MIG BRAZED HOT-DIP GALVANIZED SHEETS

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ABSTRACT

The paper presents the results of metallographic analyses of joints made by MIG brazing on deep-drawed galvanized steel sheets of DX51D + Z EN 10142/2000. The quality of brazed joints made by SG $CuSi_3$ *braze with fluctuating welding rectifier CLOOS 303 MC4 was evaluated. Argon 4.6 was used as a gaseous shield. The sheets were joined with various brazing parameters. Corrosion resistance of joints was evaluated on the basis of accelerated test in aggressive environment of* SO_2*.*

Keywords: brazing parameters, corrosion resistance, metallographical analysis, brazing direction

INTRODUCTION

Zinc coating on steel sheets causes some problems during the welding process, such as relatively low melting temperature of Zn (419ºC), or Zn vaporization at a temperature exceeding 908º C. Since the melting temperature of steel is higher, some destruction of coatings occurs and subsequently corrosion resistance at the joints decreases (Ondrejček, 2003; Sejč, 2005).

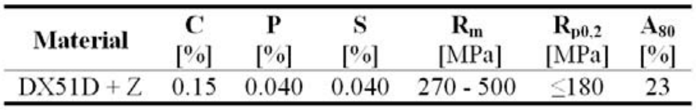
The effort of automobile producers is to produce safe and reliable automobiles with low fuel consumption. Therefore, in order to decrease the car-body mass, combinations of deep-drawing surface modified sheets, high-strength sheets for reinforcement, aluminum alloys, sandwich sheets, compounds, and plastics are used in automobile production (Viňáš *et al.*, 2008). Utilization of these materials requires applying vast knowledge and precise optimization of parameters in the technologies of their joining (Mohyla & Foldyna, 2009). One increasingly used method of car-body joining is MIG brazing (GMAB – Gas Metal Arc Brazing). This technology was applied in car-body production in the early seventies, but its usage in the car-body production is still growing (Chovet & Guiheux, 2006; Roubíček, 2003).

MATERIALS AND METHODS

In these experiments, deep-drawing sheets of DX51D + Z EN 10142/2000 of U.S. Steel production were used. The material used is a deep-drawing steel with typical ferritic-perlitic structure (Lazar *et al*., 2007). The surface was treated by dip-zinc galvanizing. Zinc coating thickness, as stated by the producer, is 16μm. The chemical composition of the tested sheet is presented in Table 1.

TABLE 1

Chemical Composition and Mechanical Characteristics of DX51D + Z EN10142/2000 Steel



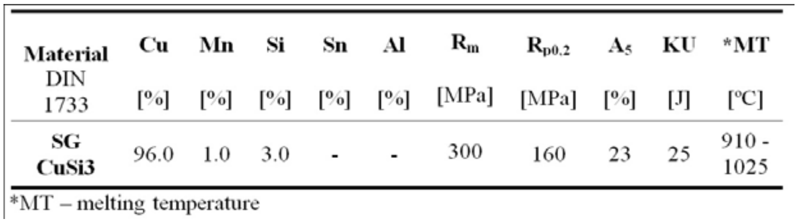
Material	C [%]	P [%]	S [%]	R_m [MPa]	$R_{p0.2}$ [MPa]	A_{80} [%]
DX51D + Z	0.15	0.040	0.040	270 - 500	≤180	23

R_m – ultimate tensile strength, $R_{p0.2}$ – proof stress, A_{80} – elongation on length 80mm

The chemical compositions of the types of brazes used and their strength characteristics are presented in Table 2. Brazes A 384 used in these experiments were made by UTP company.

TABLE 2

Standard Chemical Composition and Mechanical Characteristics of Brazes



Material DIN 1733	Cu [%]	Mn [%]	Si [%]	Sn [%]	Al [%]	R_m [MPa]	$R_{p0.2}$ [MPa]	A_5 [%]	KU [J]	*MT [°C]
SG CuSi3	96.0	1.0	3.0	-	-	300	160	23	25	910 - 1025

*MT – melting temperature

A_5 – elongation on length 5mm, KU – impact strength

Samples of dimensions 400mm x 780mm were cut from sheets of 0.9 mm thickness. Brazing surfaces were cleaned with the shearing emulsion CH_3COCH_3.

Brazing of car-body sheets was carried out on CLOOS 303 MC4 equipment. One of the possibilities of compensating the negative influence of zinc evaporation on the lapped joint is modifying the position of brazed sheets. Modification of the parallel position of brazed sheets' contact areas by an angle α (1-5°) enables better Zn evaporation from the area of brazing, and thus decreases the possibility of melting metal transfer into the joint.

The brazing parameters and marking of the tested samples are shown in Fig. 1 in the direction of brazing from right to left. Fig. 2 shows brazing parameters used for brazing from left to right.

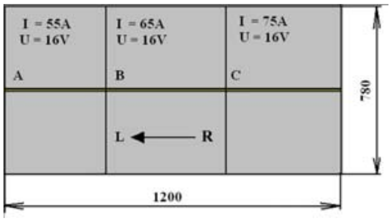


Figure 1. Brazing parameters for brazing from right to left and marking of samples.

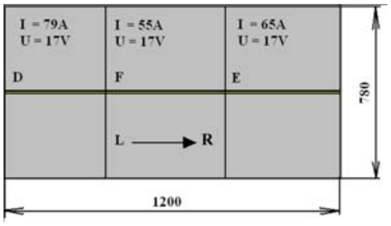


Figure 2. Brazing parameters for brazing from left to right and marking of samples.

The joint made by the brazing technology was formed with shielding gas of argon 4.6 at the lapped sheets. The angle of torch slope during brazing was 45º. The width of the lapping was from 18 to 20 mm.

TABLE 3

Brazing Parameters

Thickness of Brazing Sheets	Type of Braze	Wire Diameter of Braze	Impulse	Brazing Current [A]	Voltage [V]	Inert Gas
0.9 mm + 0.9 mm	CuSi3	1.0 mm	Yes	55 - 79	16 - 17	Argon 4.6

The macrostructure and microstructure analyses of the brazing joints quality were carried out according to STN EN 1321 standard. The metallographic scratch patterns were observed in the optical light microscope Olympus CX-31. Nital of 3% concentration was used as the etchant to enable the visualization of the basic material microstructure. The microstructure of braze $CuSi_3$ was observed after etching with a solution of ammonium persulphate (10 g of ammonium persulphate + 100 cm^3 of distilled water).

The technology of MIG brazing is presented in specialized literature as a technology that is friendly to protective coating. Therefore, the influence of brazing on the corrosion resistance, and the speed of corrosion were evaluated on the tested samples.

Corrosive losses belong among the basic quality characteristics. They characterize the corrosion resistance of metals under specific conditions. The experiments were carried out according to STN 03 8102 standard. It is an informative test for preliminary determination of corrosion resistance of materials under specific conditions. The corrosion resistance of coatings was observed under continuous exposure of the samples to pure wet atmosphere at a the temperature of 40 ± 2^oC and with a relative humidity of 100 %. The influence of the corrosive environment on the tested samples was evaluated by a weight loss test. The samples were immersed in a bath of the following composition: 50 ml of 98 % acetic acid, 950 ml of distilled water. They were immersed in one-minute time intervals. After immersion, the samples were rinsed, dried and weighed on digital scales RADWAG XA 220 with the accuracy of 10^{-4}g. The corrosion losses were observed at respective time intervals after immersing.

The volume of the condensation chamber was 300 litres. Duration of the test was chosen according to STN EN ISO 3231 standard, with the following number of testing cycles: 1, 2, 3, 7, 14, 21 and 28 days. The total duration of the test was 28 days.

Evaluation of the samples was carried out according to STN EN ISO 10 289 standard and by a visual test. The surfaces on both sides of the joined materials were evaluated.

RESULTS AND DISCUSSION

Material DX51D + Z EN 10142/2000 was analyzed by a microstructural analysis. A typical ferritic-perlitic structure was observed in the tested material.

At the chosen 45º angle of the torch slope toward the area of brazing, the process of more intense metal melting starts from the upper edge of the sheet (Fig. 3). This is in compliance with the fact that the Fe particles diffused in the brazed metal near the edge of the top brazed material (Marônek *et al*., 2005) were observed in higher resolution.

In the macrostructure of the joint, a relatively small thermal impact on joined sheets in the process of MIG brazing was observed. The detailed picture shows good braze wettability and fluidity. A presence of pores was detected in the brazed metal. An increase in the amount of pores in the brazed metal decreases the strength properties of the joint.

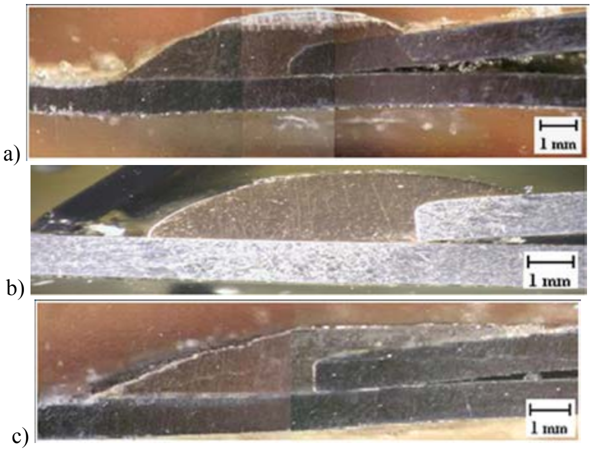


Figure 3. Macrostructure of sheets jointed by SG $CuSi_3$ braze with brazing from right to left.
a) sample A, b) sample B, c) sample C.

The influence of the brazing parameters (brazing current I) on the dimensions of the brazed joints and behavior of $CuSi_3$ metal is documented in the macrostructures in Figs. 3a, 3b, 3c. The stress and the speed of brazing were constant. On the basis of the microscopic observation, following conclusions can be stated: an increased brazing current had a significant thermal influence on the basic material. In the area of brazed material, there occurred significant grain coarsening. The transition of a coarse-grain structure of heat affected zone (HAZ) to a fine-grained structure of the basic material is fluent as shown in Fig.4. A ferritic-perlite structure with a higher content of perlite was observed in HAZ, which corresponds to the processes of basic material changes (Hudáková *et al*., 2001).

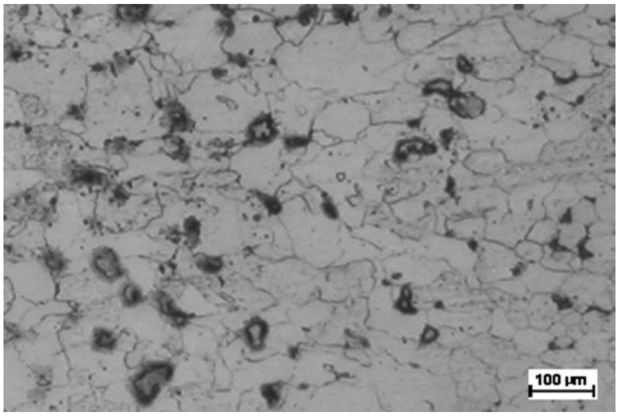


Figure 4. Microstructure of heat affected zone of DX51D + Z EN 10142/2000 steel.

In the evaluated parameters of brazing from right to left, the brazed metal had good wettability and capillarity. The adhesion of the brazing solder on the sheet can be assessed as good. Pores, cavities or other defects were not observed on the interface between brazing solder and basic material.

Samples A had a brazing bead with the maximum reinforcement in comparison to the other tested samples. But the width of the bead was smaller in comparison to samples B. Using of brazing current I = 55 A had the lowest heat influence on the basic material. The highest heat influence on the basic material and the highest diffluence of the brazing solder were observed in samples C with brazing current I = 75 A.

Fig. 5 shows the macrostructures of joints made by MIG brazing from left to right. On the basis of analyses of macro and microstructures of the evaluated samples D, E and F, it can be stated that lap joints of high quality were formed in case of all of the observed brazing parameters. The biggest diffluence with the smallest height were observed in the samples made with a brazing current of 79 A, as shown in Fig. 5a. The narrowest brazing bead with the biggest overlap was made with a brazing current of 55 A.

Despite of the lower brazing current, the brazing metal had good wettability and capillarity, as it can be seen in Fig. 6.

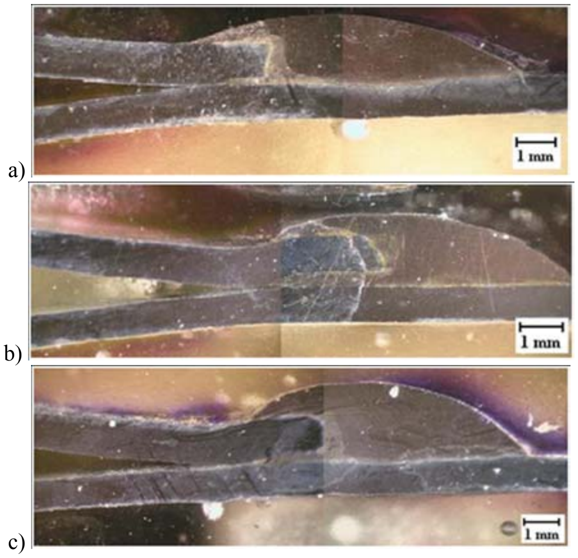


Figure 5. Macrostructure of sheets jointed by SG $CuSi_3$ braze from right to left. a) sample D, b) sample E, c) sample F.

On the basis of macrostructures analyses it can be stated that more significant heat influence was observed on the samples brazed from right to left (A, B, C). Lower heat influence was observed on sample F.

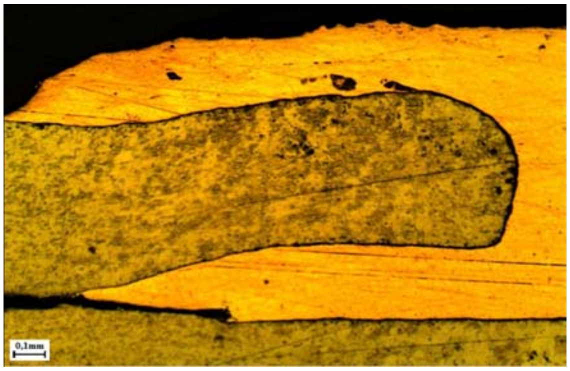


Figure 6. Detail of brazing solder wettability on sample F.

Brazing metal has its typical casting structure with numerous pores caused by the applied inert gas, Argon 4.6.

The heat in the brazing process negatively influences cohesion and the quality of protective coatings, mainly Zn. The value of brazing current can be optimized to 55 A. Good quality of joints was observed in both types of brazing made with this current. Therefore, these samples were used for the evaluation of the influence of brazing parameters on the corrosion resistance.

During brazing the sheets were in the contact angle α (1-5°), so the sheets were in full length contact.

The molten metal of the braze has such a good fluidity and wettability, that the brazing solder got to the distance of 1.8 to 2.0 mm from the contact edge of the sheets. In the macrostructure it is possible to observe lifting of the top sheet.

Good wettability is obvious from the continual covering of the upper sheet and its edge being without pores, cavities and other defects. The brazing metal covered the surface of the lower sheet, corresponding to the diameter of the used brazing solder and parameters.

Poor wettability, caused by inappropriate type of brazing solder or impurities on the surface, decreases the strength properties of the joint, because the solder-surface interaction does not arise, which is in concordance with theoretical knowledge of the authors.

The samples made with both types of brazing were used for the corrosion resistance test according to the above mentioned methodology. Fig. 7 shows the samples after a 240-hour exposure to a condensation chamber test.

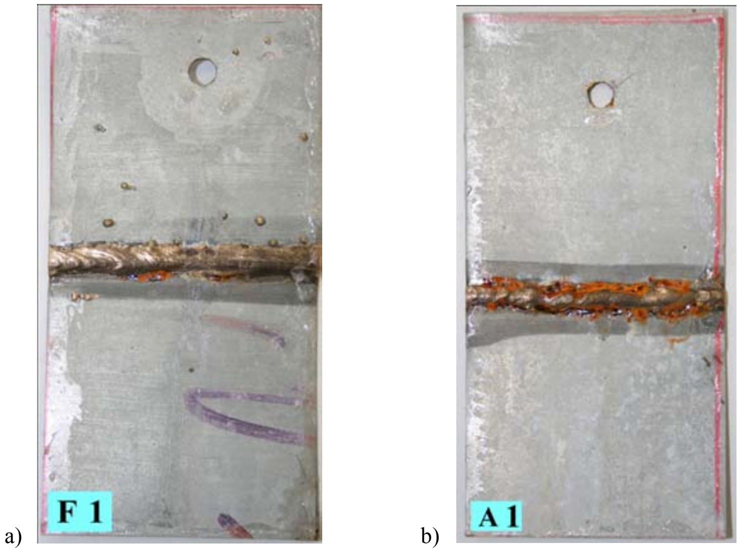


Figure 7. Samples after 240-hours exposure.
a) left-hand brazing – sample F1, b) right-hand brazing – sample A1.

Corrosion attacks were observed in both types of brazing processes. So-called white corrosion occurred in the zinc surface of the base material. The main factor that caused the white corrosion of the zinc layer and consequently the corrosion of steel core was the condensation of air humidity. Because of the humidity impact, a zinc coated sheet becomes a galvanic cell with the zinc layer functioning as the anode and the steel core as the cathode.

During the condensation chamber test, the samples made by left-hand brazing were covered with corrosion from 15 to 45 % of the evaluated brazing solder area. White corrosion covering was observed on the whole surface of the base material (Sejč, 2005).

The samples made by right-hand brazing were covered with corrosion from 70 to 80 % of the evaluated brazing solder area. White corrosion covering was also observed on the whole surface of the base material. The results of experiments are in concordance with findings of (Sejč, 2004) describing the influence of heat on the surface of joint materials.

The results of the condensation chamber test were influenced by the brazing process, where the evaporation of zinc coating occurred in a longer distance from the zone of metal transfer from the electrode into the brazing bath in the right-hand direction of brazing.

The corrosion changes were observed only on the surface of the base material (Fig. 8 and Fig. 9) in both types of brazing in the places where evaporation of zinc layer occurred.

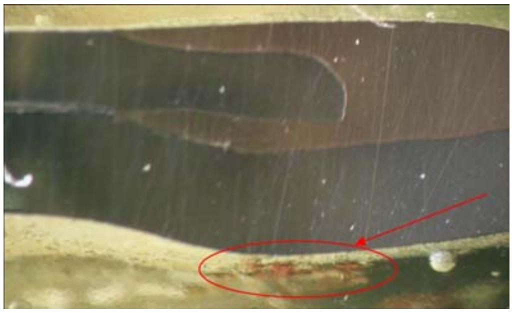


Figure 8. Detail of corrosion attack in left-hand brazing, extension of 10x.

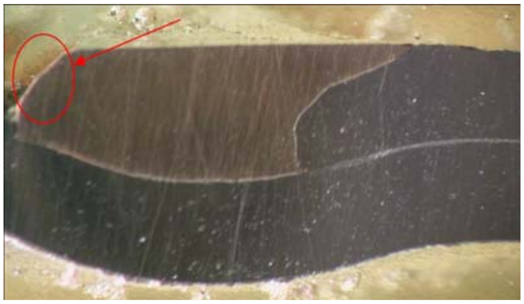


Figure 9. Detail of corrosion attack in right-hand brazing, extension of 10x.

The value of the corrosion loss was estimated by a graphical extrapolation of the straight line section to the vertical axis. The intersection of the straight line extrapolation with the vertical axis is the value of corrosion loss provided that the slope of the straight line approaches zero.

The achieved corrosion losses in particular brazing regimes are shown in Fig. 10 and 11. Graphically estimated values of corrosion losses are: 0.008 g in left-hand brazing, 0.014 g in right-hand brazing.

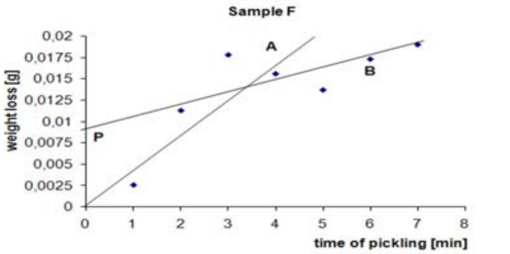


Figure 10. Average corrosion loss in left-hand brazing.
A – dissolving of corrosive product, B – dissolving of tested metal, P – corrosion loss.

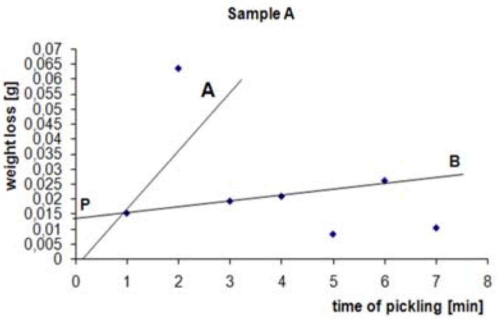


Figure 11. Average corrosion loss in right-hand brazing.
A – dissolving of corrosive product, B – dissolving of tested metal, P – corrosion loss.

CONCLUSION

Surface treatment by Zn, Al, Sn metals and their alloys has a negative influence on all conventional and unconventional brazing processes. Negative impacts on the welding process is mainly the low melting temperature of these metals as well as their low evaporation temperature. The instability of weld arcing was caused by the evaporation of Zn during the arc welding. The evaporated zinc from the sheet surface moves the arc from the place of joint to an area with lower electrical resistance. It is convenient to use an arc about 2-3mm long in the brazing process (Kersche & Trube, 2008; Lechovič *et al*., 2009).

The evaporation of zinc during brazing of zinc coated sheets causes instability of the process in general, *i.e.*, unstable arc burning, faults in the gaseous shield flow and transferring the brazing solder to the brazing bath. The above mentioned influences increased splashing of the brazing solder to the surroundings of the joint. In order to eliminate the influence of zinc evaporation on the stability of arc burning, left-hand movement of the torch is recommended where evaporation of zinc coating occurs in further distance from the zone of metal transfer from the brazing solder to the brazing bath.

The influence of zinc vapours on the joint quality could also be decreased by the choice of direction of the torch motion (bead storing). Left-hand burner operation decreases the influence of Zn vapours on the welding arc, because the evaporation occurs before the transfer of additional melting material. However, this method is very sensitive to the optimization of the torch motion speed during brazing. Right-hand torch operation provides only a short time for zinc evaporation from the metal which has negative influence on the electric arc. The dynamic effect of zinc vapours could cause a splash of the additional melting metal (also observed by Roubíček (2003)).

During the brazing with $CuSi_3$ wire it is convenient to use blended gases, namely: Ar + 1% O_2, or Ar + 2.5% CO_2. By addition of these active components it is possible to achieve lower porosity, more stable arcing and minimum splashing.

MIG brazing is one of the most applied methods of zinc coated sheets joining used in car body production in the automotive industry. But it is not possible to create the joint without decreasing the quality of Zn coating on the brazed sheets. The temperature of melting of $CuSi_3$ brazing solder is from 910°C to 1025°C which exceeds the temperature of zinc evaporation (906°C). CMT (cold metal transfer) seems to be a suitable innovation of MIG brazing. The heat effect in this method is not so significant during brazing process in comparison with MIG brazing.

ACKNOWLEDGEMENTS

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