MIG Pulse Welding

Principle

The process we use for welding of aluminium is called synergic MIG pulse welding, when we want to obtain control of the droplet transfer and the production of heat in the arc. This process holds the following advantages:

- Little or no spatter also at low mean current values, where the transfer of material in the arc would otherwise take place by a dip transfer technique or by large droplets which cause a large amount of spatter
- The possibility to control the heat input in the weld grooves in order to reduce the risk of fusion errors.
- A reduction of the number of porosities in the weld metal because the weld pool ”vibrates” in step with the current pulsation and therefore the gas bubbles are ”shook” out of the weld pool.

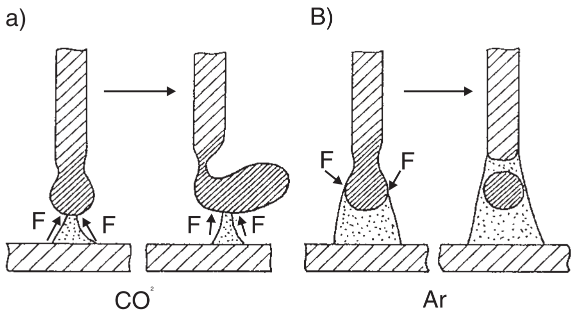
Shielding Gas

The name MIG means Metal Inert Gas, which means that the metal is transferred as metal droplets in an electrically conductive arc shielding by a gas which does not react chemically with other elements even at very high temperatures. In practice mainly the inert gas argon is used, but also mixtures with argon and helium or pure helium are used today especially when welding thick aluminium work pieces.
In order to select the most appropriate shielding gas we recommend to use the following guidelines:

Recommended shielding gases for MIG pulse welding of aluminium and its alloys		
Plate thickness	Argon content	Helium content
0 – 5 mm	100%	0%
6 – 12 mm	75 %	25%
13 – 20 mm	50%	50%
> end 20 mm	25%	75%

Experiments with other additive gases mixed with the inert argon as for instance freon or very small quantities of oxygen also carried out. (Previously oxygen, which is an active gas, was always avoided as it adds to an increased formation of porosities, but new examinations show that porosities are mainly caused by the existance of hydrogen.) The use of freon is unlikely to have any commercial use due to environmental problems.

During MIG welding the current-carrying electrode (filler material) melts in the form of small droplets at the end of the electrode due to the fierce heating from the arc. These droplets are later on pinched off and propelled with great speed into the workpiece. The pinch effect and the very directionally stable droplet transfer in argon-rich shielding gases is mainly caused by the electro-dynamical force called the “pinch effect”:

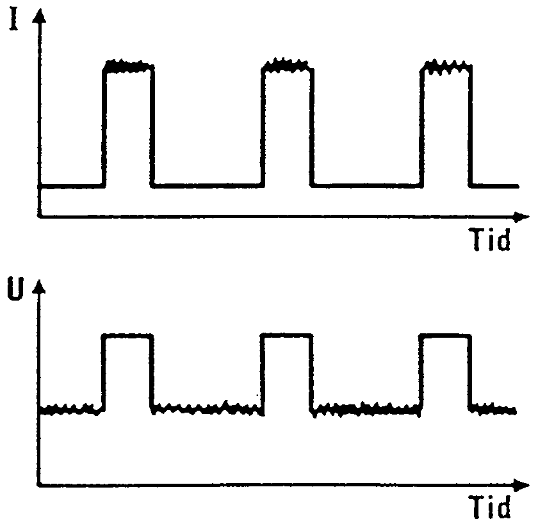


Demonstration of the pinch effect

The pinch effect shown with the shielding gases CO_2 and argon.

Type of Current

The name pulse means that the welding current is pulsing, which means that it has a base current overlaid with current peaks which are now controllable by means of the latest electronic techniques, so that the current curve can be optimized according to the need. Today it is not a problem to make the welding machine produce the wanted current; the problems only arise when the ideal current and voltage curves are to be defined depending on the wire speed (which is set by the welder on the basis of the form of the groove and the welding position), the shielding gas, the metal alloys and the wire diameter. We can therefore expect a continuous development of the welding equipment for aluminium welding, but the development is likely to concentrate on the adaptation of the current and voltage curves to fit the welders' opinion of the ideal welding process.

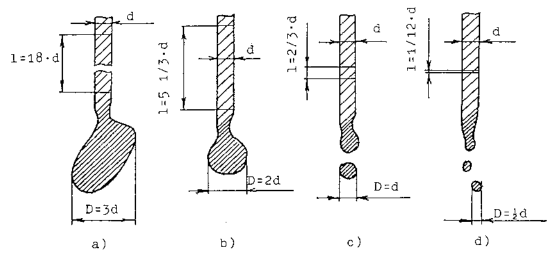


Combined control of base current and pulse voltage during pulse welding

Today the manufacturers are primarily trying to control the current pulsations, so that one droplet is pinched off per pulsation, causing as little spatter as possible, especially is the droplet is pinched off by the end of the pulsation and then transferred through the arc when the welding current is reduced to the low base current. This is meant to reduce the heating (less evaporation) of the droplet and at the same time the speed of the droplet is not further increased. However, it shows that when using the above technique at certain welds, particularly in thick aluminium, the transfer

In order to minimize the spatter loss and obtain the most stable arc it is therefore advisable to choose droplet diameters which are approximately of the same size as the wire diameter. time does not allow enough heat to be transferred to the weld grooves causing fusion errors. This can be avoided by using argon-helium mixtures as previously mentioned.

The pulse time and current are manipulated so that a droplet is formed and pinched off. this droplet has an approximate diameter corresponding to that of the electrode wire.



Definition of droplet sizes

Droplet sizes

Approx. 3 x the wire diameter
Very large droplets give an irregular pinch off. Inapplicable for welding due to the large spatter loss and irregular weld appearance.

Approx. 2 x the wire diameter
Large droplets are melted very regularly and give a large spatter loss. Normally only used in the vertical-down position and best in the groove.

Approx. 1 x the wire diameter
Small droplets are regularly melted in a very directionally stable way. In principle used for welding in all positions with very little spatter loss.

Approx ½ x the wire diameter
Very small droplets often irregularly melted from a conical electrode point with very large spatter loss, due to an unstable arc which rotates on the point of the electrode.

In order to minimize the spatter loss and obtain the most stable arc it is therefore advisable to choose droplet diameters which are approximately of the same size as the wire diameter.

A droplet diameter which equals the wire diameter can be obtained by the follwing wire speeds and frequencies (number of pulsations per second) on the condition that only one droplet is pinched off per pulsation.

Wire speed	**Pulse frequency**
4 meters/minute	100 Hz
6 meters/minute	150 Hz
8 meters/minute	200 Hz
10 meters/minute	250 Hz

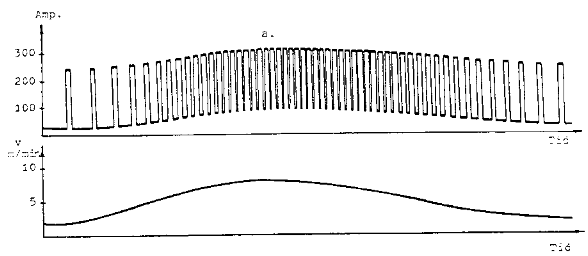
The pinch off of droplets will be most stable in an arc of argon which provides the possibility of a well-defined one-droplet transfer of material from the filler wire to the weld pool. If you choose an argon-helium mixture the above-mentioned one-droplet transfer changes into a more unstable spray arc-like condition and the surface of the weld will therefore be more uneven.

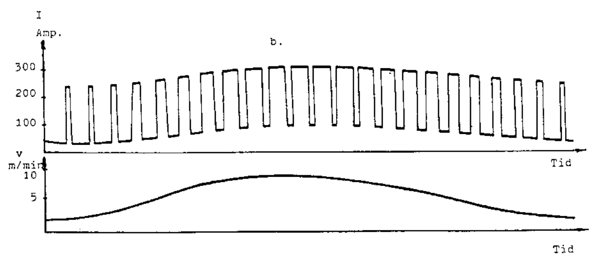
When welding thicker aluminium plates it can, however, be necessary to use helium mixures to increase the heat input to the base material in order to avoid fusion errors. An improved penetration can also be obtained by a pre-heating of the workpieces before welding starts.

Synergic means “to work together” and in connection with the welding process it indicates that the welding machine is capable of choosing the with current curve when the welder has set the wire speed, the metal alloy, the wire diameter and the shielding gas. That is the welding equipment controls the base current, the form and number of the current pulsations.

As the mean current is proportionnal with the melting (= the wire speed) the welding equipment should increase the mean current value when the welder increases the wire speed and vice versa. The control of the welding equipment can do that in several ways or combinations hereof:

An increase of the wire speed requires:
- An increase of the number of pulsations (fig. a)
- An increase of the pulse time (fig. b)
- An increase of the pulse current (figs a+b)
- An increase of the base current

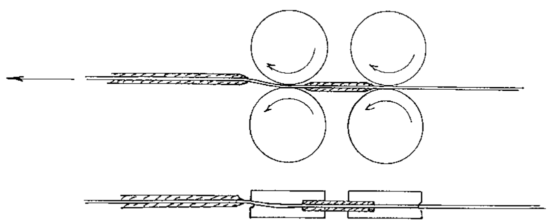




Wire Feeding

For MIG welding of aluminium it is not enough to have a suitable power source.
The wire feeding is of equal importance when the equipment is to be used for production purposes. Therefore push-pull torches are often used when the cable with the wire liner from the wire feed unit is more than three to four metres long due to the relatively soft wires of aluminium when compared with wires of steel. When choosing the push-pull torch it is important to take into consideration the weight of the torch, its size and flexibility in order to reduce the strain on the welder, especially if you are to weld in areas where access is a problem.

In order to reduce the friction of the wire it is important to choose a special wire liner for aluminium. The liner should start from the wire drive rolls of the wire feed unit and continue right to the contact nozzle wihtout separations and it should not have any sharp bends. Of course the liner must not at any time have been used for ordinary steel. In between the two set of wire drive rolls there is a tube through which the filler wire passes. This tube is intended to prevent a bending of the wire and therefore it must be so as the distance between the wire rolls allows. The tube should be lined with a piece of plastic liner in order to reduce the friction and prevent gratings between the wire and the tube. It is particularly important to use the right grooves on the wire drive rolls for aluminium wires as otherwise the soft wires can be deformed and cause trouble for the further transport through liner and contact nozzle.



It is important that the wire feeding system has no sharp bends.

Liner

Due to the fine friction characteristics of the material and its great strength and rigidity carbonfibre liners are often used nowadays.

In practice the wire feeding is still one of the important problems of MIG welding of aluminium.

Often a stopper of small aluminium gratings will form inside the liner causing difficulties and maybe preventing the wire feeding. The problem often appears periodically and can be extremely irritating and time consuming when the wire has to be removed and liner cleaned or exchanged and maybe a new contact nozzle needs to be fitted before the wire can run smoothly again.

Attempts have been made to solve this problem with aluminium gratings once and for all by using an alternative liner material or using a liner with a larger diameter or by replacing the wire drive rolls by similar rolls made of a softer material e.g. plastic, but none of these solutions have proved adequate. The problem is probably also connected with the nature of the surface of the filler wire, but that is difficult to control.

Therefore the problem is in practice solved by adjusting the pressure of the wire drive rolls on the wire, by replacing the wire rolls with rolls of another type, and if the problem still persists, to change the capillary tube, liners and wire drive rolls successively, and of course to clean the liner regularly with compressed air.

Porosities in the Weld Metal

During MIG welding of aluminium there will be a serious formation of porosities in the weld pool. Therefore an efficient degassing of the weld pool is necessary before the melted weld metal solidifies in order to avoid inclusions of gas bubbles in the weld metal.

If the formation of porosities is large and the degassing is insufficient there will be porosities in the weld metal and/or porosities in the weld surface. The porosities in the weld metal are detected by means of x-ray examinations or by a breaking test like all other interior geometrical errors.
A limited number of small porosities in the weld metal does not reduce the fatigue strength or the

static tensile strength, and the elongation strength is only slightly reduced. Small porosities which are evenly distributed are therefore normally acceptable even for heavily charged constructions.

Large porosities and especially long porosities can reduce the tensile strength and in particular the elongation after fracture quite considerably, and therefore it is important always to consider this when welding on the types of aluminium alloys which have high strength and do not loose too much of the strength in the heat-affected zone:

Examples:

- The alloy AlMg4.5 typically has a high tensile strength of approx. 280 N/mm^2 in the heat-affected zone, and even if you choose a strong filler material the weld metal will easily become the weakest point if there are porosities in the joint.
- In opposition to the above-mentioned a hardened alloy of AlMgSi0.5 will only have a strength of approx. 130 N/mm^2 after welding, and the weakest point will be there if you use a filler wire of the type AlMg5 which has a melted value of approx. 250 N/mm^2.

When comparing MIG welding with TIG welding the MIG weld pool will solidify quicker due to the higher welding speed and fewer porosities will therefore be able to bubble out of the melted metal before it solidifies. The result is that a MIG weld will contain a larger number of porosities.

The solidification time, which is also the time the porosities have to bubble out of the weld metal, can be increased by welding with a high heat input (high welding current, high welding voltage and low speed) and in the same way a pre-heating of the workpieces will result in a slower solidification of the weld pool and therefore fewer porosities.

A final run, made of e.g. 2 passes, is welded with higher welding speed and will therefore contain more porosities than a similar final run pendled up by only one pass.

Also weld joints made in vertical-down and vertical-up positions could be carried out with a larger weld pool which also solidifies slower than that of the welding positions horizontal and overhead and consequently they will be inclined to contain more porosities.

An increase of the heat-input and maybe a pre-heating of the base materials in order to reduce the number of porosities in the weld metal is not without problems. It may easily result in poor mechanical properties in the heat-affected zone and also serious deformations.

For these reasons it is often expedient to make welding tests including tensile and bending tests (procedure tests) to control that the welding parameters were not exclusively set to be very high in order to avoid geometrical errors such as porosities and fusion errors and wihtout considering the fact that metallurgic problems as for instance poor values of the tensile strength and the elongation after fracture.

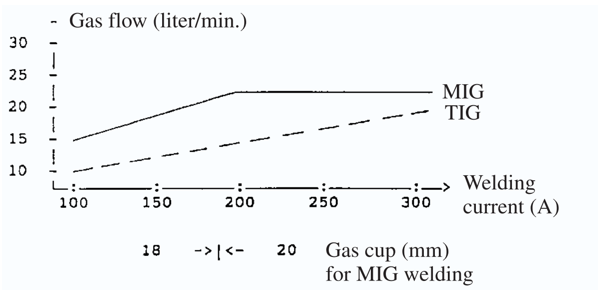
When comparing conventional MIG welding with MIG pulse welding it has been observed by means of “high speed” fotographic shootings that the degassing of the weld pool in better in MIG pulse welding as the weld pool “vibrates” in step with the current pulsations. The purification of pulse welding is therefore better than that of conventional MIG welding.

Another important method for reducing the number of porosities in the weld metal is to reduce the number porosities which form in the melted weld pool during the welding process. This means that cleanliness is necessary. In this connection it is particularly important that hydrogen or chemical combinations which contain hydrogen are not allowed to get into contact with the melted aluminium as hydrogen seriously increases the formation of porosities.

With regard to the welding techniques the above-mentioned electronically controlled pulse welding machines hold many advantages and wihtout these machines it

In practice a minimization of the formation of porosities in ensured by using an efficient inert shielding gas and a thorough cleaning of the groove edges, where it can be necessary to remove the old oxide layer by mechanical treatment to ensure that a new, homogen and dry oxide layer can be formed.

The necessary gas flow and its corresponding sizes of the gas nozzle are indicated on the following table (100% argon). If argon/helium mixtures are used of for instance 30% helium, the gas flow should be increased by 1.5 to 2 times in order to ensure a correct shielding of the weld pool.



The table shows that the flow of shielding gas should be higher for MIG welding when compared with TIG welding.

New examinations indicate that the filler wire is another very important source of the formation of porosities. This problem is very difficult to solve in a production where demands are made to the welding quality, as it is not possible to examine the suitability of the wire in another way than to make a welding test followed by an x-ray examination.

If the x-ray examination shows that the wire is not suited to fulfill the demands to the quality of the required welding positions, there is no alternative than to replace the wire reel with another one and hope for better luck next time.

Synergic MIG pulse welding machines were invented by The Welding Institute in England, and around 1980 the machines slowly began to be produced for commercial use. In the beginning the new machines came from Japan, but now the European, including the Danish, manufacturers of welding equipment are in the forefront of design and technology.

With regard to the welding techniques the above-mentioned electronically controlled pulse welding machines hold many advantages and without these machines it would not be possible to perform high quality welding with high productivity.

What remains to be solved is the environment in the viscinity of the arc and the problems it causes for the welder and his surroundings.

This subject will be further described in a later chapter.