cold materials such as iron powder or cold wire can be used in filling passes.

For the same energy input per unit length of weld, the addition of iron powder results in a smaller heat-affected zone than does conventional submerged arc welding, which is beneficial in respect of the strength of the weld. The energy input per unit length of weld reduces in proportion to the increasing amount of iron powder.

In comparison with submerged arc welding, productivity increases by almost 50%. This means that the labour cost of welding is correspondingly reduced. In addition, the length of time during which the workpiece is in the workshop is also reduced, resulting in financial savings.

Single-wire welding with separate addition of iron powder requires a backing strip or root pass in order to prevent the iron powder from running through the joint. Normally, it is not reasonable to expect that the joint is sufficiently tight to prevent the powder from running through. The powder requires a feed device, which is included in the range of ESAB A6 welding equipment. It consists of a feeder unit and a control unit, incorporating a display for direct readout of the quantity of powder.

Iron powder is usually alloyed with manganese (about 1.8%), although nickel-alloyed powder is also available.

OK Grain 21.85 consists of low-alloyed iron powder with a mesh size of 0.5–0.7 mm. When added to the weld, it assists welding in thick plates or where a high throat dimension is required in horizontal fillet joints, by enabling the weld to be filled with fewer passes. Penetration is reduced, which reduces the risk of burn-through at joint gaps and in the event of inadequately sized root faces. In some cases, the reduced penetration into the parent metal is an advantage.

5.4 Selection of filler materials

When making fabrication welds, the prime concern is to select a filler material, which produces a weld of the same material and structure as the parent metal. Naturally, it is not possible to demand exact similarity of analysis, as the requirements of weld metallurgy often necessitate the weld metal being deposited in a particular manner, while it is generally also the case that the composition of filler materials represents a compromise to allow them to be used with a relatively wide range of similar steels. However, the main principle is that the filler material should provide a weld, which in terms of mechanical strength, is at least as good as that of the rest of the material. Over the years, considerable experience of different diluted weld metals has been accumulated by both manufacturers and users of filler materials, but it is naturally always wise to perform initial trials in order to ensure that the filler material selected for use with the particular steel results in a joint having the required properties.

The following table indicates the most important types of OK Fluxes and filler wires for submerged arc welding, how they should be combined and for what materials they should be used.

Applications of various fluxes and wire types

FLUX	WIRE TYPE	APPLICATION
OK Flux 10.70 OK Flux 10.71 OK Flux 10.80 OK Flux 10.81	OK Autrod 12.10 OK Autrod 12.20	General structural steels, pressure vessel steels, elevated strength steels (max about 600 N/mm²-class)
OK Flux 10.61 OK Flux 10.62 OK Flux 10.71	OK Autrod 12.20 OK Autrod 12.24 OK Autrod 12.34	Low-alloyed steels, Domex, Ox etc.
OK Flux 10.91 OK Flux 10.92	OK Autrod 16.10 OK Autrod 16.30 Strip	18/8-steel 18/8 Mo-steel Cladding
OK Flux 10.96	OK Autrod 12.10 OK Autrod 12.40	Cladding HRC 32/40 Cladding HRC approx 46
OK Flux 10.71	OK Tubrod 15.40 OK Tubrod 15.42 OK Tubrod 15.52	Cladding HRC 27/34 Cladding HRC 35/44 Cladding HRC 55/60
OK Flux 10.61	OK Tubrod 15.74	Cladding HRC 45/65 Cr=11.5–14.5 %
OK Flux 10.16	Nickel base	
OK Flux 10.69		Backing flux for Cu bar

The effect of flux type on various weld properties and quality

CHARACTERISTICS	FLUX 10.40	FLUX 10.80	FLUX 10.81	FLUX 10.70 10.71	Flux 10.61	FLUX 10.62
Current tolerance	XXX	XXX	XX	XX	X	X
AC weld	X(X)	XX	XX	XXX	(X)	XXX
Pore safety	XXX	XX	XX	XX	XX	XX
Fillet weld characteristics	X	XX	XXX	XX	X	X
Bridging	X	XX	XXX	XX	XX	XX
Slag release	X	XXX	XXX	XX	XX	XX
Welding speed	XX	XX	XXX	XX	X	X
Weld appearance	XXX	XXX	XXX	XX	X	XXX
Crack safety	X	X	X	XX	XXX	XXX
Mechanical properties	X	X	X	XX(X)	XXX	XXX

X = NORMAL XX = GOOD XXX = VERY GOOD

6 WELD DEFECTS

Weld defects can, of course, occur with all types of automatic welding. They are largely the same as those encountered in manual welding. A common feature of weld defects that occur in automatic welds is that they generally occur relatively clearly and are therefore fairly easy to identify. If they are properly diagnosed, the chances are then much better of being able to deal with them. However, it should be borne in mind that welding data for a particular type of joint can be varied within only modest limits.

6.1 Types of weld defects

Apart from faults caused by excessive current densities, welding defects can be summarised by the following groups:

- Root defects
- Thermal cracks, pipe
- Surface pores (pinholes)
- Porosity
- Slag inclusions
- Undercutting

Root defects

Root defects are simply inadequate penetration of the cross-section of the joint. They reveal themselves on radiographic films as sharp straight lines. In the case of automatic welding, penetration in the joint is an important factor, and in those cases where root defects occur penetration can be said to have been inadequate.

If welding is carried out from two sides, and the two passes have not met at the bottom, the explanation may be that a joint shape has been used having too high a root face, insufficient joint angle or both, that the welding current has been too low, that the welding speed has been too high or too low ($v < 15$ m/h) or that the weld beads have not been deposited directly opposite each other.

The welding current is the variable that has the greatest effect on the depth of penetration as soon as welding speed exceeds about 15 m/h.

Hot cracks, pipes

Hot cracks are characterised by the fact that they normally occur in the middle of a weld, and then continue as an essentially straight line along the direction of the weld. Hot cracking can be so severe that, after welding, the workpiece is still in two pieces.

Hot cracks can occur in both butt welds and fillet welds.

Hot cracks occur at a temperature of 1 200 °C, and are sometimes caused by segregation phenomena that occur as the molten metal solidifies. These result in carbon and sulphur being concentrated along the centre line of the weld with the result that, at high temperature, the strength of the material in this area is greatly reduced. However, the cause of hot cracking in automatic welds is generally the result of pipe formation in combination with segregation of carbon and sulphur. Pipe formation occurs if the ratio of the width of the weld convexity and the depth of the weld, i.e. the form factor of the weld, is too low. For submerged arc welding, this form factor should be 1.0 or more. Cracking in such cases is due to shrinkage, rather than to cracking in the true meaning.

Hot cracking can be eliminated by forcing the weld to cool from the bottom towards the surface, so that the primary crystals are forced to grow diagonally upwards towards the surface of the weld, e.g. by welding against a heat-removing base. When welding thicker plates, hot cracking can occur if the rate of cooling is too high. Preheating may be required.

Pinholes

Pinholes are due to the release of gas (mainly hydrogen) during solidification of the metal, i.e. during primary crystallisation. The gas is unable to escape sufficiently easily from the weld metal, but is retained in the metal and acts as nuclei around which the metal solidifies. Pinholes form in the middle of the weld, running along it like a string of beads.

Pinholes usually occur in connection with high rates of crystallisation, i.e. in general if the welding speed is too high, and particularly if the parent metal is rusty or damp or if damp flux is being used. In addition, more pinholes will be formed with AC welding than with DC welding.

Pinhole formation can be reduced by reducing the speed of welding, carefully cleaning the surface of the weld joint prior to welding and drying it by preheating.

A relative of pinholes is the gas flats effect on the surface of the weld caused by gas inclusions between the weld and the slag cover. The reason for occurrence of these gas flats can be that the flux is damp.

Porosity

Pores are not visible on the surface of the weld. They are caused by gas coming out of solution in the weld as it solidifies. There are two types of pores. One occurs if the weld beads do not merge with each other satisfactorily. In this case, the gas from the solidifying melt comes from slag between the passes. Pores of this type are particularly likely to be encountered where one side of the joint has been manually welded, due to the fact that penetration will have varied and caused the manually-welded pass and the automatically welded pass to fail to meet at some points.

The second type of porosity occurs in fillet welds, if the gap between the web and flange has been too great. This can allow slag to collect, which will release gas.

In order to avoid porosity, care should be taken to ensure that the weld passes meet properly and, when performing fillet welding, to ensure particularly that the gap between the web and the flange is as small as possible. In addition, all metal surfaces should be carefully cleaned of rust.

Slag inclusions

Slag inclusions are uncommon in automatic welds. If they do occur, it is usually between the passes in multi-pass welds. When making such welds in thick plate, care must be taken to remove all traces of slag.

Undercutting

Undercutting occurs when welding speed is too high. Generally, undercutting is not a problem in the case of horizontally welded joints, but can be troublesome in connection with welding of upright fillet joints, where it occurs in the web.

Undercutting can be countered primarily by reducing the welding speed, and also by reducing the arc voltage.

Other defects

Particularly when the welding current is high – about 1100 A or more – submerged arc welding can result in uneven beads. This is caused by the arc penetrating the flux cover, with the result that the layer of molten slag above the weld is of uneven thickness. The reason for this effect is that the penetration is excessive for the wire size in use, causing the molten metal to be ejected over the edge of the joint and sometimes also causing lack of fusion.

At the arc voltages normally used for submerged arc welding, the current value for a particular wire size must not exceed a given value if these phenomena are to be avoided. If currents in excess of these values are to be used, it is necessary to change up to the next wire size.

6.2 Corrective measures

Undercutting

- Reduce the arc voltage
- Reduce the welding speed
- Increase the wire diameter and reduce the arc voltage
- Change the wire to negative polarity

Cracks in fillet welds

- Reduce the arc voltage
- Reduce the welding speed
- Increase the wire diameter and reduce the arc voltage
- Change the wire to negative polarity
- Preheat the work
- Change to a different wire material.

Cracks in I-joints

- Reduce the welding speed
- Check that the plates are securely fastened
- Make sure that there is no copper dilution from a root support

Poor penetration

- Increase the welding current
- Change the wire to positive polarity
- Reduce the arc voltage for fillet welds and V-joints
- Use a short stick-out
- Increase the joint angle of V-joints

Transverse cracks in multi-pass welding

- Increase the inter–pass temperature
- Reduce the welding speed
- Reduce the arc voltage
- Reduce current and voltage

Cracks in the root pass

- Reduce current and voltage
- Change the wire to negative polarity
- Increase the gap width
- Preheat the work
- Check that joint gouging on the reverse is not narrow and deep

Difficult slag removal in fillet welds or I-joints

- Change to a different grade of filler wire
- Increase the arc voltage
- Reduce linear welding speed
- Perform fillet welds in the vertical position if possible
- Remove mill scale, rust and dirt

Difficult-to-remove slag in deep or narrow joints

- Reduce the arc voltage
- Reduce current and voltage

Rust porosity

- Change to a different wire grade
- Increase the arc voltage
- Reduce welding current
- Change the wire to positive polarity
- Apply a gas flame ahead of the arc
- Clean the joint carefully
- Reduce welding speed

Organic porosity

- Change to a different wire grade
- Change the wire to positive polarity
- Reduce welding speed
- Carefully degrease the joint

Arc blow porosity

- Change to a different wire grade
- Change the wire to positive polarity
- Reduce the arc voltage
- Reduce current and voltage
- Increase wire diameter and reduce the voltage

Tracing and rectification of mechanical and electrical faults

Symptom	Fault	Rectification
Varying and unstable values of voltage and current.	Contact jaws worn or of incorrect size, resulting in poor electrical contact. Insufficient pressure on the pressure and feed rollers.	Fit new contact jaws.
Difficult to adjust arc voltage and welding current.	Oxidised control resistor.	Turn the resistor back and forth serveral times to remove oxide from the contact surfaces.
Abnormally rapid wear and burning of contact tips on bare or coated wire.	The pressure screw in the clamping sleev is slack, resulting in poor contact pressure and sparking between the wire and contact jaws.	Fit a new pressure screw.
Filler wire loose in the contact tips.	Contact jaws worn or of wrong size.	Fit new contact jaws, or adjust the existing ones.
Burnt or internally roughened contact tips.	Poor electrical contact between the jaws.	Clean the contact jaws: replace if badly burnt.
Uneven and jerky wire feed.	Too high or too low pressure on the feed roller. Wrong roller size or worn wire groove in the roller.	Adjust the roller pressure to normal value. check roller size or replace if necessary.
When using small-diameter wires, the wire twists and gets tangled.	The brake hub of the wire bobbin is too slack.	Tighten the brake hub adjusting nut until a suitable retarding force is obtained.
Overheating of the welding current cables.	Oxidised or slack connections. Welding cables undersized for the welding current.	Clean and tighten all terminals. If necessary to carry the current, fit an additional cable.

7 WELDING DATA TABLES

Welding data, butt joints

The following tables apply for DC welding, with the wire positive. For AC welding, the arc voltage should be about 2 V higher. It is typical welding data for submerged arc welding of C-Mn steel with OK Flux 10.70, OK Flux 10.71, OK Flux 10.80 and OK Flux 10.81. When using OK Flux 10.40, the arc voltage should be about 2 V higher.

Butt joints welded from both sides

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc voltage V	Welding current A	Welding speed cm/min
6	3–4	1	30–32	350–400	50–70
		2	31–33	400–450	50–70
8	3–4	1	30–32	450–500	60–70
		2	30–33	500–550	50–60
10	4	1	30–32	450–500	60–70
		2	31–33	550–600	60
12	4–5	1	32–35	600–650	60
		2	33–35	700–750	60–65
14	4–5	1	33–35	650–700	50–60
		2	33–35	750–800	40–50

Weld strength, typical values of all-weld-metal test pieces

OK Flux 10.40/ OK Autrod	Tensile yield strength N/mm2	Ultimate tensile strength N/mm2	Impact toughness J	Charpy V °C
12.10	370	470	60	-20
12.20	410	510	50	-20

Classification society approvals

OK Flux 10.40/ OK Autrod	ABS	LR	DnV	BV	GL	USSR
12.10	2TM	2TM	IITM	A2TM	2TM	2TM
12.20	2T, 3M 3YM	2T, 3M 3YM	IIT IIIYM	A2T A3YM	2T 3YM	K2T3M

Butt joints welded from both sides without a gap opening.

Typical welding data for submerged arc welding of low-alloy steels with OK Flux 10.61 and 10.62. Butt joints Welded from two sides without gap.

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc voltage V	Welding current A	Welding speed cm/min
6	3	1	29	300–350	60–67
		2	30–31	375–425	60–67
8	3	1	30–31	450	60–67
		2	31–32	500	65–67
10	4	1	30–31	500	60–67
		2	30–32	575–600	60–67
12	4	1	30–32	600	60
		2	30–32	650	60

Weld strength, typical values of full test pieces.

OK Flux 10.62/ OK Autrod	Yield strength N/mm2	Ultimate tensile strength, N/mm2	Impact toughness J	Charpy V °C
12.22	420	510	100/50	-40/-60
12.24	520	600	50/-	-40/–
12.32	470	570	100/70	-40/-60
12.34	580	660	100/60	-40/-60
13.10	430	560	200	+20
13.20	450	590	100	+20
13.21	470	560	120/60	-40/-60
13.27	500	570	120/80	-40/-60
13.40	630	700	60/40	-40/-60
13.43	710	800	70/50	-40/-60

Welding data, butt joints, V-Joints, X-Joints

Typical welding data for submerged arc welding of C-Mn steel with OK Flux 10.40, OK Flux 10.70, OK Flux 10.71, OK Flux 10.80 and OK Flux 10.81.

V-joints, 60`, with 8 mm root face

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc voltage V	Welding current A	Welding speed cm/min
16	4–5	1	32–34	700–750	40–45
		2	33–36	650–750	40–45
18	5–6	1	32–34	800–850	37–40
		2	36	850	45
20	5–6	1	32–34	925	30
		2	34–36	850	42–46

X-joints, 70`, with 6–8 mm root face

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc voltage V	Welding current A	Welding speed cm/min
18	5–6	1	33–34	700–750	50
		2	34–36	800–850	50
20	5–6	1	34–36	750–800	42
		2	34–36	800–850	42
25	5–6	1	34–36	750–850	33
		2	34–36	900–950	33
30	5–6	1	32–36	900	25
		2	34–36	1000	25

NB: 30 mm plate should be welded with two passes from each side in the interests of impact toughness etc. This means that welding parameters will differ from those shown in the table above.

Welding data, fillet welds

Guide values for submerged arc welding of fillet welds in unalloyed and C-Mn welding structural steels with OK Flux 10.70 and 10.81.

One welding head

Plate thickness mm	Wire diameter mm	Throat thickness mm	Arc voltage V	Welding current A	Welding speed cm/min
6	3	3	26–28	450	75
8	4	4	28–30	575	70
10	4	5	28–30	650	60

One welding head, positional welding, horizontal

Plate thicknessm m	Wire diameter mm	Throat thickness mm	Arc voltage V	Welding current A	Welding speed cm/min
8	4–5	4	32–34	750–800	83
12	5	6	32–34	850	60
15	5–6	7	33–35	850–875	42–45

Twin-wire

Plate thickness mm	Wire diameter mm	Throat thickness mm	Arc voltage V	Welding current A	Welding speed cm/min
–	2x2.5	4	26–28	800	110
–	2x2.5	5	26–28	800	75

Two welding heads, AC welding

Plate thickness mm	Wire diameter mm	Throat thickness mm	Arc voltage V	Welding current A	Welding speed cm/min
–	4	4	+29	550	125
			~34	630	
–	4	5	+29	550	120
			~34	630	

Welding data for stainless steel

Welding data for submerged arc welding of 18/8 stainless steel: joint types and guide values. Filler materials OK Autrod 16.10, OK Flux 10.91 and OK Flux 10.92.

I-joints

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc voltage V	Welding current A	Welding speed cm/min
6	3	1	30–32	350	60–70
		2	32	400–450	60–70
8	4	1	32–33	450–500	60–70
		2	34	550	60

V-joints, 60°, with manually welded bottom pass, 0–2 mm gap, 2 mm root face

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc voltage V	Welding current A	Welding speed cm/min
10	3–4	1	28–30	350–500	40–65
		2	32–33	400–550	
12	3–4	1	28–30	350–500	
		2–3	32–34	400–550	
20	4	1	28–30	350–550	
		2	32–34	400–550	
		3–5	32–34	400–550	

X-joints, 70°, 4–5 mm root face

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc voltage V	Welding current A	Welding speed cm/min
12	4	1	32–34	500	60
		2	32–34	600	60
14	4	1	32–34	550	50
		2	32–34	600	50

X-joints, 60°, with manually welded root pass, 0–2 mm gap, 2 mm root face

Plate thickness mm	Wire diameter mm	Weld pass no.	Arc Voltage V	Welding current A	Welding speed cm/min
25	4	1	28–30	550–600	60
		2	32–34		50
		3–4	32–34		50
		5	28–30		50
		6	30–32		50
		7–8	32–34		50–60

8 PRACTICAL ADVICE

- Check that feed rollers, contact jaws and contact tips are of the right size.
- Ensure that the wire is properly aligned, in order to prevent abnormal wear of the contact jaws and contact tips. Worn or burnt contact jaws will result in unstable welding and varying values of voltage and current. If the grooves in the feed roller are worn, wire feed will be jerky.
- When using DC for fabrication welding, the positive pole must be connected to the filler wire.
- Maintain the distance between the workpiece and contact tip at 25–35 mm.
- Cut off the end of the wire on the diagonal to ensure good ignition when starting to weld. The sharp tip helps the wire to penetrate mill scale and any pieces of slag.
- Ensure that the return current conductor is in good electrical contact with the workpiece.
- Position all cables so that they cannot interfere with the welding process.
- Do not use a higher air pressure for flux recovery than necessary. Too high an air pressure can break the grains and cause dust.
- Contact jaws and contact tips must be regarded as consumables.
- When welding small-diameter round workpieces, use a flux feed funnel instead of a flux tube. This will provide improved control of the flux bed, thus reducing wastage of the flux from the weld.
- Take the same care of automatic welding machines as of other workshop equipment.
- For best welding performance, ensure that all surfaces to be welded are free from mill scale etc.

9 LITERATURE

PT. Houldcroft: "Submerged arc welding", Woodhead Publishing Ltd.

N.A. Kennedy: "Narrow-gap submerged arc welding of steel – a technical review", Metal Construction 1986.

ESAB subsidiaries and representative offices

Europe

AUSTRIA
ESAB Ges.m.b.H
Vienna-Liesing
Tel: +43 1 888 25 11
Fax: +43 1 888 25 11 85

BELGIUM
S.A. ESAB N.V.
Brussels
Tel: +32 2 745 11 00
Fax: +32 2 726 80 05

THE CZECH REPUBLIC
ESAB VAMBERK s.r.o.
Prague
Tel: +420 2 819 40 885
Fax: +420 2 819 40 120

DENMARK
Aktieselskabet ESAB
Copenhagen-Valby
Tel: +45 36 30 01 11
Fax: +45 36 30 40 03

FINLAND
ESAB Oy
Helsinki
Tel: +358 9 547 761
Fax: +358 9 547 77 71

FRANCE
ESAB France S.A.
Cergy Pontoise
Tel: +33 1 30 75 55 00
Fax: +33 1 30 75 55 24

GERMANY
ESAB GmbH
Solingen
Tel: +49 212 298 0
Fax: +49 212 298 204

GREAT BRITAIN
ESAB Group (UK) Ltd
Waltham Cross
Tel: +44 1992 76 85 15
Fax: +44 1992 71 58 03

ESAB Automation Ltd
Andover
Tel: +44 1264 33 22 33
Fax: +44 1264 33 20 74

HUNGARY
ESAB Kft
Budapest
Tel: +36 1 20 44 182
Fax: +36 1 20 44 186

ITALY
ESAB Saldatura S.p.A.
Mesero (Mi)
Tel: +39 02 97 96 81
Fax: +39 02 97 28 91 81

THE NETHERLANDS
ESAB Nederland B.V.
Utrecht
Tel: +31 30 248 59 22
Fax: +31 30 248 52 60

NORWAY
AS ESAB
Larvik
Tel: +47 33 12 10 00
Fax: +47 33 11 52 03

POLAND
ESAB Sp.z.o.o
Warszaw
Tel: +48 22 813 99 63
Fax: +48 22 813 98 81

PORTUGAL
ESAB Lda
Lisbon
Tel: +351 1 837 1527
Fax: +351 1 859 1277

SLOVAKIA
ESAB Slovakia s.r.o.
Bratislava
Tel: +421 7 44 88 24 26
Fax: +421 7 44 88 87 41

SPAIN
ESAB Ibérica S.A.
Alcobendas (Madrid)
Tel: +34 91 623 11 00
Fax: +34 91 661 51 83

SWEDEN
ESAB Sverige AB
Gothenburg
Tel: +46 31 50 95 00
Fax: +46 31 50 92 22

ESAB International AB
Gothenburg
Tel: +46 31 50 90 00
Fax: +46 31 50 93 60

SWITZERLAND
ESAB AG
Dietikon
Tel: +41 1 741 25 25
Fax: +41 1 740 30 55

North and South America

ARGENTINA
CONARCO
Buenos Aires
Tel: +54 11 4 753 4039
Fax: +54 11 4 753 6313

BRAZIL
ESAB S.A.
Contagem-MG
Tel: +55 31 333 43 33
Fax: +55 31 361 31 51

CANADA
ESAB Group Canada Inc.
Missisauga, Ontario
Tel: +1 905 670 02 20
Fax: +1 905 670 48 79

MEXICO
ESAB Mexico S.A.
Monterrey
Tel: +52 8 350 5959
Fax: +52 8 350 7554

USA
ESAB Welding & Cutting Products
Florence, SC
Tel: +1 843 669 44 11
Fax: +1 843 664 44 58

Asia/Pacific

AUSTRALIA
ESAB Australia Pty Ltd
Ermington
Tel: +61 2 9647 1232
Fax: +61 2 9748 1685

CHINA
Shanghai ESAB A/P
Shanghai
Tel: +86 21 6539 7124
Fax: +86 21 6543 6622

INDIA
ESAB India Ltd
Calcutta
Tel: +91 33 478 45 17
Fax: +91 33 468 18 80

INDONESIA
P.T. Esabindo Pratama
Jakarta
Tel: +62 21 460 01 88
Fax: +62 21 461 29 29

MALAYSIA
ESAB (Malaysia) Snd Bhd
Selangor
Tel: +60 3 703 36 15
Fax: +60 3 703 35 52

SINGAPORE
ESAB Singapore Pte Ltd
Singapore
Tel: +65 861 43 22
Fax: +65 861 31 95

ESAB Asia/Pacific Pte Ltd
Singapore
Tel: +65 861 74 42
Fax: +65 863 08 39

SOUTH KOREA
ESAB SeAH Corporation
Kyung-Nam
Tel: +82 551 289 81 11
Fax: +82 551 289 88 63

UNITED ARAB EMIRATES
ESAB Middle East
Dubai
Tel: +971 4 338 88 29
Fax: +971 4 338 87 29

Representative offices

BULGARIA
ESAB Representative Office
Sofia
Tel/Fax: +359 2 974 42 88

EGYPT
ESAB Egypt
Dokki-Cairo
Tel: +20 2 390 96 69
Fax: +20 2 393 32 13

ROMANIA
ESAB Representative Office
Bucharest
Tel/Fax: +40 1 322 36 74

RUSSIA-CIS
ESAB Representative Office
Moscow
Tel: +7 095 937 98 20
Fax: +7 095 937 95 80

ESAB Representative Office
St Petersburg
Tel: +7 812 325 43 62
Fax: +7 812 325 66 85

Distributors

For addresses and phone numbers to our distributors in other countries, please visit our home page

www.esab.com

ESAB AB
SE-695 81 LAXÅ
SWEDEN
Phone +46 584 81 000
Fax +46 584 123 08

www.esab.com

021008