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Resistance spot welding macro characteristics of the dissimilar thickness dual phase steels

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ABSTRACT

In the present work, macro characteristics of the dissimilar thickness dual phase steel resistance spot welding joints were described in terms of melting rate, indentation rate, nugget diameter and indentation diameter. The results revealed that the melting rate of the DP600 side was higher than that of the DP780 side and the indentation rate of the DP600 side was lower than that of the DP780 side of the welded joints. The base metal lap order had the important effect on nugget diameter, and the DP780/DP600 spot welded joints tended to get the larger nugget diameter than DP600/DP780 spot welded joints with the same process parameters. The indentation diameters of DP600 and DP780 sides depended on the electrode geometry and force.

1. Introduction

Advanced high-strength steels (AHSS) combine strength and ductility by phase transformation and solution strengthening and achieve a strength-to-weight ratio for lightweight applications in the automobile industry [1,2]. Dual phase (DP) steel is one of the most common AHSS due to the good formability and ductility with relatively high strength, continuous yielding followed by rapid work hardening, a low yield to tensile strain ratio and non-aging behavior at ambient temperature [3–5]. In order to maximize efficiency and performance, the dissimilar material combinations are very widely used in automotive industry [6]. The adoption of dissimilar metal combinations provides possibilities for the flexible design of the products using each material efficiently.

Resistance spot welding is an important method in automobile manufacturing till today and a typical vehicle could need 3000–7000 spot welds [7,8]. Quality and performance of the resistance spot welds are very important to the durability and safety design of vehicles [9]. The quality of the spot-weld was examined by destructive tests to determine whether a satisfactory weld had been produced, such as quasi-static tensile test and dynamic cycle test. Pal and Bhowmick [10] studied the high cycle fatigue behavior of DP780 steel sheet and found that DP780 spot-weld joints had almost similar fatigue behavior at low load high cycle and high load low cycle. Khan et al. [11] studied the hardness profile of dissimilar HSLA350/DP600 resistance spot welds and found that the hardness in the fusion zone (FZ) was higher than that in the base metal (BM) due to the formation of lath martensite. Hernandez et al. [12] studied the mechanical properties of dissimilar DP600/DP780 spot-weld joints and found that HAZ softening promoted a pullout failure mode and fracture occurred first in the DP780.

The macro characteristics of spot welded joint also have important influence on quality and performance. Increasing independent depth led to stress concentration and provided the potential location for shear–tensile failure [13]. Nugget diameter affects the tensile–shear strength of the spot welded joints. However, there are few literatures about macro characteristics of spot-welded joints.

Considering the facts above, the aim of this research is to study the macro characteristics of dissimilar thickness dual phase steel RSW joints including melting rate, indentation rate, nugget diameter and indentation diameter. The effects of process parameters and BM lap orders on the spot welded joint macro characteristics are discussed.

2. Experimental details

1.2 mm thick dual phase steel DP780 and 1.5 mm thick dual phase steel DP600 were used as the base metals. The mechanical properties of the base metals are presented in Table 1. The

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Table 1
Mechanical properties of DP780 and DP600.

	Tensile strength (MPa)	Yield strength (MPa)	Yield tensile rate (%)	Elongation (%)
DP780	842	530	0.63	18.5
DP600	610	395	0.65	26

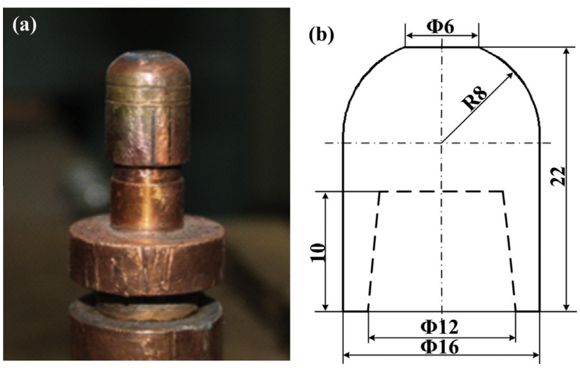

Fig. 1. Electrode shape (a) and geometry dimensions (b).

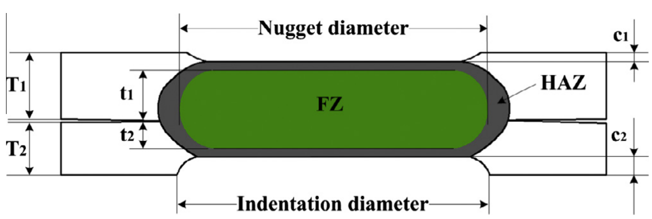

Fig. 2. Schematic of the weld joint cross-section.

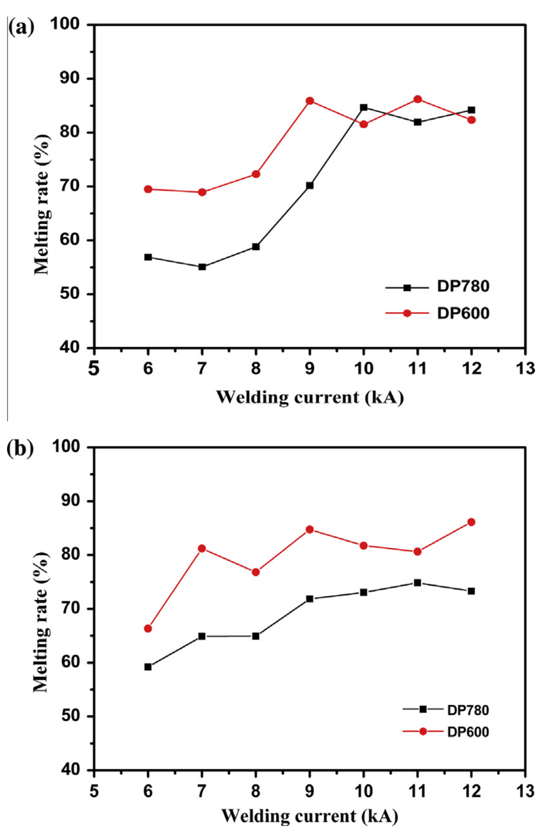

Fig. 3. The effect of welding current on the melting rate of the welded joints (T = 18 cycles, F = 4.0 kN), (a) DP780/DP600 and (b) DP600/DP780.

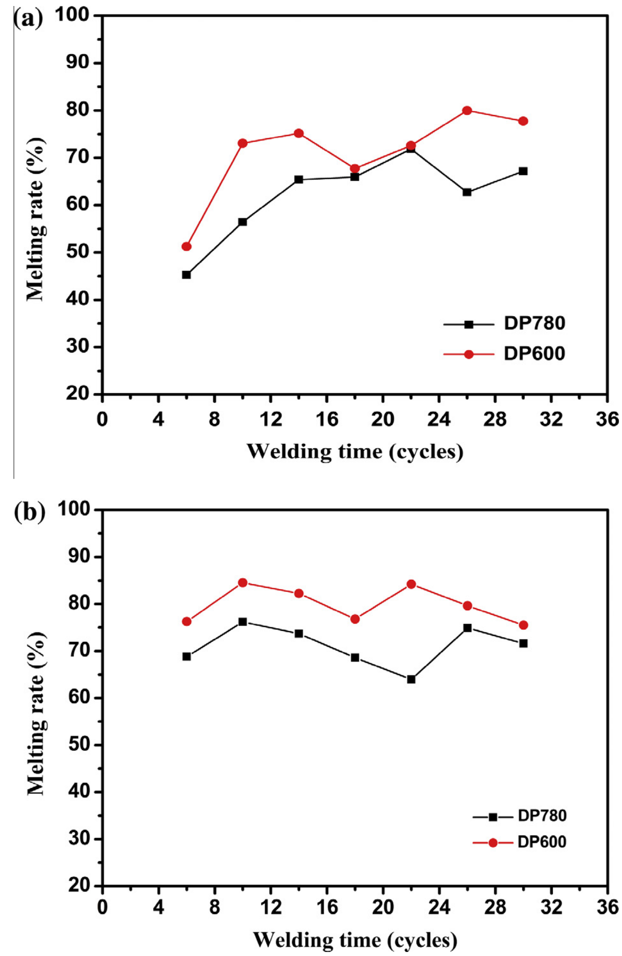

Fig. 4. The effect of welding time on the melting rate of the welded joints (I = 8.0 kA, F = 4.0 kN), (a) DP600/DP780 and (b) DP780/DP600.

dimensions of the base metals were 110 mm × 30 mm. RSW was carried out on a 200 kVA pneumatically operated single phase RSW machine. Truncated cone caps of 16 mm diameter and 6 mm tip diameter made from RMAW Class II copper–chromium material were considered for bottom and top electrodes, as shown in Fig. 1a and b.

After welding, spot welded joints were cut using an electrical discharge cutting machine. The samples were grounded and polished, and then were etched by a 4% nital solution for 7–10 s at room temperature. The macrostructure of the spot welded joint was characterized by optical microscopy and the dimensions were measured by auto-CAD software. Two lapping modes were used during RSW. One is DP780/DP600, which means DP780 is on the top; the other is DP600/DP780, which means DP600 is on the top. The macro characteristics of the welded joints were described in terms of melting rate, indentation rate, nugget diameter and indentation diameter. These characteristics were evaluated using a standard tensile test according to JIS [14]. Fig. 2 shows the schematic of a welded joint cross-section. Indentation rate can be calculated by the following equation:

$$\delta = c/T \times 100\% \tag{1}$$

where δ is indentation rate, c is indentation depth, T is the thickness of BM. The melting rate is evaluated as follows:

$$\gamma = t/T \times 100\% \tag{2}$$

where γ is melting rate, t is the maximum melting depth, T is the thickness of BM.