ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume X (XX), 2011, NR2

PROBLEMS WHEN JOINING THIN SHEETS

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Keywords: galvanized sheets, joining methods, precautions

Abstract: Coated thin sheets (galvanized or painted with organic paints) raise specific problems at joining, generated by the necessity of preserving intact the protective coating and maintaining its anticorrosion properties. Possible joining methods are identified in the paper, with parameters and technical information, with applicability in various industry fields, from automobile construction, metallic structures, to agriculture equipments, using manual, mechanized, automated or robotized joining processes. Precautions necessary to be taken are also the object of this paper.

1. INTRODUCTION

Thin sheets used for metallic constructions, automotive industry, aeronautic, buildings, shipbuildings, agriculture etc, can be joined using different methods (manual, mechanized, automated, robotized), that meet the requirements of the components itself or the respective domains [12]. The quality of the joints made from thin sheets respectively coated thin sheets must respond to the demands imposed by the quality assurance systems.

The use of thin steels (less than 10 mm thick) has increased significantly in the last decades, from 10% to 90% in the last years. The increased use of thin sheets is driven by designs requiring a reduction in weight, offering performance increases in the final product.

2. GENERALITIES REGARDING JOINING THIN GALVANIZED PLATES

The most used galvanized steels are those zinc or zinc alloy coated. In the following, aspects related to their welding are presented. Zinc is deposited in layers, having a thickness of 5-17 μm, on parts working in inner spaces and 15-25 μm for parts working outside.

During the welding process, zinc coating is destroyed by a smaller or larger area, depending on the combining process used and the mode of operation.

Also to ensure the strength of welded joints must be considered zinc sulphides, which can remain in the welded joint [9]. Table 1 presents comparative properties of steel and zinc.

Table 1 Comparative properties of zinc and steel [9]

Material/properties	Zinc	Steel
Electric conductivity, [m/mm^2]	16,9	9,3
Thermal conductivity, [J/cm s °C]	1,13	0,5
Melting temperature, [°C]	419	1510
Boiling temperature, [°C]	907	2500
Specific heat, [J/g C]	0,38	0,46
Melting heat, [J/g]	105	255

The main problem when fusion welding galvanized steels is the forming of zinc vapours at the temperature of 906°C (zinc evaporation temperature), as compared with the fusion temperature of steels, which is of about 1500°C.

In order to join galvanized steels the following factors are to be considered:

- ratio between the galvanized plate thickness and the thickness of the galvanizing layer;
- type of joining;
- welding parameters (joining);
- nature of the filler material;
- protection gas used when during the shielding gas welding.

Taking into account the previously presented data, joining of thin sheets and coated thin sheets, may be done with the processes systematized presented in figure 1.

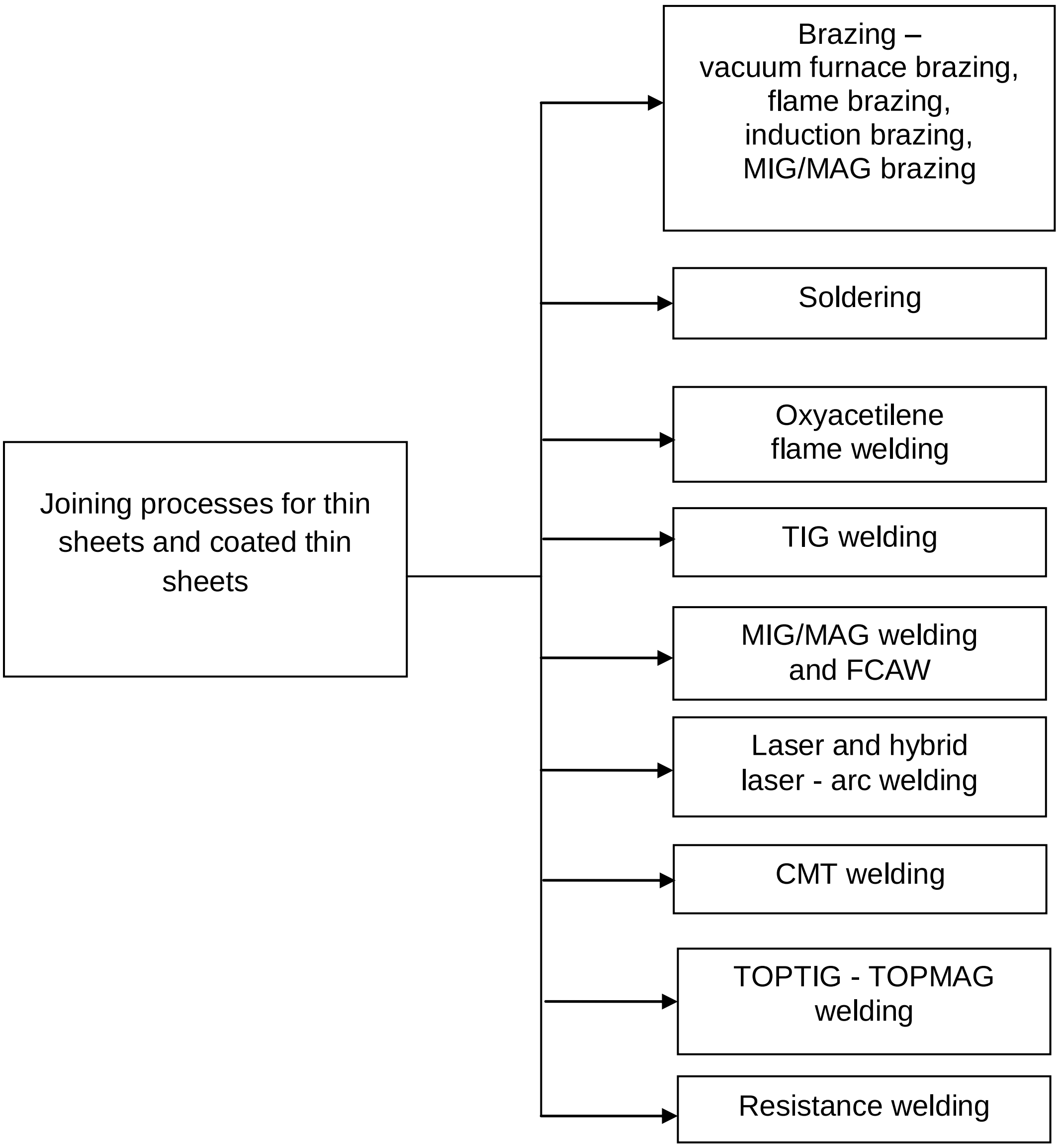

Figure 1. Schematic representation of joining processes for thin sheets and coated thin sheets

3. POTENTIAL VARIANTS OF JOINING THIN SHEETS AND COATED THIN SHEETS

3.1 Brazing process

Brazing, itself or in the complex, sometime hybrid variant (brazing, vacuum furnace brazing, flame brazing, induction brazing, MIG/MAG brazing, CMT etc) gains field in specific applications, being the subject of numerous studies and researches. Remarkable results thus obtained led to the replacement of some traditional more expensive technologies, and to the identification of new applications [3].

MIG/MAG brazing

Brazing is a joining process of materials by means of a filler material that has a much lower in value melting temperature than that of the base material. In this case, the base metal does not reach the melting temperature, during the joining process. As filler materials are used copper alloys having the melting temperature lower than that of steel, the electric arc heats the base metal and melts the filler material; this is similar to the bonding process.

Shielding gases, in this case, are inert gas such as argon and small amounts of active gases, oxygen, respectively. As it can be seen in table 2 if 2.5% CO_2 or 1% O_2 is added to the shielding gas there results an improvement of the arc stability, porosity diminishes and fluidity of the deposited material increases.

Table 2 Effect of shielding gas in MIG/MAG brazing [9]

Filler material	Shielding gas	Arc stability	Porosity	Thermal conductivity	Aspect of joint
SG-CuSi3	Argon	+	0	++	+
	99%Ar, 1%O_2	++	++	0	++
	97.5%Ar, 2.5%CO_2	++	+	0	+
	98%Ar, 2%N_2	++	-	0	++
	98%Ar, 2%H_2	+	-	0	+
	70%Ar, 30%He	+	+	+	+
SG-CuAl8	Argon	+	++	++	+
	99%Ar, 1%O_2	+	++	0	+
	97.5%Ar, 2.5%CO_2	+	++	0	+
	98%Ar, 2%N_2	-	+	-	-
	98%Ar, 2%H_2	-	-	-	0
	70%Ar, 30%He	++	++	++	++
SG- CuSn10	Argon	++	0	++	+
	99%Ar, 1%O_2	++	+	0	++
	97.5%Ar, 2.5%CO_2	+	+	0	++
	98%Ar, 2%N_2	++	-	0	-
	98%Ar, 2%H_2	-	-	-	-
	70%Ar, 30%He	+	0	+	+

„++” – very good; „+”-good „0”-medium; „-”- low

The welding equipment must allow the pulsed current welding.

Welding materials consist in wire electrode, which is a copper alloy - 3%Si, shielding gas – argon or argon mixtures with 1-3%CO_2, or 1%O_2. By introducing these gases in argon an improvement of arc stability was found, as well as a better aspect of the joint. Table 5 presents the main wires used for MIG brazing of galvanized steels [1].

Table 3 Main wire grades used for MIG brazing [9]

Wire type	Wire grade	Wire composition	Melting temperature, °C
Silicon bronze	SG-CuSi3	Cu+3%Si	910-1025
Tin bronze	SG-CuSn6	Cu+6% Sn	910-1040
Aluminium bronze	SG-CuAl8	Cu+8%Al	1030-1040

Welding parameters when joining these steels are much difficult to be established than when welding common steels. The selection of corresponding pulse parameters is indispensible to achieve a quality joining.

3.2 Soldering

Soldering is a joining process that requires the usage of organic flux, the most popular solder composition is 40% tin – 60 % lead. The recommended heat source is a soldering iron, wettability is improved if prior to soldering a caustic treatment is applied.

3.3 Oxyacetylene flame welding

Galvanized plates can be welded using as filler material copper coated steel. The aim is to damage as less as possible the galvanizing layer; so it is recommended not to oscillate the torch during the welding process. It is recommended to perform the welding from the left to the right [9].

It can be also used a 60% Cu and 40% Zn filler material, which melts at the temperature of 900-930ºC. Using this material the zinc layer stays practically intact [9]. Technological recommendations for this procedure are as follows:

- utilisation of a smaller gas nozzle than that used when welding not coated steels having the same thickness;
- utilisation of an oxidant character flame;
- welding from the left to the right and avoid side torch oscillation.

3.4 TIG welding

By using this welding process there will be reduced the amount of volatilized zinc. A disadvantage is that the extremity of the tungsten electrode is rapidly loaded with zinc and deteriorates in a short time. That is why it is recommended to use a tilting angle of the tungsten electrode, against the horizontal of 70°, as well as the use of a larger diameter nozzle, to diminish the deterioration of the electrode [1].

It is also recommended to increase the gas flow from 7l/min to 12l/min, in order to remove zinc vapours; a long arc is also to be used to reduce the penetration of the weld. High frequency ignition is recommended against the lift-arc ignition [9].

The TIG welding process allows the use of a filler material from copper and aluminium or copper and silicon when welding galvanized steels.

Table 4 presents the technological recommendations related to the welding parameters, using a SG-CuSi3 filler material, the shielding gas used is argon and the gas flow is 12l/min, for four versions of plate thickness.

Table 4 Parameters used for galvanized plates TIG welding [9]

Plate thickness [mm]	1	1.5	2	3
Pulse current [A]	80	100	110	120
Base current [A]	38	50	55	60
Pulse frequency [Hz]	2.5-3	2.5-3	2.5-3	2.5-3
Wire feed speed [m/min]	4	4.5	8.5	11
Welding speed [cm/min]	50-70	50-70	50-70	50-70

3.5 MIG/MAG welding

MIG/MAG welding with solid wire or cored wire is the most used process for welding galvanized steels, as the productivity is higher as compared with the other electric arc processes [9].

This process has applicability especially in the automotive industry to assemble thin galvanized plate components. It is to be mentioned that the penetration when using MIG welding for galvanized steels is smaller as compared with the MIG welding of not coated steels.

The main problems appearing in this situation are as follows:

- spatter;
- excessive porosity, particularly at filler welds;
- deterioration of the zing layer on a larger area, as compared with the other welding processes;
- gas release;
- cracking due to the liquid zinc.

As there is a great loss of material due to the intense spattering, the shielding gas plays an important role when welding these materials. CORGON 18 is the most indicated shielding gas and the transfer mode is the short-circuit one [9].

These drops adhere on the component and the aspect is poor. That is the reason why before welding anti-adhesive material may be applied to the work piece. The reduction of pores is a major problem, especially for fillet welds. In order to diminish pores more technological versions have been tried. A technological version refers to the welding groove opening, at least 1.5 mm.

The composition of wires for MIG welding galvanized steels is recommended to contain a high content of manganese, Ni-Cu alloyed wires, low silicon wires and high titanium wires [9].

Other researchers recommend high manganese and silicon wires, which give good results when using pulsed MIG welding, even if the pool viscosity is diminished.

Good results are also obtained using wires with a high content of de-oxidation elements (Al, Ti, Zr). According to some tests performed in the automobile construction, it was shown that classical cored wires assure reduced properties as compared with solid wires, due to the fact that the electric arc is very unstable [9].

The new generation of cored wires, without slag, is used in manual or mechanized welding of thin galvanized plates. These types of cored wires reduce spatter, the aspect of the weld is a good one and diminish the width of the destroyed layer during the welding process. They contain a reduced percentage of aluminium and titanium, which soothes and streamline the metal pool and facilitate the release of gas.

The welding equipment must allow welding with low values of the arc voltage, about 9.5-10V for a 1mm wire as compared with 20-26 V, for traditional MAG welding. A mixture of argon, CO_2 and O_2 must be used. Table 5 presents recommended parameters for the

MIG/MAG welding of galvanized steels. The shielding gas used is argon and the gas flow is 12l/min, thickness of the welding wire is 1mm, and the welding speed is 50-70 cm/min.

Table 5 Welding parameters of galvanized plates MIG/MAG process [9]

Thickness [mm]	1	1,5	2	3
Arc voltage [V]	14	14,3	14,5	17
Welding current [A]	55	72	90	118
Wire feed speed [m/min]	2,3	3,4	4,5	6

3.6 FCAW welding

Flux Cored Arc Welding (FCAW) is similar to GMAW in that it is a semi-automatic welding process using a tubular filler material as the electrode. The tube contains a flux for cleaning and shielding, and metallic particles as filler material. The filler material is in form of particles, so the heat input necessary to reach the melting point is lower in comparison to GMAW.

FCAW is a new welding method, which allows high speed welding, increase of the deposition rate, the possibility of additional alloying of the weld metal through the core, ensuring a stable arc with decreased spatter, reduced sensibility towards the air currents, rapid solidification of the slag. FCAW creates its own protective atmosphere for the electric arc and the molten pool due to the core's gasifier components.

The major disadvantage of this process is the pronounced fumes emissions which impose to take some safety measures. Other advantages of this process are the microalloying possibilities, the decrease of the cracking risk, fine surface of the weld, lack of marginal notch, higher penetration etc.

In America and Japan, tubular wire represents 28 up to 30% from the total quantity of wire, while in Europe, the quantity of tubular wire that is used represents a small percent.

3.7 CMT (Cold Metal Transfer) joining

Application of the Cold Metal Transfer (CMT) process to join thin plates represents an intermediary version between brazing and welding [2].

In CMT joining the drop assisted detachment technology is especially used. In this case, if the welding technological parameters were correctly selected, at each controlled touch of the wire and the base material a single drop of filler material should be detached from the wire electrode [9]. Result can be called „drop by drop welding”.

Advantages when using this welding process are as follows:

- thin components can be welded, under 0.8 mm;
- large diameter wire electrode can be used with low welding current (wire with a diameter of 1.2 mm can be welded with a current stable I_S = 65A);
- good welding position;
- heat introduced in the component is smaller with about 30% as compared with classical MIG/MAG welding;
- small deformations;
- process is suitable for full mechanization.

All mentioned aspects are valid both for MIG/MAG welding and for CMT (Cold Metal Transfer) process the only difference is the transfer mode of the metal drop.

3.8 Hybrid Laser-Arc welding

The hybrid-laser arc welding process (figure 2) employs laser beam welding and gas metal arc welding in a combined process that overcomes deficiencies encountered with each individual process. Laser beam provides increase penetration at relatively fast travel speeds, while gas metal arc welding is efficient in adding material resulting in a higher root opening tolerance [4].

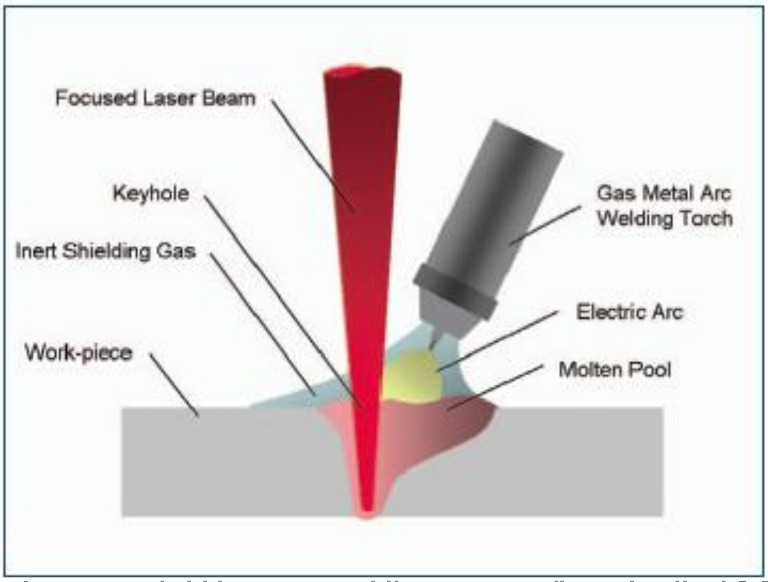

Figure 2. Hybrid laser arc welding process (laser leading) [4]

It allows to obtain reduce distortion welded joints, especially when welding large size panels.

3.9 TOPTIG-TOPMAG

TOPTIG process is a new process namely a combination of MIG and TIG processes. Originally TOPTIG is meant to improve robotic TIG cold-wire brazing of thin plates (up to 3 mm). Galvanized steel thin silicon bronze, stainless steel, aluminium, is frequently used in the automotive industry. TOPTIG was successfully used for different applications such as thin galvanized steel brazing using silicon bronze wire, no spatter, stainless steel welding in the food processing and metal furniture industries [14].

TOPMAG is in fact MIG/MAG twin-wire welding to reach great productivity. The combination of two arcs extends the energy input and increases the length of the molten pool as well as the welding speed. Different joints can be made such as butt joints, lap joints, flat joints of thin and medium plates.

3.10 Resistance welding

Resistance welding or spot welding may be used to join thin sheets, coated sheets also, especially if the coating is thin. Coating damage is usually of minor significance, requiring little or no repair.

4. CONCLUSIONS

The paper presents a synthesis of possible joining methods for thin sheets and coated thin sheets (brazing, soldering, oxyacetylene flame welding, TIG welding, MIG/MAG welding, FCAW welding, CMT (Cold Metal Transfer) joining, hybrid laser-arc welding, TOPTIG-TOPMAG, resistance welding).

General problems concerning joining of thin sheets are presented, together with the factors to be considered when joining this type of sheets.

For each joining process, the paper presents the aspects that are particular to coated sheets. For the most used joining processes, the paper presents also the parameters required by the joining method.

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