ESAB pulsed gas-shielded metal arc brazing of surface-coated sheets

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1. Gas-shielded metal arc brazing

Brazing is a process for joining metallic materials with the aid of a melted filler (solder), the melting temperature of which lies below that of the parent metal. The parent metal is wetted, without being melted.

In Gas-shielded Metal Arc (GMA) Brazing, copper-based alloys are often used as the filler, the melting temperature of which is below that of the steel to be joined. In an ideal situation, the parent metal is not melted at the edges. Although the arc, which burns under a shielding gas atmosphere, is used to warm the parent metal and melt the filler, the process is much more like soldering. Suitable shielding gases for GMA-Brazing are inert gases like Argon but gas mixtures consisting of Argon and small amounts of active gases like Oxygen are more common. Because of that the process is called GMA-Brazing including MIG- and MAG-Brazing.

2. Area of application

Sheet steel and steel sections are more and more frequently provided with protection from corrosion in the form of an aluminium coating or layers of zinc, applied either electrolytically or by hot-galvanising. Typical areas of application are vehicle bodywork, components used in ventilation, cooling and air-conditioning equipment, household equipment, fire-resistant doors, roof and facade components in the building industry etc. Of course, many of these components have to be joined.

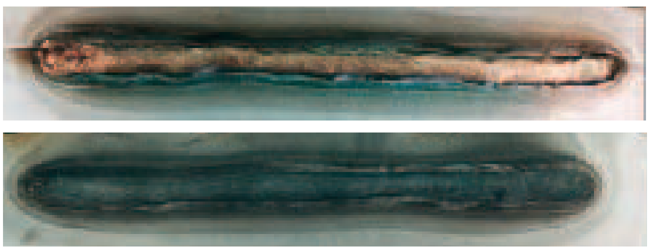


Figure 1. Front and back of a GMA brazing seam on vehicle body panels. A residual zinc coating is retained adjacent to the seam and on the back.

3. GMA-brazing is given corrosion-protection

When welding galvanised structures, the evaporation of the zinc close to the seam causes a zone which is prone to corrosion because of the lack of a protective layer. Wires of the type EN 440 – G2Sil are also used to reduce the tendency to produce pores, the weld metal from which offers no rust protection whatsoever. In this case the destroyed corrosion protection has to be restored subsequently at considerable expense, e.g. by regalvanising. In contrast, copper wires are used in GMA-Brazing, which produce a corrosion-resistant solder. Copper is characterised by high solubility for zinc. An example of this is provided by the various brass alloys. The melting range of the CuSi3-alloy OK Autrod 19.30 is approximately 910–1025°C, the melting point of zinc is 419°C. During brazing, the liquid zinc remaining on the surface of the sheet metal is included in the solder alloy, as a consequence of which a brass solder is produced. This applies particularly to the transition between the solder and zinc top layer adjacent to the seam. In the transverse micro-section illustrated (figure 2) the bronze solder can be seen on the right side. The light yellow colouring indicates the low proportion of

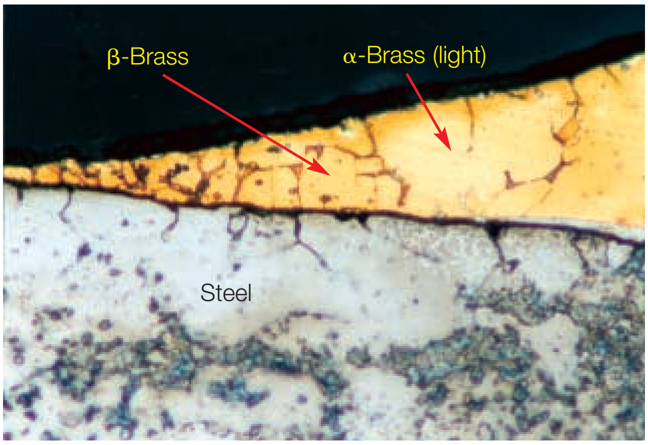


Figure 2. Transition from copper braze to galvanized base material. The braze and the zinc coating mix to form brass.

zinc. This mainly involves α-brass. As the transition from the solder to the remaining zinc layer is approached, the proportion of dark coloured areas increases. The concentration of zinc in the solder is higher here, ß-brass is present. The fluid transition from the CuSi-solder via a mixed layer consisting of brass to the zinc produces a sealed corrosion protection layer. This also applies to the back of the weld on which a residual layer of zinc is retained, even with thin sheet. The ESAB pulsed GMA-Brazing process makes subsequent corrosion protection superfluous, digital regulation of the parameters reduces the evaporation of zinc next to the seam and from the back of the sheet.

4. Heat input and Zinc vapour

The boiling point of pure zinc is 907°C. Zinc begins to evaporate from this temperature onwards. As the amount of heat input into the galvanised sheet increases, a larger quantity of zinc evaporates. The zinc vapour counteracts the transfer of droplets and deflects the droplets. Targeted transfer of droplets into the molten pool becomes impossible; the result is considerable formation of spatter and at the very least a seam with an unattractive appearance. Therefore, when GMA-Brazing the rule is: Only as much heat as necessary!

5. Pulsed GMA-brazing using the ESAB Aristo 2000-System

A few users of the GMA-Brazing process have been working to date without a pulsed arc, which is only advantageous in the PG-Position. In these cases, the process takes place within the short arc mode. The short circuits associated with this between the wire electrode and the parent metal lead to considerable spatter formation if the power source is not sufficiently well regulated. The heat input can only be controlled to an unsatisfactory extent. In addition, the welder or "brazer" must adhere to a very constant contact tube distance as even slight deviations lead immediately to considerable changes in the parameters and consequently impair the process and the result. Handling is difficult and the welder has the result "in his hands" in a very real sense.

The pulsed GMA-Brazing process with the ESAB Aristo 2000-System offers the best possible preconditions for a successful bond. As a consequence of the process, the flow of zinc vapour counteracts the arc pressure. This must be countered by using a slightly forehand torch action and especially an extremely short arc. This requirement makes very high demands on the equipment.

The digital Aristo 2000 achieves very high current rise rates with very steep pulse signal edges in order to enable small droplets to be transferred to the molten pool in a targeted way with short pulse current times. The digital regulation system has to work extremely quickly and precisely to achieve this – a requirement which the ESAB Aristo 2000-System fulfils exceptionally well.

Successful pulsed GMA-Brazing also makes high demands on the wire feed unit because the process does not tolerate even slight changes in the rate at which the wire is fed. The regulated ESAB wire feed system keeps the speed required at a constant level regardless of external disruptions.

With the ESAB Aristo 2000-System, handling pulsed GMA-Brazing is less "the driving force for the weld" because the tolerance is much greater in sofar as the distance away of the contact tube is concerned. The application of heat is reduced; where very thin bodywork sheet is concerned, there is less risk of the seam collapsing. Taken as a whole, the ESAB technology provides a better result in sofar as quality assurance, corrosion protection and the appearance of the seam are concerned.

The digital Aristo 2000 system used offers both the convenience of a synergy setting and the possibility of optimising all the parameters relevant to the process individually. The values produced can be filed on a PC-

Figure 3. Transverse section through GMA -brazing seam on a body panel (s = 0.8 mm). Location of section: underside of panel. A residual zinc coating is retained.

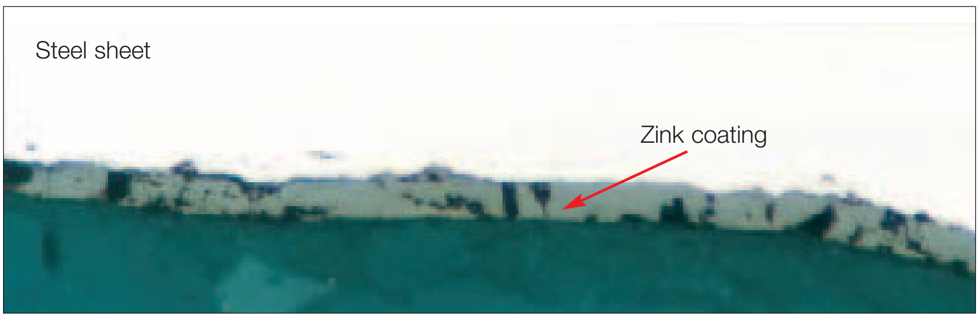


Figure 4. ESAB Aristo 2000 – LUD 320.

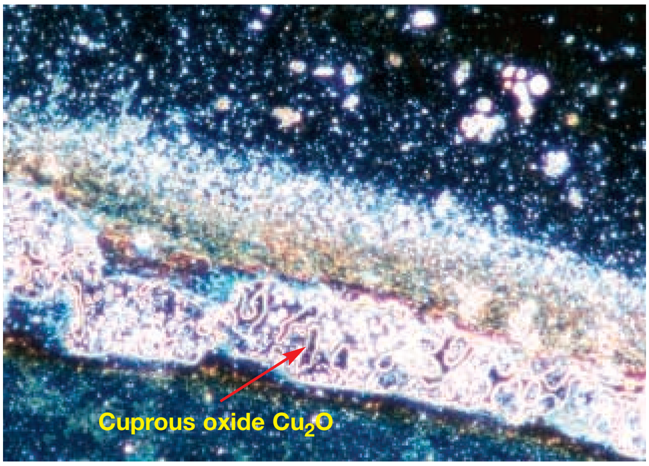


Figure 6. Dark-field image of the CuSi3 braze when using an M13 protective gas. The few eutectic precipitations contain only small fractions of Cu_2O.

memory card and loaded into the system again when required. If the arc power is to be adjustable continuously over a certain range, the user can program his own characteristic curves for synergy without entering into the system. In this way, he can combine the individuality of his optimised setting with the convenience of a synergy. Using this PC-memory card, we can also find parameters for you at our premises, optimise and store them. Then you simply load these data into your LUD and start.

6. Wire for GMA-brazing

A number of different copper wires can be used for GMA-Brazing. Normally, the 3% Si-alloy OK Autrod 19.30 (DIN 1733: SG-CuSi3) is used:

Wire	Cu	Si	Mn	Melting range °C
OK Autrod 19.30	Basis	3.0	1.0	910-1025

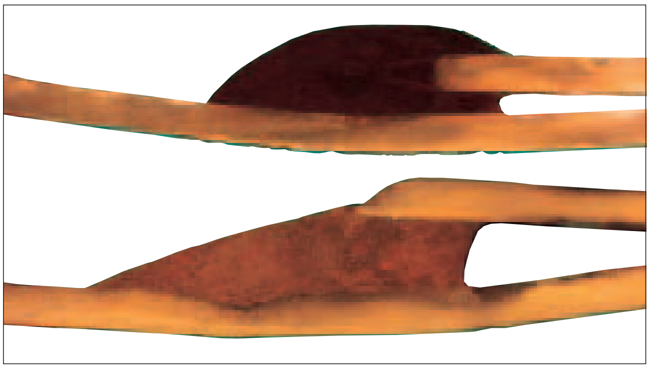


Figure 5. Transverse section through ESBA GMA-brazed joints on vehicle body panels (s = 0.8 mm) with different gap widths. The braze flows deep into the gap.

The wire diameter 1.0 mm is the main one used. Delivery is usually on 15 kg basket spools. For mechanized and fully automated systems OK Autrod 19.30 Ø1.0 mm is also available in the ESAB MARATHON PAC™ Octagonal.

OK Autrod 19.30 is particularly suitable for GMA-Brazing. Hardly any spatter is produced when combined with the ESAB Aristo 2000-System. No pores or cracking of the solder was found in the brazing specimens investigated. No scales are formed and there is only a very thin layer of slag on the surface. The ESAB OK Autrod 19.30 provides very good wetting and gap bridging (figure 5). As a consequence of capillary action, the solder flows into the air gap of overlap joints well. The relatively soft solder makes it easy to remove the weld reinforcement, in so far as this is at all necessary to produce a flat seam. When removing it, the zinc layer alongside the seam is damaged far less than is the case with hard weld metal.

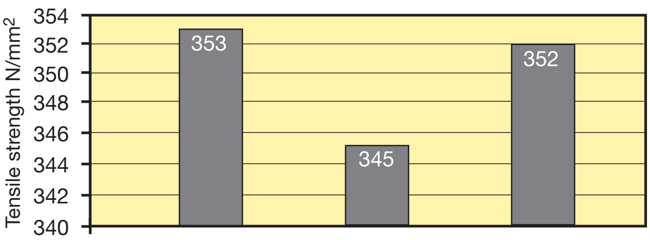
7. Shielding gases for GMA-brazing

Pure argon is frequently used in practice for GMA-Brazing. However, gases with a proportion of active gas are also suitable for GMA-Brazing, e.g. gases EN 439-M12 with CO_2-proportions of 1–3%. More recent investigations at ESAB have shown that the use of an M13 shielding gas complying with EN 439 (Ar+1% O_2) is advantageous. The surface tension of the molten pool is reduced, as a consequence of which the flow and wetting characteristics are improved significantly. At the same time the stability of the arc improves. No scales are formed in the seam and it has an excellent appearance. However, the use of shielding gases containing proportions of active gas raises a number of questions. Copper forms copper oxide (Cu_2O) when combined with dissolved oxygen. Cu_2O is deposited at the particle boundaries which can tear open during cold forming. In general, a very brittle microstructure is produced. As a consequence of the embrittling effect of the copper oxide, only well de-oxidised types of copper are deemed suitable for welding. More precise investigations were undertaken at ESAB to establish whether using shielding gases with an active gas content has a disadvantageous effect on brazed seams. It became apparent during the latte that only extremely small proportions of copper oxide can be detected in the solder and that these are only present in a small number of zones containing eutectic separations. The silicon present in OK Autrod 19.30 has a deoxidising effect and keeps the Cu_2O-proportions very low.

As small proportions of Cu_2O are only present in restricted areas and no marked particle boundary films were found anywhere, no embrittling effect is to be expected. Consequently, there are no objections to small proportions of active gas in the shielding gas. This was also supported by the investigations undertaken on strength.

8. Strength of the brazed joints

Pulsed GMA-brazed joints were produced on an overlap joint in electro-galvanised sheet metal bodywork 0.8 mm thick. OK Autrod 19.30 Δ1.0 under shielding gas M13 with 1% O_2 and the ESAB Aristo 2000-System were used. Then flat tensile test specimens were taken and tested:



The position of the fracture in the tensile test specimen was always in the unaffected parent metal! Therefore the ESAB GMA-brazed joints fulfil the demands made of the joint completely.

9. Suggestions for practical use

The optimum parameters are more difficult to set for GMA-Brazing than for MIG/MAG-welding. The thickness and position of the zinc layer, in particular, play a very large part. Setting all the pulse parameters individually is indispensable for the best possible result.

Torch position

In GMA-Brazing, the torch position can have a considerable influence on the formation of the seam and the introduction of heat into the parent metal, as in MIG/MAG-welding. Less heat is brought into the galvanised parent material if the torch is in a forehand position. It causes a smaller quantity of zinc to evaporate and the degree to which droplet transfer impaired is significantly lower. With the torch held in a forehand position, the brazed seam is flatter and somewhat wider, but more importantly, there is less spatter. The unavoidable amounts of spatter, which occur at the start of the process because the evaporation of the zinc is stronger, land before the torch and are reliably melted again.

Molten pool

GMA-Brazing can be done with the molten pool running slightly ahead. This is a little strange to the MIG/MAG-welder at first because he usually has to ensure the avoidance of bonding errors and reliable penetration. However, deep penetration is undesirable in GMA-Brazing; it is only necessary to ensure good wetting.

10. Conclusion

ESAB provides all the pre-conditions for successful pulsed GMA-Brazing. The Aristo 2000-System makes digitally regulated power sources and wire feed devices available which fulfil the high demands of the pulsed GMA-Brazing process in the best possible way. Combined with the wire electrode OK Autrod 19.30, brazed joints are produced which demonstrate the best quality and excellent mechanical quality values.

About the authors

Hendrik Rohde graduated in 1991 as a mechanical and welding engineer from the Technical University of Magdeburg and joined ESAB Germany in the same year. In 1995, he became a European Welding Engineer. He is now product manager for arc welding products with GMAW as the main field and he also specialises in modifications for the use of welding machines with mechanised equipment.

Jochen Katic is an EWS and works as a demo-welder for mechanised welding processes. He joined ESAB GmbH Solingen in 1990. Mr. Katic is also a specialist in welding with flux-cored wires and he is often involved in research and development projects for customer applications in automatic and robotic welding.

Rolf Paschold, product manager at ESAB GmbH Solingen (Germany), graduated in 1990 as a mechanical and welding engineer. He joined ESAB in 1991 and is the sales support manager for welding consumables. Mr Paschold has always shown a special interest in tailor-made process applications developed together with the customer.