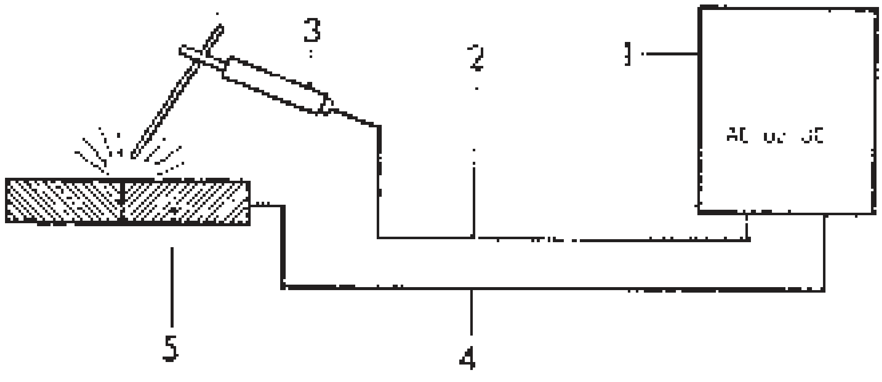
MMA Manual Metal Arc Welding



1 Power source
2 Welding cable
3 Electrode holder
4 Return cable
5 Workpiece

Manual Metal Arc welding, also called hand welding, is still the best known and most common method of welding.

Manual Metal Arc welding is noted for:

1. Low investment cost.
2. Low cost of filler material in relation to kgs. weld deposit. 3. Filler material (stick electrodes) are easily available in a wide range of types and dimensions.
4. Less strict demands on edge preparation and purity of the parent material than by other welding methods.
5. The same equipment can be used for all non-alloyed, low alloyed and stainless welding construction steels. Also for cast iron, modular iron and weldable non-ferrous metals.
6. Short set-up times, good at piece fabrication.
7. Can be used in all positions. Also in narrow spaces with hard to get at welding points.
8. Often gives a more machineable weld deposit than Gas Metal Arc Welding.
9. Reasonable heat input to the parent material. This gives reasonable grain growth and thus a transformation zone less exposed to brittle fracture than other methods working with higher heat input.

The efficient and economical use of the Manual Metal Arc welding method can be summed up in the following seven recommendations.

1. Weld in the horizontal position with high recovery stick electrodes whenever possible. This minimizes both weld time and energy consumption. The use of roller beds and positioners can often contribute to a shorter weld time by making horizontal welding possible.
2. Use sufficiently strong power sources to make possible the use of fast welding high recovery electrodes.
3. Save on electricity by using power sources with high efficiency and low no load rating.
4. Use welding transformers for heavy plates, framework and in other cases when DC welding will interfere through magnetic arc blow.
5. Use a static welding converter (rectifier or inverter) for welding of heavy plates if the mains supply is weak.
6. Use gravity welding for mass production of long straight fillet welds.
7. Weld vertical down instead of up whenever possible.

Equipment

The equipment consists of power source, welding cable, electrode holder and return cable. Below is a survey of the characteristics of different power sources.

Welding transformers

They give alternating currency (AC) and are the least expensive power sources. They have a high efficiency 80-90% for the most commonly used transformers for welding. They are used for welding of unalloyed, low-alloyed stainless steels and cast iron but not for e.g aluminium.

Certain electrodes have better welding characteristics on alternating current (AC) than on direct current (DC). Among these electrodes you find in particular the high recovery types, and notably the larger dimensions.

Welding rectifiers

In this case a rectifier has been added to the transformer, thus supplying DC. It costs approximately twice as much as a transformer of corresponding size. For modern rectifiers, the efficiency is 60-80%.

For both rectifiers and transformers, the efficiency is lower, the lower the used current is. Vice-versa a higher utilization of the capacity of the power source gives a higher efficiency. The rectifier may be used for all weldable materials.

Welding converters

One electric motor (AC) is coupled to a generator (DC). Generally, a more expensive solution than a rectifier of corresponding size. The efficiency is 50-60%.

Its range of use is the same as that of the rectifier.

Engine driven generators

These normally provide DC. They are more expensive than converters and as a rule heavier.

The smaller types normally have 2-stroke petrol engines, whereas larger ones have diesels. In both cases the engine drives the DC generator.

Welding inverters

This is the most recent development within Manual Metal Arc welding. Inverters produce DC or AC/DC. The efficiency is high - 80-90%. The cost is somewhat higher than that of a conventional thyristor regulated rectifier.

The Inverter's main components are:

- A rectifier which turns the incoming 3-phase AC (sometimes only 1-phase AC) into DC.
- An inverter which changes this DC into HIGH FREQUENCY AC.
- A transformer which takes this current down to a lower voltage (20-50 V).
- A rectifier which transforms the AC into DC suitable for welding.

The entire process is controlled by a control circuit.

The inverter's main features are low weight and volume. Since both efficiency and power factors are high, smaller mains cables and fuses may be used in comparison to conventional rectifiers.

Productivity-Welding Speed

A modern high recovery electrode, such as OK Femax 38.95, 6.0 mm and an efficient power source, such as THH 630, can reach a weld deposit of 13 kgs/hour when welding horizontally. Maximum weld deposit for OK Femax 33.80, dia 6.0 mm, is about 8.5 kgs/hour.

For fillet welds with 4-5 mm effective throat thickness, the maximum weld speed is 0.5 m/min when using OK Femax high recovery electrodes.

For gravity welding using 600-700 mm long electrodes, you can reach a speed of up to 60m/manhour when welding straight fillet joints. For gravity welding, AC is always used. The effective throat thickness may be varied by using different electrode dimensions.

Range of application-Material types

Manual Metal Arc welding is used for all unalloyed, low alloyed and stainless common structural steels according to Swedish Standard (SS) and other comparable steels. See also "Standards, Classification System and Codes" in the ESAB Welding handbook-Filler Materials.

These steels comprise:

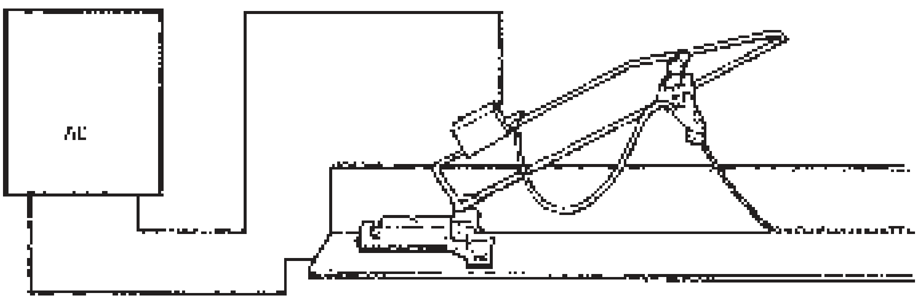
- Common structural steel.
- Pressure vessel steel.
- Ship plate.
- Cast steel and machine steel.

Manual Metal Arc welding is also used for:

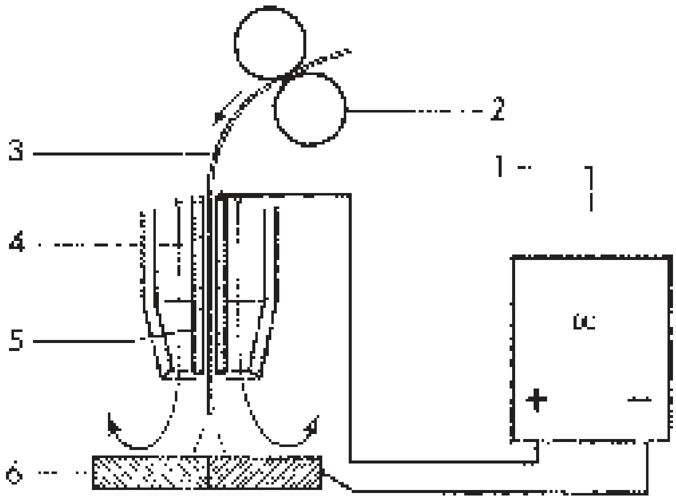
- Cast iron.
- Spherolitic cast iron.
- Malleable iron.
- Weldable non-ferrous metals.

Range of application-Plate thickness

Metal Arc welding is used for plate thicknesses from about 2 mm to the thickest normally used.



MAG WELDING



1 Power source
2 Electrode feed unit
3 Electrode (wire)
4 Shielding gas
5 Contact tip
6 Workpiece

Gas metal arc welding with active gas

For this method it is significant that DC is used, and that the electrode is a wire which is automatically fed to workpiece. The arc is surrounded by the shielding gas.

The negative pole of the power source is connected to the workpiece.

MAG welding takes place in a shielding gas zone consisting of Carbon Dioxide (C02) or a gas mixture consisting of 80% Ar!Jon and 20% Carbon Dioxide.

The Argon/C02 mixture is costlier than pure C02' But it gives a softer arc, smoother weld and less spatter. The mixture also contributes to a higher strength and ductility of the weld metal.

The Argon/C02 mixture is therefore generally preferred for welding of thin plate and often for low alloyed steel.

The electrodes are usually solid wires with diameters 0.6, 0.8, 1.0, 1.2 or 1.6 mm, usually on spools of 5-15 kgs, or flux cored wires with diameters 1.2, 1.4, 1.6, 2.0 or 2.4 mm on spools of 15 and 25 kgs.

Short Arc welding means a low arc voltage giving a short arc. Practically all metal transfer through the arc is completed by short-circuiting globules.

Spray Arc welding needs more than 200 A and 25 V. On the whole, the metal transfer is by free-flight globules being forcefully propelled through the arc.

Short Arc welding is the best method for:

- Thin plate.
- Thin pipes.
- Root runs in butt joints with edge preparation.

With Short Arc welding you weld in all positions. Welding vertical down should be limited to thin plate. There is a risk of insufficient penetration which grows with a growing plate thickness. This is more apparent at vertical down than in other welding positions.

Spray Arc welding IS tne best method for plate thickness above 3 mm.

Spray Arc welding is only used in horizontal and vertical butt position.

Productivity-Welding speed

The welding speed of MAG welding is measured in kgs of weld deposit per hour. When welding horizontal fillet weld in thick materials, MAG welding is slower than Manual Metal Arc welding using high efficiency stick electrodes.

MAG welding is suitable for thin plates. You can also weld medium size plate, piece constructions and small to medium sized crossbar jobs with good economy.

The advantages of MAG welding are:

1. No stoppages for change of stick electrodes (in comparison with Manual Metal Arc welding)
2. Less distortion due to shrinking in comparison with Manual Metal Arc welding. The advantages are:
   - less straightening work after welding
   - often simpler welding fixtures
   - possibly a better bead appearance
3. Smaller joint volumes when compared to Manual Metal Arc welding because of the thinner electrode. A 6.0 mm coated high recovery stick electrode may have an outside diameter of about 15 mm.
4. There is no de-slagging. A certain quantity of metal oxide is found as “slag isles” on the bead. The origin is a chemical reaction between Mn, Si and C02' They should be removed, if strict rules apply to the surface of the weld.
5. There is no risk of hydrogen brittleness in quenching steels caused by moisture in a stick electrode coating.
6. The weld deposit quality may well be compared with what can be achieved with normal basic electrodes.

Range of application - Materials - Plate thickness

All unalloyed and low alloyed steels may be welded.

Use Short Arc from about 0.8 to 3 mm and Spray Arc from about 3 mm plate thickness.

MAG welding with flux cored wires is done with plate thicknesses from about 8 mm for longer beads and up to 10 mm for shorter (less than 0.5 m).

MIG WELDING

Gas Metal Arc welding with Inert (non-active) Gas

In MIG welding, as in MAG welding, you work with Short Arc as well as Spray Arc. The most common gas is Argon, but mixtures of Argon and Helium are also used. When welding stainless steel, it is often difficult to achieve a good penetration. If some few per cents of Oxygen are added to the mixture, this disadvantage is overcome and the arc will be stabilized.

Helium-Argon mixtures give a “hotter” weld than pure Argon. These mixtures are therefore often preferred for thick copper and aluminium materials.

For aluminium welding of medium thickness, pure Argon is used.

Welding positions are: Short Arc-all positions, Spray Arc-horizontal position.

The radius of action is 3-16 m from the wire reel, depending on machine model.

The equipment is the same as for MAG welding.

The shielding gas Argon wth 2% C02 has given as good results as Helium with Argon, when welding heavy stainless plate. Since Argon witn 2% C02 is less expensive than Argon/Helium, the former gains in popularity for stainless.

However, steels with extra low carbon content should not be welded with Argon/Helium. Instead, Argon+2% 02 is used.

In any case, the quality of the weld deposit is the best, provided parent material and the filler material are of good quality and the welding carried out professionally.

Productivity - welding speed

For materials which are welded by MIG, you seldom use as high welding current as for unalloyed or low alloyed steels.

The maximum weld speed is therefore usually lower with MIG than with MAG welding. The MIG method in comparison with Manual Metal Arc welding is highly productive method for stainless steel, aluminium, copper, copper alloys, nickel and nickel alloys.

Range of application - materials - plate thickness

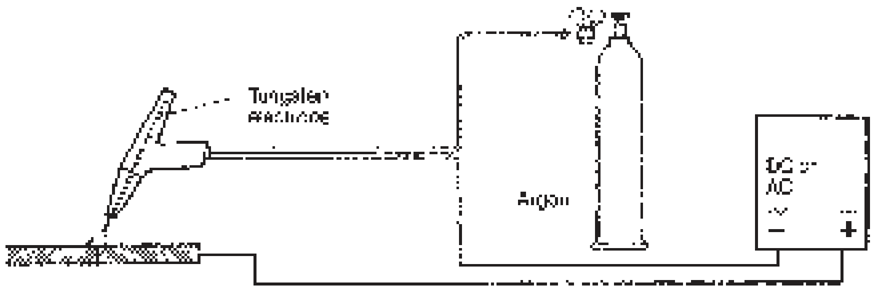
MIG is used for

- Stainless steels.
- Aluminium and aluminium alloys.
- Copper and copper alloys.
- Nickel and nickel alloys.

These materials are welded from about 1 mm thickness and up.

Unalloyed steel is MIG welded in the same joint preperations as for Manual Metal Arc welding.

TIG (GTAW WELDING)



TIG is a welding method where the electric arc is created between a non-melting electrode and the workpiece in an atmosphere of inert gas. That means that the gas does not take part in any chemical reaction during welding.

The arc melts the parent metal and the welding consumable, if any. The molten pool, as well as the electrode, is protected from Oxygen and 'Nitrogen in the air by the shielding gas. This gas is usually Argon, but Helium or mixtures of Helium and Argon are also used.

TIG welding is done with DC or AC. DC negative pole is used for all metals which do not form oxides which are difficult to weld, like e.g aluminium and magnesium. They are instead welded with AC, the positive amplitude of which has a good breakdown effect of the oxide.

The name of this method was taken from the first letters of Tungsten Inert Gas.

Range of application

The TIG process is noted for high weld quality, purity of weld material and an even surface. It is used where quality demands are high, e. g. within the nuclear and process industries, but also for difficult-to-weld materials such as titanium, monel, copper-nickel etc. The largest range of application is for stainless steels and light metals.

TIG is used both for manual and mechanized welding. For manual welding, the welding consumable is fed by hand, as for oxyacetylene welding. In equipment for mechanized welding, a feed unit is used for wire. The welding wire is on a spool and is automatically fed to the welding torch.

TIG welding is used from 0.5 mm material thickness and up to 5-6 mm. For heavier material, TIG is often used for root beads in order to make sure of a perfect root pass. No other method equals TIG in this respect. Consecutive beads are made with more productive methods and filler materials such as Gas Metal Arc, Submerged Arc or Manual Metal Arc with high recovery electrodes.

With plate thickness of less than 1 mm, you often use flange butt joints and edge joints. Butt joints are welded up to 3-4 mm thickness. Above that, you use, V- or U-joints. Sometimes also x-joints. In this case the groove angle should be 60° and the unbevelled edge 1-1.5 mm.

A general rule for selecting the welding current is: Aluminium 45 A, copper 70 A, steel 50 A per mm thickness.

TIG is used in all positions.

Productivity-Welding speed

Manual TIG welding	: about 30 cm/min
Mechanized TIG welding	: about 80 cm/min

Range of application - plate thickness - edge preparation

Use I-joints for plate thickness about 2-12 mm. Use Vjoints or double V-joints above that. The joint must be accurately cut. Gaps, if any, must not exceed 1 mm.

In order to profit from the economical benefits of the method, the joint must be well planned and executed. It should be easy to weld with this method, all dimensions are to be exact. This will give an even weld without burning through or giving root defects. It should have a proper bottom section, consisting either of parent material, a backing bar or a handwelded root bead. Having this, the joint will withstand the deep penetration which is typical for Submerged Arc welding.

Of course the joint must be clean. Impurities of water, oil, paint and rust will always mean a risk of pores being formed.

Submerged Arc Welding requires in short a more expensive edge preperation than Manual Metal Arc. The difference in cost is, however, so small that there is no reason to try to save on the preparation work. A clean, well prepared joint permits higher welding speed. This amply compensates for the more expensive edge preparation.

Common Faults in Arc Welding

Weld faults are in most cases hidden deep under the surface of the weld, and therefore difficult to detect. The most common and reliable methods of detection presently used are ultrasonic and X-ray tests. These methods permit quality control of the weld without changing or destroying it. You can expose most faults with respect to type, size and position.

The X-ray test has also proven to be of great importance to the welder himself. It has been established that certain faults, which the welder perhaps makes more or less unconsciously, gradually disappear if he is shown X-ray pictures and informed of what they reveal.

In other words, the X-ray picture is an excellent educational means. It makes the weld so to speak ''transparent" and shows it in full length. The welder can easily learn from the fault, since you can conclude how the fault arose from the nature and position them. In this way, the welder can steadily manage to eliminate possible shortcomings and improve his craftmanship.

The most common faults are pinholes, slag inclusion, undercuts, root defects, incomplete penetration, and cracks.

Above all, incomplete penetration, slag inclusion, undercuts and root defects can be linked to lack of skill and precision on behalf of the welder.

Incomplete penetration that is incomplete fusion between weld and parent material, may easily occur at Gas Metal Arc welding if not done professionally. In most cases, the cause is a too short training period. The welder has been put into the production before theoretical and practical training have been carefully accomplished.

A common cause of incomplete penetration with Gas Metal Arc welding is usually too low travel speed. This gives a molten pool too large for the arc to melt the joint walls.

On the other hand, incomplete penetration is not rare when thick stick electrodes are used in Manual Metal Arc.

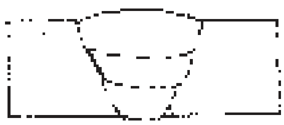
Incomplete penetration will occur if the welder strikes the arc against one of the fusion faces and lets the molten pool run down onto the other, cold face. It may also occur if too low current is used on very thick material. Then the heat supply will not be sufficient to melt the parent material.

Slag inclusions

On an X-ray picture, slag inclusions stand out as lines. The picture below shows a cross section of the weld. Here, the de-slagging has been incomplete between the beads. When the top bead was welded, pieces of slag from the previous bead were not melted. Instead, the top bead sealed them in.

You will observe this on the X-ray picture as typical lines.

The risk of creating this fault is greater if the underlaying bead is strongly convex. If, for some reason, a strongly convex bead is welded, it is recommended to grind off some of it. Then the risk of fault is eliminated.



Incomplete penetration
A fault caused by insufficient fusion between weld and parent material.

Appearance on the X-ray picture
A thin dark line with sharp edges. Depending on the fault orientation in relation to the X-radiation, the line might give a blurred appearance.

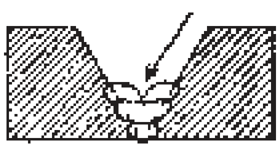
Slage in grooves

Appearance on the X-ray picture
Long, more or less contours parallel with the weld.

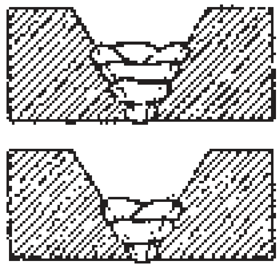
Arc Equipment

Please pay special attention to multi-bead welds! check carefully that there exist no sharp angles between the different beads. If so, it may be impossible to remove the slag or melt down slag deposits all the way to the bottom when laying the next bead.

The pictures below shows a multi-bead weld which is incorrectly done. Narrow grooves have been created beween the beads. The same weld, but correctly done, is shown further on.



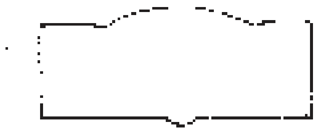
Stage in grooves (incorrect)
The convex bead should be ground.



Correct weld

Undercut

Undercut may be caused by too high current, incorrect electrode movement, or welding electrode/gun/head angle. Under certain conditions they are disastrous. Through their form they can serve as dangerous indications of fractureespecially so if the welded joint is exposed to variations in pressure and elongation.



Undercut
Groove along the rim of the weld.

Appearence on the X-ray picture
Dark line.Sometimes broad and blurred along the rim of the weld.

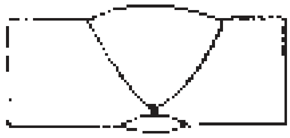
Undercut will always mean a weakening of the joint. Therefore please always weld so that undercut is avoided. If, in spite of all precautions, this cannot be achieved, then in most cases the undercut should be welded up.

In undercut, it is common to find slag deposits remaining inside the weld. But the X-ray film will reveal slag inclusions.

Root defects

Root defects are simply caused by incomplete penetration. They appear on the X-ray film as sharp straight lines.

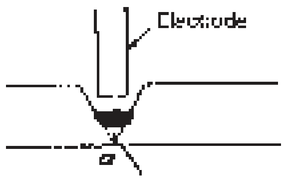
In Manual Metal Arc welding, they may be caused by the use of an electrode of too large diameter. The electrode has been too thick to go down far enough. Root defects can also arise if the gap between joint edges is too small.



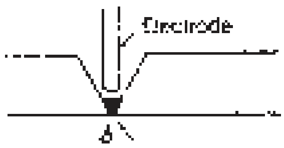
Root defects
Incomplete penetration at the root or a gap which was not filled by weld metal.

Appearance on the X-ray picture
Dark continuous or interrupted line at the middle of the weld.

In the case of V-joints, the welder should often check, by looking, if there is a root defect or not. If there is a defect, it must be removed through root gouging. If it is not



Incomplete penetration



Complete penetration

removed, the defect is closed-in by the backweld. It will then be revealed by the X-ray or ultrasonic inspection.

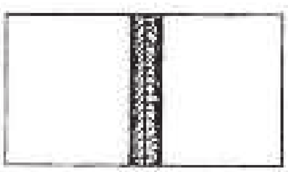
In Submerged Arc welding, the penetration in the joint is an important factor. When root defects appear, the penetration has been inefficient.

If, in the case of double-sided welding, the beads have not met at the bottom, there could be several reasons such as:

- The joint had a too big unbevelled edge.
- Too small groove angle.
- Possibly both these causes together.
- Too low welding current.
- Too high or low welding speed.
- The two beads are not exactly facing each other.

Cracks

In most cases, cracks are not directly dependant on the welder's skill. But a weld can be done in such a way that formation of cracks is promoted. If there are faults in the weld, of course the risk of cracks is.greater due to tension or other influences than if the weld is completely homogeneous.



Hot cracks

X-ray pictures often show that cracks emanate from slag inclusions, small root or other defects - especially with alloyed steels.

Incorrect weld sequences and the tensions they cause may be of course also result in cracks. If welding jobs are well planned, the weld sequences should be decided by the construction department or works management and marked out on drawings.

In this connection, attention should also be devoted to the tact welds. If you want to achieve a truly high-quality weld, you should remove the tacks as the welding proceeds. It sometimes happens that weak tack welds crack d.ue to influence of shrink-tensions. If you weld over such a cracked weld, you cannot be sure that it is molten and absorbed in the pool. The result might be a remaining crack in the finished weld. In cases where the workpiece is accessible for welding from both sides, you often tack weld at the back. The tacks are then removed in connection with the gouging of the root before the back bead is welded.

It should, however, also be noted that cracks may appear in the weld or the parent material which have nothing to do with the welding procedure.

Examples of this are hot cracks or solidification cracks which run along in the middle of the weld. These are common at fillet welds, where a difficult tension situation is at hand.

The reason for these cracks may be parent material. This could be difficult-to-weld steel, having too high contents of Carbon, Sulphur and possibly Phosphorus. These elements give certain segregation effects when the molten pool solidifies.

Acid electrodes are especially sensitive to impurities. Rutile electrodes are less sensible and basic ones are practically nonsensitive.

Unlimited weldable steels have maximum proportions of Carbon 0.20%, Sulphur 0.05% and Phosphorus 0.04%. If parent metals containing more of these are to be welded, basic electrodes should be used. Then you will avoid hot tears also by high proportions of these elements.

The same advice is given also for the use of basic electrodes if you have to weld a material where the composition is unknown.

Hot tear

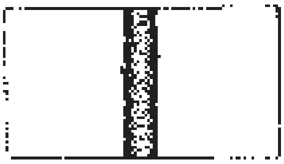
The most common cause of hot tear in Submerged Arc Welded joints is a pipe-formation combined with segregation of Carbon and Sulphur.

The relation between width and depth of the weld reinforcement should be gre(:!.ter than 1. If this is insufficient, formation of pipes will occur. In such a case it is in reality a question of shrink holes and not crack formation as such.

If crack formations are found in the parent material in close vicinity of the weld, these are definitely hardering cracks. The composition of the parent material has been such that the sections heated by the welding up to hardening temperature cracked during the subsequent cooling.

The result is a hard and brittle zone close to the weld, giving cracks. This is a risk always at hand with hardenable parent materials if the cooling-off speed is not prolonged. Such a prolongation is to a certain extent achieved by using thicker electrodes. These give a greater heat input during the welding. But often this is not enough, for instance at welding of low alloyed steels, which also a relatively low Carbon contents are very disposed to hardening.

The relation width: depth should be greater than 1

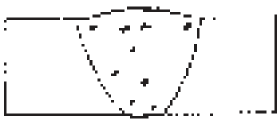


Hardening crack

The parent material must then be preheated. Depending on the disposition to hardening of it, you chose a higher or lower preheating temperature or rather working temperature. If this temperature is correctly chosen, also steels disposed to hardening may get a soft transformation zone.

Pinholes

Pinholes may appear in different forms. Gases formed during the solidification of the molten pool do not escape. They are "stuck" and the solidification takes place around the gas bubles. One kind of pinhole is called surface porosity and may form a string along the weld - easily visible. In this case, the gas formation occured under heavy



Pinholes
Caused by trapped gas bubbles

Appearance on the X-ray picture
Sharp marked round blackenings

pressure and the direction was oriented up through the middle of the molten pool. This is the last portion to become solidified.

In Manual Metal Arc welding, porosity is commonly caused by Hydrogen from basic electrodes which were stored incorrectly. Porosity can also be caused by moisture, paint and other impurities on the fusion faces.

Gas Metal Arc welding is even more sensitive when it comes to paint, oil and other impurities. Porosity may also be caused by a poor gas shield. The surrounding air is sucked into the molten pool and form CO (carbon monoxide).

In Submerged Arc welding, the penetration is powerful. Porosity may occur if the plates are lamellated. During the penetration, the weld will absorb too much of the oxides present in this kind of defect. Submerged Arc welding requires the same cleanliness of the fusion faces as Gas Metal Arc welding.