5 MIG/MAG welding

Until the 1970s, manual metal arc was the most dominant method of welding. Today MIG/MAG is the obvious leading contender in most industrial countries. Gas metal arc welding (GMAW) can also be referred to as MIG (metal inert gas) if the shielding gas is inert as for example argon or MAG (metal active gas) if the gas has a content of an active gas such as CO₂.

5.1 Equipment

Figure 5.1 The principle of MIG/MAG welding.

Figure 5.1 shows the principle of MIG/MAG welding. The arc (1) is struck between the workpiece and a metal wire electrode (2) that is continually fed forward into the arc. The wire is supplied on a reel (3), and is fed to the welding gun by the drive rollers (4), which push the wire through a flexible conduit (5) in the hose package (6) to the gun (7). Electrical energy for the arc is passed to the electrode through the contact tube (9) in the welding gun. This contact tube is normally connected to the positive pole of the power source, and the workpiece to the negative pole. Striking the arc completes the circuit. The gas nozzle (11) that surrounds the contact tube (9) supplies shielding gas (10) for protection of the arc and the weld pool (12).
Figure 5.2 Equipment for MIG/MAG welding (ESAB).

**Wire feed unit**

The wire reel is placed on a brake hub with adjustable friction. The intention is to stop rotation when the feeding has stopped in order to keep the wire in place. The electrode is passed to the drive rolls, which then push the wire through the hose package. Even in normal use it is common for the friction to vary, e.g. when the curvature of the hose is changed or when particles or dirt fill up the wire conduit. The wire speed must not vary too much, otherwise this could result in unwanted variations in the welding data. Superior control of the wire feed speed can be achieved if the motor is equipped with a pulse-generator and feedback system.

Figure 5.3 Heavy duty 4 drive roll assembly.

The drive rolls have a trace that fits to the wire. Therefore it may be necessary to change the rolls when the wire is changed. The number of driven rolls influence the feeding force that can be achieved.
Figure 5.4 Drive rolls with different types of traces are used. For soft electrode material as aluminium, U-type traces are recommended.

Welding gun and feeding properties

The welding gun with hose package, see Figure 5.5, is an essential part of the welding equipment. It brings the shielding gas, electrode and welding current to the arc. It is difficult to design a robust welding gun for this tough environment but at the same time make it small and light enough to be acceptable for working in narrow spaces.

Experience shows that careful maintenance is necessary to avoid disturbances that could occur from constant hot and heavy operation.

- At higher welding data the heat from the arc increases. It is important to choose the proper size of gun to avoid temperature overload.
- Keep the gun free from spatter. Spatter will catch easier to a hot surface.
- Use a water-cooled gun when necessary.
- Choose a proper wire extension. Too short distance will increase the risk for burn-back of the arc. That will also increase the heat take up from the arc.
- Carefully choose the clearance between wire and the diameter of conduit. Small clearance increases the risk for stoppage and too big will give irregular feeding.
- When feeding problems occur, the reason could be that metal particles from the wire have increased the friction in the conduit. Just to stretch the pressure between the feeder rolls is not always the best action. To avoid future problems it is recommended to blow it clean now and then.
- For the most critical usage, such as extra long hose package or the use of soft aluminium wires, a push-pull wire feeder is recommended, see Figure 5.6.
The difference between a push and push-pull wire feed system. In a push or pull wire system friction is built up and increased in every curve of the conduit. This is avoided by the use of a push-pull system.

**Power source**

DC power sources, with relatively straight characteristics, are used for MIG/MAG welding. See also the section about power sources: page 13.

- Controlled by a stepping switch. Tap-changer rectifier units have been traditionally used, and are the most common type.

- Thyristor-controlled rectifier units are larger and somewhat more advanced: the most advanced types are inverter power sources.

- Inverter power sources have the most advanced design. In addition to their generally good characteristics and control facilities, inverters are often used for welding aluminium and stainless steel, which benefit from the use of pulsed MIG welding.

**Cooling units**

Water-cooled welding torches are often used in the higher current range (300-500 A). Cooling water is circulated from a cooling unit, which may be separate or be incorporated in the power source. The water cools the copper conductor in the hose and cable bundle, the gas nozzle and the contact tip. Cooling units normally include a water container, a pump and a fan-cooled radiator.

### 5.2 Setting of welding parameters

The MIG/MAG welding process is dependent on a number of welding parameters:

- Electrode diameter
- Voltage
- Wire feed speed and current
- Welding speed
- Inductance
- Electrode stick-out
- Choice of shielding gas and gas flow rate
- Torch and joint position

Most of these parameters must be matched to each other for optimum welding performance. The *working point* must be within the working range or *tolerance box* for the particular welding situation.
**Electrode diameter**

The size of electrode is chosen according to welding current, but in opposition to covered electrodes each electrode has a large and overlapping range of current. As a rule, the material transfer is smoother with a thinner electrode. When welding with soft aluminium wire, the risk of feeding problem can be reduced with a thicker electrode.

**Voltage**

Increased voltage increases the arc length and gives a wider weld bead. Undercut is a sign of too high a voltage. If short arc welding is used a higher voltage reduces the short circuit frequency, which will give larger drops and more spatter.

Too low voltage, on the other hand, will increase the risk for stubbing and bad start performance.

On thin plates short arc welding gives the possibility of high welding speed without burn through. Normally the voltage here is adjusted to a low setting but only where the short circuit frequency is still high and the arc stability good.

**Wire feed speed and current**

Current is set indirectly by the wire feed speed and diameter. Current is the main parameter for welding and has to be chosen to plate thickness and welding speed with respect to the weld quality.

**Welding speed**

Welding speed has also a considerable effect on shape and penetration of the weld, see Figure 7.6 on page 74.

**Inductance**

It is often possible to adjust the inductance of the power source to fit the wire size and to give the right welding properties. The most sensitive is short arc welding. A low value gives a distinct and concentrated arc but the spatter will increase. A higher value gives a softer behaviour, a somewhat wider bead and a softer sound. Too high inductance gives bad stability with a tendency for stubbing.

**Electrode extension**

Easiest to measure is the contact tip distance from the joint surface, (see Figure 5.7). A rule of thumb says that a normal distance is 10–15 x diameter of the electrode. Too small stick-out increases the risk of burn-back, where the arc will weld the electrode together with the contact tip. Too long a distance to the workpiece will increase the risk for stubbing, especially at the start.

The contact tip-to-work distance also has an influence on the current and penetration profile. If the electrode extension is increased the current and heat input decreases while the amount of deposited metal remains. This reduces the penetration, and if it was unintentional a risk for lack of fusion appears. A good rule is therefore to keep the wire stick-out constant during the welding operation.
Choice of shielding gas

Mixtures of argon with 5–20 % carbon dioxide (CO₂) are most popular for the welding of mild and low alloyed steels. For spray and pulsed arc welding, a low content of CO₂ can be an advantage. Pure CO₂ is an alternative for short arc welding that gives good penetration and safety against lack of fusion but increases the amount of spatter.

For stainless steels argon is also used but with only small additions of CO₂ or oxygen (O₂).

For welding of aluminium, copper and copper alloys normally pure argon or argon helium mixtures are used. Helium increases the heat input, which will compensate for the large heat conduction in thick walled aluminium or copper.

Gas flow rate

The gas flow must be adapted to the arc. At low current it can be enough with 10 litres per minute while at higher welding data up to 20 litres may be required. Welding in aluminium needs more gas than steel does.
Torch and joint position

Angles of the torch relative to the joint are also an important welding parameter. If it's directed away from the finished part of the weld (*forehand technique*), it will make the penetration profile more shallow and the width of the seam wider, see Figure 5.8. On the other hand, if it's directed towards the finished part of the weld (*backhand technique*), the penetration will be deeper and the seam width narrower.

The angle of the torch in the section across the welding direction has a direct influence on the risk for lack of fusion. See Figure 5.9.

![Figure 5.9 Gun angle and position across the welding direction at fillet welding. The electrode is on such thickplates often positioned 1–2 mm offset on the base plate. That will compensate for the higher heat dissipation in the base plate and gives a symmetrical penetration profile.](image)

If the plate to be welded is not totally horizontal but has an inclined joint, it will affect the weld contour and penetration profile. By welding downhill, the weld reinforcement can be lower and the welding speed will usually increase. At the same time, the penetration is lower and weld bead wider. This is beneficial for welding sheet metal. Uphill welding causes the weld pool to flow back and form a high and narrow weld.

To reduce the risk of lack of fusion it is essential to prevent the melted metal from flowing too much before the arc. This can be the case when welding with high heat input, a large pool and welding with too much forehand or in downhill position.

Contact tip-to-work distance, (see Figure 5.7), should be kept constant when welding.

5.3 Consumables

MIG/MAG welding is used for mild steel, low alloyed and stainless steel, for aluminium, copper and copper alloys, and nickel and nickel alloys etc. Plate thicknesses down to 0.7 mm can be welded. There is no technical limitation upward, but the risk for cold laps at low heat input or oversized pool will increase. The filler material has often a chemical composition that is similar to that of the base material.

Filler wires

The electrodes for MIG/MAG welding are available in the 0.6–2.4 mm range for use with many different types of materials. Wires are normally supplied on reels and wound to ensure that the wire does not snag when being withdrawn. Important factors are that it must be clean with a smooth finish to feed easily and free from metal flaws. Best feeding
performance have wires coated with a thin layer of copper. One important condition is that the copper is well fixed to the wire, if not, it will clog up the wire conduit and prevent smooth feeding of the wire.

To get the most effective performance from the arc, it is essential that the current will be transferred to the electrode close to the opening of the contact tip. To improve the contact force and to define the contact point the electrode is somewhat curved, i.e. it has a radius of 400–1200 mm, see Figure 5.10. The helix size should not exceed 25 mm, if problems with arc wandering are to be avoided.

![Figure 5.10 Checking cast diameter (1) and helix size (2).](image)

The electrode is normally delivered on 10–15 kg coils (steel) but for large consumption a container of about 200 kg can be ordered.

**Solid or cored wires?**

One can distinguish between solid wires and cored wires. The latter type consists of a metallic outer sheath, filled with flux or metal powder, as shown in Figure 5.11. The flux cored wires can have either a rutile or basic filling. They can also be self-shielded for use without shielding gas.

The cost per unit of cored wire is considerably higher than that of solid wires, but they are in some respects superior to solid wire. Cored wires are mainly used for somewhat thicker plates. High deposition rate and good side wall penetration characterise cored wire. Basic flux cored wires have similar performance to that of basic manual stick electrodes giving a tough and crack resistant weld metal.

![Figure 5.11 Cross section of solid and cored wire.](image)

**Welding technology**

The stability of a DC arc with a consumable electrode (i.e. a filler wire) depends largely on how the molten metal is transferred in the arc. One can distinguish essentially between two different types of arcs, depending on the material transport: the spray arc and the short arc (short-circuiting arc).
Spray arc welding
Spray arcs are characterised by the transfer of molten material in the form of many small droplets, the diameter of which is less than that of the filler wire. As there are no short circuits, the arc is stable and spatter-free. A prerequisite for successful spray arc welding is that the values of current and voltage should be over certain limits. This, in turn, means that more heat is supplied to the workpiece than with short arc welding, and so only materials of 5 mm thick or more are suitable for spray arc welding. The high heat input means that the weld pool is also large, so welding has to be performed in the horizontal position. It should be noted that a pure spray arc cannot be obtained when using CO₂ as the shielding gas: the shielding gas must be pure argon or (preferably) with a small proportion of CO₂ (not more than 25 %) or O₂. Spray arc welding is particularly suitable for MIG welding of aluminium and stainless steel, for which the shielding gas is mainly argon.

With a thin filler wire, it is possible to perform successful spray arc welding at lower currents than with a thicker filler wire.

The arc voltage should be set at such a value that it is just sufficiently high to maintain a short-circuit-free arc. The filler wire is normally connected to the positive pole.

Short arc welding
The heat input from short arc welding is low, which makes the process suitable for welding in thinner materials. The drops from the electrode dip into the weld pool. The arc is therefore periodically replaced by a short-circuiting bridge of molten metal.

This can be repeated up to 200 times per second. If the short-circuit current is too high, it has a considerable effect on the pinch-off forces, causing weld spatter. Some means of limiting the short-circuit current must therefore be provided in the power unit, e.g. through the use of an inductor coil.

It is not easy, with short-arc welding, to achieve a completely stable arc. The best way to judge if the welding is going well is by the noise of the arc. The objective is to
achieve a consistent, high short-circuiting frequency, resulting in small droplets being transferred to the workpiece and spatter droplets being so fine that they do not adhere to the workpiece. Good welding characteristics in the power source are necessary, although wire feed speed, current transfer in the contact tip and the welder's skills are also important.

![Figure 5.13 Droplet short-circuiting with a low inductance in the power unit. a) Arc period. b) Drop transfer. c) Low inductance setting gives high short circuit current and spatter is developed when the short circuit breaks.](image)

Ignition of the arc can also be sensitive, and therefore it is important that all parts of the equipment should be in good condition in order to avoid irritating chattering when striking the arc.

### Globular transfer

At currents lower than needed for spray transfer and with voltage above pure short arc welding there is a mixed region characterised with droplets larger than the electrode diameter and often with an irregular shape. The molten drop grows until it detaches by short-circuiting or by gravity. The globular transfer mode is most often avoided.

### Pulsed MIG welding

Pulsed arc welding is used mainly for welding aluminium and stainless steel, although it can also be used for welding ordinary carbon steel. The method of controlling the transfer of the droplets by current pulses (30–300 Hz) from the power source makes it possible to extend the spray arc range down to low welding data. The process provides a stable and spatter-free arc as a welcome alternative to short arc welding.

The pulses serve two purposes: supplying heat to melt the filler wire, and also to pinch off just one molten droplet for each pulse. This means that, as the wire feed speed increases, the pulse frequency must also increase. This will result in keeping the droplet volume constant at all times. A low background current contains the arc between the pulses. Although the current amplitude in each pulse is high, the average current – and thus the heat input to the joint – can be kept low.

Pulses from the power source pinch off the drops from the electrode at the same speed as the electrode is fed. Therefore it is possible to avoid short circuits and spatter generation. Whilst short arc welding is normally the most suitable method for thin sheet carbon steels, pulsed arc is often the best choice for stainless steels or aluminium. Modern electronic inverter power sources are able to calculate the pulse shape needed for the actual choice of electrode size, material and shielding gas and the pulse frequency needed to keep the arc length constant.
The stable and controlled drop transfer with pulsed arc allows the use of an increased electrode diameter. This is utilised in aluminium welding where the electrode is difficult to feed because of its softness.

![Diagram showing pulse current and background current over time](image)

**Figure 5.14 Naming of the pulse parameters.**

**Advantages**

- The process is fully controlled and spatter-free.
- The ability to extend spray arc welding down to lower welding data is particularly suitable when welding materials such as stainless steel or aluminium. It becomes possible to weld thin materials, or to perform positional welding, with better results than would be obtained with short arc welding.
- Pulsed arc welding is sometimes used within the normal spray arc range in order to provide better penetration into the material.
- Stable welding performance can also be achieved with a somewhat thicker filler wire. This is useful when welding aluminium, as it is difficult to feed thin filler wires due to their softness.
- Recent work indicates that the efficient droplet pinch-off reduces overheating of the droplets, resulting in less fume production.

**Disadvantages**

- Production speed is generally lower than with short arc welding. The greater heat input, relative to that of short arc welding, reduces the maximum usable wire feed speed.
- Pulsed arc welding restricts the choice of shielding gases. As with spray arc welding, the CO₂ concentration of an argon/CO₂ mixture must not be too high: the usual 80/20 % gas mixture, as used for short arc welding, represents the limiting value.

Pulsed welding restricts the choice of shielding gases. As for spray arc welding, the CO₂ concentration in an Ar/CO₂ mixture must not be too high. Common 80/20 mixed gas, as used for short arc welding, represents a limit value.
Cored wire welding

The use of flux cored arc welding (FCAW) appeared as early as the 1920s, although at that time it was only in connection with the application of wear-resistant cladding. It was easy to produce high-alloy filler materials by mixing the alloying constituents in powder form inside a cored unalloyed steel electrode.

There are today two main types of cored wires:

- Wires that require the use of shielding gas, usually CO₂ or Ar/CO₂ mixture.
- Wires that do not require additional shielding gas, known as self-shielded flux cored wires.

Equipment

Essentially the same equipment is used for cored wire welding with shielding gas as for ordinary MIG/MAG welding. However, the welding torch, the wire feed unit and the power source all need to be more powerful due to the higher current density and the thicker wire. Welding is usually carried out using DC, with the filler wire connected to the positive pole. The power source characteristic is generally slightly drooping, which gives a self-regulating arc.

When carrying out cored wire welding without a shielding gas (self-shielding), the same power source and wire feed unit are usually used as would be used for welding with shielding gas. However, the welding torch can be simpler, as there is no need for a gas supply.

Fume is a problem when welding with high current, not least when using self-shielded flux cored wires. One solution to this problem is to use a welding torch with an integral extraction connection.

Structure and characteristics of cored wires

A cored filler wire consists of an outer tube of unalloyed steel, filled with powder. The composition of this powder differs for different types of wires. The proportion of filler powder can also vary, depending on differences in the wall thickness.

We distinguish between metal-cored arc welding (MCAW) and flux-cored arc welding (FCAW) wires.

Figure 5.15 A section through different types of cored filler wires.

The function of the powder fill

The powder fill affects the welding characteristics and the metallurgical analysis of the weld material. Wires can be optimised for a range of characteristics by varying the composition of the powder.

- Refining of the weld metal is achieved through the addition of anti-oxidising elements such as manganese or silicon.
Slag-forming elements are added in order to protect the weld while it is solidifying, to control the shape of the weld metal and to improve positional welding performance.

Arc-stabilising additives produce a stable, spatter-free arc.

Alloying elements such as nickel, chromium, molybdenum and manganese can be incorporated in the powder in order to modify the mechanical and metallurgical properties of the weld.

Adding metal powder alone produces a slag-free cored wire that has a higher productivity than a flux-cored wire.

The two slag systems used for cored wires are basic and rutile. The rutile type produces a spray arc, the best welding characteristics and the best positional welding performance. Today, rutile cored wires produce equally good mechanical properties as do basic cored wires, while at the same time producing little hydrogen entrainment in the weld metal. Typical hydrogen concentrations lie between 3 and 10 ml/100 g of weld metal.

The metal powder-filled cored wires contain a powder that consists mainly of iron and alloying elements. The only slag formed is in the form of small islands of silicon oxide. These wires have a high productivity in the horizontal position.

Flux-cored wires are best suited for positional welding, as the slag provides better control of the weld pool. In comparison with solid wires, cored wires are also regarded as producing somewhat less risk of poor fusion.

Self-shielded flux cored wires are filled with a powder that develops gases to protect the weld pool. This is done by means of appropriate additives which are gasified in the arc. The resulting substantial expansion excludes the surrounding air from the arc and weld pool.

Cored wires are manufactured from 0.8 mm upwards in diameter, with the commonest sizes being 1.2, 1.4 and 1.6 mm. The range of weld metal grades is wide, and is constantly increasing. In particular, the range of cored filler wires for use with stainless steel has increased.

Welding speed is higher with cored wires than when using coated electrodes (MMA). As the current flows through the outer wall of the wire, current density is higher, with a correspondingly higher rate of melting of the metal.
Applications
The use of cored wire electrodes is increasing in parallel with the introduction of new types of wire. They are used, for example, for:
- sheet thicknesses from 4 mm and upwards.
- both butt and fillet welds.
- manual welding in all positions.
- robot welding in the horizontal position.

The benefits of cored filler wires are:
- high deposition rate as a result of the high current density.
- ease of varying the alloying constituents.
- stabilising substances in the powder extend the range of usable welding data.
- basic electrodes are tolerant of contamination in the material, producing a tough, crack-resistant weld.
- better transverse penetration than with solid filler wires.

The drawbacks of cored filler wires are:
- Self-shielded wires produce relatively large quantities of fume.
- A higher price than for solid wires (does not necessarily mean a higher total cost).
- Troublesome thermal radiation at higher welding currents.
- Finishing work required when using slag-forming wires.

High productivity gas metal arc welding with solid wires

Single-wire methods
The productivity of mechanised MIG/MAG welding, using conventional solid filler wires, has constantly improved in recent years. One of the leaders in this development was Canadian John Church, who launched the TIME method (Transferred Ionized Molten Energy). Compared to conventional MAG welding, this method intentionally uses a long, high-current filler wire stickout. Resistive heating means that the wire is preheated, thus permitting a higher rate of feed without a corresponding increase in the current.

The TIME method includes a special patented 4-component shielding gas. The AGA and Linde welding companies have investigated the method, and further developed it for use with other gas mixtures, calling the resulting processes Rapid Processing™ and Linfast® respectively.

The higher feed speed results in a higher productivity: in some cases, at a rate of up to 20 kg/h of deposited weld metal. Linear welding speed can be twice that of conventional MIG welding, while producing the same appearance of the weld bead and penetration profile. Different types of arc are used: perhaps the commonest is a type of forced short arc that is within the range covered by conventional welding equipment.

Under certain conditions, a rotating arc is produced when welding at higher welding data. The high productivity, in combination with a higher current and larger weld pool, mean that welding must be carried out in the most favourable horizontal position.
Tandem and twin wire welding
Another way of improving productivity and raising the welding speed is to use double filler wires. Both wires can be connected to the same power unit, which means that they share a common arc. This method goes under the name of Twin Arc. Alternatively, if two power units are used, the method is referred to as Tandem Welding. Nevertheless, the two wires are so close to each other they weld into a common weld pool.

Welding with two wires can increase the speed to at least twice the normal value or, when welding thin sheet, even higher. In some applications, linear welding speed can be up to 6 m/min.

Setting the welding current and voltage can be much more complicated when two wires are used, particularly with tandem welding as it is necessary to set the welding data separately for each wire. Because the two arcs are close to each other, they can sometimes interfere through magnetic arc blow effect. Therefore this process often uses pulsed welding, with the pulses on each wire displaced out of phase with each other.

Arc spot welding
This is a MIG/MAG method intended to produce spot welds. The welding torch has a gas nozzle with support legs, and the welding time is controlled by a timer. The resulting welds are often overlap joints, as produced by conventional resistance spot welding. However, in this case, the workpiece does not need to be accessible from both sides. The support legs provide the correct wire stickout, and also serve to some extent in pressing the two pieces of metal into contact with each other.

Welding data (voltage and wire feed) are considerably higher than what is usual for the particular metal thickness concerned. The welding time is controlled to produce a through-weld within a relatively short time, generally less than one second. This produces a low convexity with good coverage, without burning a hole in the upper piece of metal.
In comparison with continuous welding, the process has the following advantages:

- Less heating and distortion.
- Very simple to operate: simply position and press.
- Lower, better-shaped convexity, particularly when welding thin sheet.

As the welding process is short but intensive, the method is less sensitive to welding position, imbalance in the metal thicknesses, gap width variations etc., and can therefore be used when such effects would otherwise make it difficult to produce successful continuous welds.

The welding environment

As with other arc welding processes, the welder is exposed to various health risks. These include fumes and gases, as well as ultraviolet radiation from the arc. Spatter is not a particularly serious problem, as long as it is in the form of very small particles. Perhaps the commonest problem is that of minor burns from the radiation, or from some errant drop of molten metal. It can be difficult to work with high welding data during the summer, as welders need to wear full protective clothing. For manual welding, the maximum usable current, as determined by the amount of heat generated, is about 400–500 A.

MIG/MAG welding seldom gives rise to health problems, although it is important to be aware of the risks.

Fumes and gases

On average, the fume produced by MIG/MAG welding is less than that produced by the use of coated electrodes. The fume consists of solid airborne particles, often metal oxides from the electrode or from any surface coating on the workpiece. Oil fume is also formed if the workpiece is oily or greasy.

The normal protective measures consist of good ventilation, preferably in the form of local extraction immediately above the weld, and attempting to avoid breathing in direct fume from the weld. Particular care should be taken in certain cases:

- If unusually large amounts of fume are produced. Cored wire containing flux, and being welded with high welding data, can produce substantial quantities of fume.
• Ozone is formed for example when MIG welding aluminium at high currents and with a high-radiancy arc. Note, however, that shielding gases are available that actively help to break down the ozone. Avoid welding in the presence of chlorinated hydrocarbon solvents (e.g. trichlorethylene): a chemical reaction can produce phosgene, which is poisonous and damages the lungs.

• The fume from aluminium can cause damage to the nervous system.

• The fume produced when welding stainless steel contains chromium or nickel. A low hygienic limit is set for this fume, as it is a cancer risk.

• The use of CO₂ as the shielding gas can produce carbon monoxide which, under unfavourable circumstances, can reach health-hazardous levels.

• Welding galvanised steel produces substantial quantities of fume due to the low boiling point of the zinc. Inhalation of this fume can cause an ague-like response.

In these situations, and also when welding in confined spaces where there is insufficient ventilation, it can be appropriate to use a fresh air breathing mask.

![Figure 5.19](image1.png) **Figure 5.19** When welding in confined spaces where there is a risk that the concentration of fumes and gases could be too high, the welder must use breathing protection with a supply of clean air.

Welding torches with integral extraction can remove most of the fume before it reaches the surrounding air. The position of the extraction nozzle should be adjustable, in order to avoid interfering with the shielding gas.

![Figure 5.20](image2.png) **Figure 5.20** Welding torch with integral fume extraction.
Noise
Short arc welding is relatively noisy, producing noise levels up to 80 dB. Welding is often also accompanied by noisy grinding work in the vicinity. By using a suitable welding process, shielding gas and welding technique that minimises grinding and slag removal, the noise problem can be reduced.

Arc radiation
The arc is a strong source of radiation in the infrared, visible and ultraviolet ranges of the spectrum. Special protective glasses must be used for the eyes, and all skin should be protected by fully-covered clothing.

Arc eye (Flash) is a strongly irritating inflammation of the cornea of the eye, caused by ultraviolet radiation.

As an alternative to ordinary protective goggles, there are welding helmets with liquid crystal screens that sense ultraviolet radiation and switch extremely rapidly between clear and opaque.

![Figure 5.21 Recommended filter shade levels for protective glass filters. More detailed information is given in the standard EN 169.](image)

Ergonomics
Welding thicker, heavier and/or larger parts manually and during assembly welding involves more static loading on the welder. The welding times are longer and the weight of the equipment is greater. In addition, the working position in this case is dependent on the position of the weld joint. Working with the hands in a high position at or above shoulder level should be avoided whenever possible. Overhead welding is unsuitable from an ergonomic angle.
Welding small items in fixtures is often characterised by many short welds, with monotonous, unchanging movements between them. When planning a workplace, the working height plays an important part in creating the correct working position. In this context, positioners and lifting tables can be very useful. The working position is partly determined by the welder's need to have his/her eyes close to the workpiece to be able to see the molten pool clearly while welding. If the working height is too low, the welder has to bend to see properly. A chair or stool might then be very useful. It is also a good thing if the workpiece is placed in a positioner and is positioned to ensure the best accessibility and height (Figure 5.22). A more comfortable working position can be created and, at the same time, welding can be facilitated as the joint is in the best welding position.

Figure 5.22 A positioner for the workpiece.

In conjunction with heavier welding, the gun and hoses are also heavier. A counterbalance support can provide valuable help in this situation. Lifting the hoses off the floor also protects them from wear and tear, as well as facilitating wire feed.

Figure 5.23 A counterbalance arm reduces the weight of the hose bundle over the entire working area.
Spatter
In some cases, the spatter produced by welding can cause discomfort and even burns. The risks increase in connection with overhead welding or if the welding is performed in confined spaces. Spatter can be reduced by using the correct welding parameters and an appropriate shielding gas with a high argon content. Fine spatter is normally fairly harmless. To avoid these problems, it is important to use fully-fitting clothing and clothing made of suitable heat-resistant material.

5.4 Weld quality
Welded constructions may be vehicles, pressure vessels, cranes, bridges and others. It is an important task to ensure the welding quality. Quality systems are specified in standards. They include tasks and responsibilities for the welding coordination (EN 719), approval testing of welders (EN 287) and specification and approval of welding procedures (EN 288).

The reader will be introduced shortly to the work that has to be done before and after welding to ensure overall quality. The most common imperfections in welds are also described together with the most common causes on why they occur.

Joint preparation
Before commencement of welding, the joint surfaces and area around the weld should be cleaned. Moisture, dirt, oxides, rust and other impurities can cause defective welds. Stainless steels and aluminium needs special care.

Aluminium joints have to be cleaned by degreasing with alcohol or acetone. The oxide must be removed by a stainless steel brush or other ways. Welding must to be carried out in conjunction with cleaning before new oxide builds up.

High quality stainless steel joints need to be cleaned in a similar way. Tools and brushes must be made of stainless steel.

Striking the arc
The normal procedure for striking the MIG/MAG welding arc is for the gas supply, the wire feed unit and the power unit all to be started before the welder presses the trigger switch on the welding torch. This is also the method that is generally preferred in most cases, as it results in the quickest start. However, problems can arise: for example, the wire may hit the joint, or there may be one or more false starts before a weld pool is created and the welding stabilises.

Creep starting provides a gentler start. The wire is fed forward at reduced wire feed speed until electrical contact is established with the workpiece, after which the wire feed speed increases to the set value.

Sputtering during starting is a problem that can occur from a number of causes. The tendency to sputter increases if the inductance is high and the voltage is low. Welding data that may operate satisfactorily once welding has started is perhaps less suitable when starting to weld.

Gas pre-flow is used when welding sensitive materials, such as aluminium or stainless steel. The gas flow starts a short (and adjustable) time before the arc is struck. The function ensures that there is proper gas protection of the workpiece before welding starts. Note, however, that if the gas hose between the gas bottle and the wire feeder is
long, it can act as a 'store' for compressed gas, which is then released as an uncontrolled puff of gas when the gas valve opens, involving a risk of creating turbulence around the weld, with reduced protection from the gas. However, a gas-saving valve is available as an accessory, reducing the pressure from the gas bottle and thus eliminating the risk of a puff of gas. The gas pre-flow function will also eliminate this problem because the puff is rather short.

The hot start facility increases the wire feed speed and arc voltage for a controllable time during the start of welding. It reduces the risk of poor fusion at the start, before full heat inflow has become established.

![Image](image-url)

**Figure 5.24** X-ray picture of an aluminium weld containing pores.

### Pores

Pores in the weld metal are often caused by some disturbance in the gas shield, but there are also different reasons.

- Wrong setting of gas flow. The flow must be enough; it should be adjusted according to the welding current. Too high a flow of gas will cause problems with turbulence in the gas nozzle.
- Draught in the place of welding. Airspeed above 0.5 m/s can interfere with the gas stream from the gun (somewhat depending on the setting of the gas flow).
- Defect equipment. Clogged channels or leakage can prevent the gas from flowing. Control if possible by measuring directly at the opening of the gas nozzle. Clean the inside of the nozzle regularly from spatter.
- The joint surfaces are contaminated with oil, rust or painting.

### Lack of fusion

Problems with lack of fusion between weld and parent metal have different reasons.

- Incorrect setting. Low voltage or long electrode stick-out will result in welding where the added heat is not in proportion to the amount of filler material.
- If the melted metal in the pool tends to flow before the arc. This can be caused if the weld is sloping, and if the welding torch is not properly aligned with the direction of the weld. The problem will also be worse if there is a large weld pool as a result of high heat input and slow travel speed of the welding torch.
- The large thermal dissipation at thick workpieces.
- Unfavourable geometry or too narrow joint angle.
• The arc is directed in the wrong way (misalignment) and one edge of the joint is heated insufficiently.

Figure 5.25 Example of a fillet weld with lack of fusion against the base plate.

End craters

End craters arise as a result of direct interruption in welding. This allows a crack or crater to form in the final part of the metal to solidify, as a result of shrinkage forces during solidification. When grains from opposite sides grow together, low melting-point constituents and impurities can be swept ahead of the solidification front to form a line of weakness in the centre of the weld.

The crater filling function available in advanced power sources can be used to avoid the creation of craters when welds are finished. The arc continues to provide a reduced heat input while the weld pool solidifies. This has the effect of modifying the solidification process so that the final part of the weld pool solidifies at the top, thus avoiding the formation of a crater.

Figure 5.26 A crack may appear as an effect of direct interruption of the welding.

Post weld treatment

The corrosion resistance of stainless steels is degraded if oxides from welding remain. Special root gas is used to avoid oxidation and chemical and mechanical post weld treatment has to be done.