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Investigation of mechanical properties of MIG-brazed joints of DP600 steel plates using different working angle

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ABSTRACT

Purpose: In this study, DP 600 (Dual Phase) steel plates having 1 mm thickness were joined by copper-based (CuAl8) wire in gas metal arc brazing technique. Specimens were prepared in joining forms as overlap joint.

Design/methodology/approach: Brazing operations were done with five different working angles of 45°, 50°, 60°, 70° and 80°. CuAl8 wires composed largely of copper serves as the filler metal were used. Having accomplished the brazing operations; tensile properties of joints were detected, and micro and macro-structures of joints were investigated in order to see the joinability of DP 600 steel by gas metal arc brazing technique.

Keywords: MIG-brazing; Dual phase steel; DP 600 steel; Tensile strength

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PROPERTIES

1. Introduction

Recently, it becomes important in automotive industry to improve gas mileage by reducing total weight of vehicles while maintaining their level of safety. Therefore, using high strength materials, which provide higher strength for automobile body parts, has rapidly increased in the sheet metal industry [1]. Dual phase steels are among the most important advanced high strength steel (AHSS) products recently developed for the automotive industry. This group of steels is very interesting for light weight constructions because it combines a high ultimate strength with a high fracture strain [2]. The dual phase DP 600 steel, which is among the steels developed within the scope of measures to provide fuel saving, has become a product widely used in automotive industry [3,4]. The DP 600 steel enables both a reduction in vehicle weight, an increase in strength for those carrying greater loads, and provides thinner application thickness [5]. The DP 600 steel was reported as being used in Arcelor Mittal automobile applications, in parts such as seat flange, wheel, wheel webs, light weighted longitudinal rails, shock towers, and fasteners [4,5].

The car assembly industries have recently been using zinc-coated carbon steel sheets in passenger car bodies because they combine good mechanical properties, good corrosion resistance and low purchase cost of this material [6]. Galvanized DP steel sheets are widely used in construction with corrosion resistance and especially in the automotive industry [7]. In car assembly, where conventional welding processes like gas metal arc welding (GMAW) are used, the zinc coating is subject to severe evaporation and oxidation, leaving the weld bead and part of the base metal unprotected against subsequent oxidation. To reduce the risk of zinc evaporation, new welding processes with a low heat supply have begun to gain ground, for example MIG-brazing, which combines the advantages of the MIG process (high deposition rate, high welding speed and adaptable to automation) and brazing (without any intense fusion of the welded parts and without any appreciable alteration of the mechanical properties of the base metal and the coating applied) [8].

In this paper, mechanical properties of overlap joint form in MIG-brazed joints of DP600 thin zinc coated steel plates using different working angle were studied by using copper based filler and it is found that the joint strength is higher than that of the base materials [9,10].

2. Material and method

2.1. Materials

A zinc coated DP 600 dual phase automotive steel which was mainly ferritic with a fraction of hard phases of martensite was used in this study. The chemical composition of the steel was given in Table 2. In the tests the steel plates were 1 mm thickness, with 7.5 µm zinc coating. DP 600 steel plates were cut 200 x 200 x 1 mm, Fig. 1. MIG-brazing operations were done with five different working angles of 45°, 50°, 60°, 70° and 80°. CuAl8 wire composed largely of copper serves as the filler metal was used. Argon was used as the shielding gas at a flow rate of 12 L/min. The chemical composition of filler wire was given in Table 1.

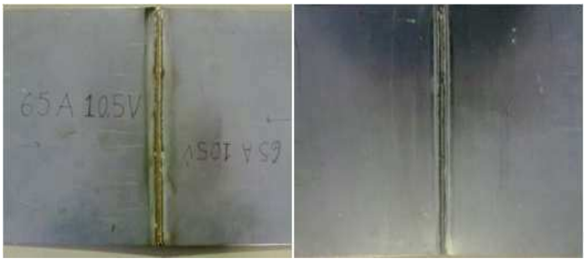

Fig. 1. Front and back appearances of typical joints

Table 1.
Chemical composition of the filler metal

Cu, %	Al, %	Mn, %	Fe, %	Sn, %	Melting temperature, °C
Rest	8	<0.5	<0.5	<0.5	1030-1035

Table 2.
Chemical composition of DP 600 galvanized steel

C, %	**Si, %**	**Mn, %**	**Al, %**	**Sn, %**
0.091	0.239	1.858	0.039	0.001
Cu, %	**Nb, %**	**V, %**	**Fe, %**	**P, %**
0.012	0.001	0.004	96.282	0.011
S, %	**Cr, %**	**Mo, %**	**Ti, %**	**Ni, %**
0.001	0.573	0.004	0.002	0.024
N, %	**B, %**	**Al-ZO, %**		
0.0035	0.0001	0.038		

2.2. Methods and procedure

The surface of the samples was cleaned by acetone before MIG-brazing. Five sets of welding parameters of different working angle were selected, as shown in Table 3. The heat input, HI is calculated using the equation:

$$HI_{linear} = \frac{(60 \times UI)\eta}{V} \tag{1}$$

$$HI_{normalized} = \frac{HI_{linear}}{e} \tag{2}$$

where η_{MIG}: 0.7 is the arc efficiency factor, e: thickness (mm) U and I are the mean values for the arc voltage, respectively for the current intensity and V (cm/min) is the brazing speed [11]. MIG-brazing process parameters such as current intensity, voltage, wire feed speed, shielding gas at a flow rate of 12 L/min, brazing travel speed were presented in Table 3. All MIG-brazing tests were performed automatically on a machine with a robot. The brazed sheet was cut transversally with a fine diamond-tipped disc, sanded with six sandpapers with a granulometry from 200 to 1200 mesh, and polished with alumina paste having a granulometry of 0.3 µm. To determine the structure of the base metal a solution of nitric acid and ethyl alcohol (Nital 3%) was used.

The shape and dimensions of the samples for tensile test and bending test are shown in Figures 2 and 3.

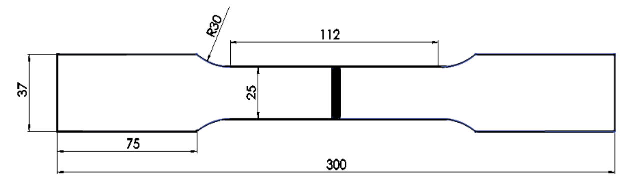

Fig. 2. Classified as EN 895 design of tensile test specimen

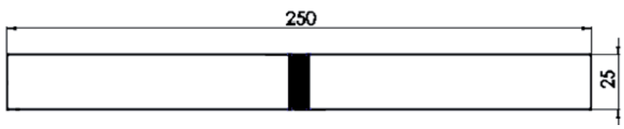

Fig. 3. Classified as EN 910 design of bending test specimen

3. Result and discussion

3.1. Tensile tests

To measure the standard joint strength, MIG brazing and tensile testing was conducted first. The experiments showed that most of the tensile test specimens fractured at the base materials. It was obvious that the joint zone was strengthened. Having examined the strength values in Table 4, it was observed that strength increased with the increase of working angle. When analyzed bending test results; no fracture was observed in the joint zone.

3.2. Microhardness test

Figure 4 shows the measured microhardness value of the joints for different brazing gap. It was seen that micro-hardness value was highest at HAZ and the HAZ hardness was higher than that of the copper filler and base material.

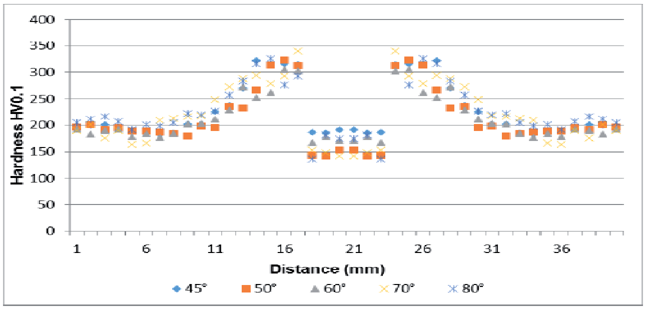

Fig. 4. Hardness profile in Heat Affected Zone in DP600 steel

Table 3.
MIG-brazing process parameters

MIG-brazing parameters					
Current intensity, A	Wire feed speed, m/min.	Voltage, V	Shielding gas, L/min.	Travel speed, cm/min.	Working angle, °
65	3.4	12.3	12	24	45
65	3.4	12.3	12	24	50
65	3.4	12.3	12	24	60
65	3.4	12.3	12	24	70
65	3.4	12.3	12	24	80

Table 4.
Experimental results for different working angle

Working angle, °	Tensile strength, MPa	Bending force, N	Heat input, j/cm
45	635	1309	1399
50	622	1073	1399
60	627	1300	1399
70	512	1271	1399
80	556	1299	1399

Macro appearance of the weld seams for different working angles are shown in Figure 5.

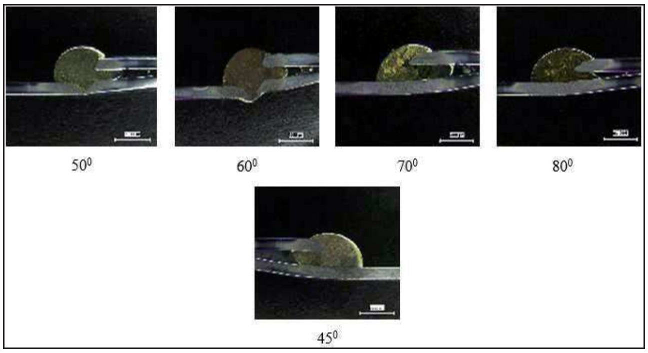

Fig. 5. Macro appearance of the brazing seams for different working angles

Microstructure appearances of the brazing seams for different working angles are shown in Figure 6.

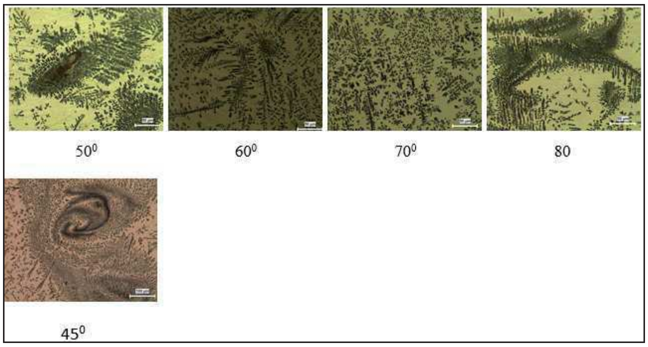

Fig. 6. Micrographs of MIG-brazing joints obtained on DP600 with different working angles

The chemical composition of brazing was investigated using SEM and EDX analysis, as shown in Fig. 7. and Table 5.

EDX chemical analyses of the brazed seams are shown in Fig. 7. During the arc brazing process, it was observed that the number of dendrites increased on the surface of the joint zone. These dendrites' action caused micro iron particles to melt and migrate, and to become distributed throughout the filler metal zone.

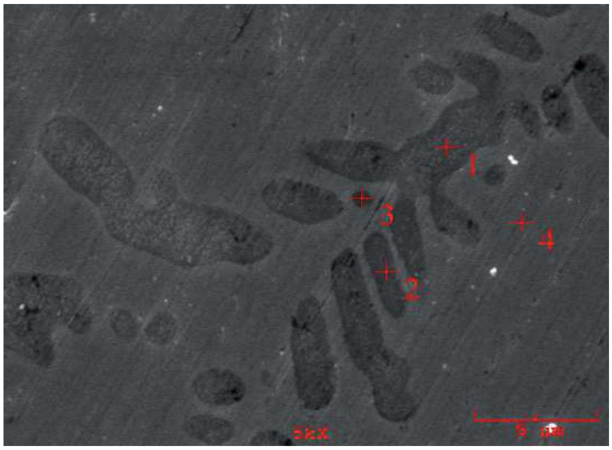

Fig. 7. EDX chemical analysis of the brazed seams in big dendrite (1), smalldendrite (2), copper matrix (4)

4. Conclusions

This work has presented an investigation on the effects of strength of working angle. The conclusions from this study can be driven as follows;

- MIG-brazing method provided lower heat input in comparison with other fusion methods.
- It was observed that strength decreased with the increase of working angle. The best strength arose in 45^0 working angle. When analyzed bending test results, no fracture was observed in the joint zone.
- SEM images confirmed that the increase of iron diffusion brought about stretching of dendrites like branches. Additionally, increase of dendrites resulted in increase of hardness and strength.

Table 5.
EDX chemical analysis

Point	Element, wt%						
	Al	Si	Cr	Mn	Fe	Cu	Zn
1	9.343	0.640	0.376	0.332	74.143	11.197	0.739
2	8.317	0.628	0.461	-	71.278	16.314	-
3	9.412	0.780	-	-	36.625	50.209	0.274
4	8.696	0.335	0.143	0.304	5.503	78.789	0.546

Additional information

This study was presented at the IMSP 2016.

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