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Use of modified electrode caps for surface quality welds in resistance spot welding

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ABSTRACT

Surface quality of resistance spot welds is important in many applications. The surface quality of welds made with a modified electrode cap on the face side of the weld was investigated and compared with welds made using a copper backing bar and standard electrode caps. The surface features of the spot welds were evaluated and compared using laser surface scanning technology. The results indicate that the welds made with the modified electrode caps are equivalent to the welds made using copper backing bars in regards to the surface quality. The weld lobes were determined for resistance spot welding using combinations of standard electrode caps, an Asian T-16-D type, and the modified electrode caps T-16-D-10 plus the T-16-D type, on the face and bottom side of the weld. The weld lobes made using the latter combination of caps are shifted towards higher currents compared to those welded with standard electrode caps. Metallographic examination was carried out to compare the weld nugget sizes and locations within the welded steel sheets for various welding parameters. Use of the modified electrode caps instead of the copper backing bars can increase flexibility of the welding process and significantly reduce cost of the fixtures utilised in the production lines.

1. Introduction

Resistance spot welding is a major process utilised in the automotive industry for building vehicle bodies. The process is robust, flexible and easy to adapt into robotic applications. Basic quality requirements for spot welds include a spot weld nugget diameter and surface appearance [1,2]. The nugget diameter is important due to strength requirements of the resistance spot welded joints, and associated car body structural integrity. The diameter of the nugget formed during the resistance spot welding process depends on the process parameters such as welding current and welding time, as well as welding force. All of these parameters influence the amount of energy delivered to the welded parts in the process of welding [3]. An important part in the resistance spot weld development is played by the welded materials, namely the material electrical resistivity and surface conditions. The latter defines contact resistance of the abutting surfaces in the early stage of welding, and the former the bulk resistance of the material at the later stage of welding [4,5]. The contact resistance depends strongly on the welding force, the kind of coating present on the material surfaces, as well as the surface roughness [6–8]. Presence of surface contaminants such as oxides and stamping oil is also important [9–11]. Imprints of welding electrodes left on the surface after welding can have a negative influence on the strength of the spot weld and appearance of the weld surface. The imprints, in the form of indentations, could be responsible for loss of the joint strength due to material thinning [12]. Surface appearance and quality of resistance spot welds is of primary importance for visible surfaces, for cosmetic reasons, and for surfaces that are required to be flat for processing reasons [13]. To fulfil these requirements and minimise the surface marks, the resistance spot welding needs to be carried out with the use either a flat electrode or a copper backing bar on the face side of the joint [14]. Depth of an indentation is a function of not only welding parameters such as; weld current, weld time and weld force, but also the number of welds performed by an electrode [15,16]. This is related to a progressive increase in the electrode tip diameter over a number of completed welds in the welding process up to a certain number of welds. At this point of the electrode tip diameter wear, electrode re-dressing is recommended to return the tip to the initial shape [17]. The electrode tip dressing frequency depends also on the electrode geometry and cooling efficiency [18]. It is well established that the use of the electrodes with increased flat face diameter results in a decrease in both a weld nugget diameter and joint strength [3]. Therefore, the initial shape of the electrode needs

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Table 1
Material used for experiments.

Thickness *t* (mm)	Material grade	C %	Mn %	P %	S %	Al %	Si %
0.8	GMW2M-ST-S-CR5-HD60G60G-E (Body Side)*	*0.02*	*0.25*	*0.020*	*0.020*	*0.015*	–
0.8	GMW3032M-ST-S CR210P HD60G60GU**	*0.08*	*0.70*	*0.08*	*0.030*	*0.015*	*0.50*
1.2	GMW3032M-ST-S CR210P HD60G60GU**						
1.4	GMW3032M-ST-S CR210P HD60G60GU**						

* Max. content specified by GMW2; material specification. Low carbon sheet steel, October 2012.
** Max. content specified by GMW3032; material specification. High strength sheet steel, 180 MPa through 700 MPa Yield Strengths. January 2013.

Table 2
Welding parameters for samples used in weld surface evaluation test.

Spot	1 & 2	3 & 4	5 & 6	7	Electrode Indentation (Max) (mm)	Surface eruption (Max) (mm)
Material thickness (mm)	0.8 + 0.8	0.8 + 0.8	0.8 + 0.8	0.8 + 0.8	0.2	0.15
Welding current (kA)	10.2	10.2	10.2	10.7		
Welding time (ms) (c)	320 (16)	320 (16)	320 (16)	320 (16)		
Welding force (daN) (kgf)	306 (300)	357 (350)	408 (400)	408 (400)		
Sample (set of electrodes)	Electrode caps					
A (S)	S/S	S/S	S/S	S/S		
B (M + S)	M/S	M/S	M/S	M/S		
C (S + Cu + S)	S/Cu/S	S/Cu/S	S/Cu/S	S/Cu/S		

(S/S)—standard electrode caps T-16-D on both sides of the joint.
(M/S)—modified electrode cap T-16-D-10 on the face side and standard T-16-D on the other side of the joint.
(S/Cu/S)—standard electrode caps T-16-D plus Cu backing plate on the face side and standard T-16-D on the other side of the joint.

to be sustained by periodic re-dressing [19]. The other option is to compensate for the increased tip diameter by increasing the weld current (current stepping) to sustain the required nugget diameter and spot weld strength [20,21]. This work compares results of welding with standard Asian type T-16-D electrode caps with a flat face diameter of 6 mm to modified T-16-D-10 electrode cap with a flat face diameter of 10 mm (T-16-D-10) on one side (face side) and a standard T-16-D electrode cap on the other. The results of welding using a copper backing plate and the standard T-16-D electrode caps (on face side and back side) were also analysed for comparison. The spot weld surface quality was evaluated using a laser surface scanning. Weld lobes for materials welded with the standard and modified electrode caps were determined for; 0.8 mm, 1.2 mm and 1.4 mm thick zinc coated steel strips.

2. Experimental procedure

Materials used in this investigation, their grades, chemical compositions and thicknesses are presented in Table 1. The welding schedules used for the weld surface evaluation test are listed in Table 2. The welding schedules used for weld lobes determination are listed in Table 11. The welds were made using single pulse welding starting with the parameters producing undersised nuggets for each particular material thickness; the welding current and time were subsequently increased in increments to the level at which first expulsions were observed. A spot weld test sample geometry and layout in the test sample is shown in Fig. 1.

A robotic welding gun utilised in the production line of the GM Holden Body Shop was used for the experimental welding trials conducted in this work. The gun was an Obara SRTC-K0819 servo welding type with a maximum design force of 408 daN. The gun was operated by a FANUC robot and the test samples for welding were fed to the welding gun manually. A mid frequency (1000 Hz) direct current (DC) power source of 110 kV A with a NADEX IWC5 type controller were utilised for welding.

Two types of electrode caps were used for the welding experiments; an Asian type T-16-D, with a 6 mm diameter flat contact area (T-16-D), and a modified T-16-D caps with a 10 mm diameter flat contact area (T-16-D-10), see Fig. 2. The caps were made of Cu–Al_2O_3, RWM Class 20 material (UNS C15760). The copper backing bar (plate) was a 10 mm thick Cu–Cr, RWM Class 2 material (UNS C18400).

A NIKON MMD × 100 laser scanner was used for evaluation of the weld spot surface quality. The spot weld indentation depth and material eruptions heights, see Fig. 3, were measured using the laser scanning technique. The laser accuracy was verified using two test pieces with steps of known value, the dimensions and results are shown in Fig. 4.

The peel test was used for determination of the nugget (button) diameter of the spot welds produced for the weld lobe determination. Some of the welds were examined metallographically to verify the nugget size determined by the destruct test. The welds were also inspected visually for defects and examined for failure modes. The welding current and time, a number of cycles, were measured using a calibrated Miyachi 315A Weld Checker.

An Olympus EPOCH 600 ultrasonic instrument was used for measurement of the weld spot material thickness (t), to determine material thinning. The Leica Application Suite MZ16A, a light microscope, was used for metallographic examinations of the macro sections of the weld spots. The macro sections of the spot welds were prepared for microscopic examination using standard procedures including samples sectioning, mounting in epoxy, grinding and final polishing using 6 μm diamond paste. Etching was carried out using a 2.5% Nital solution.

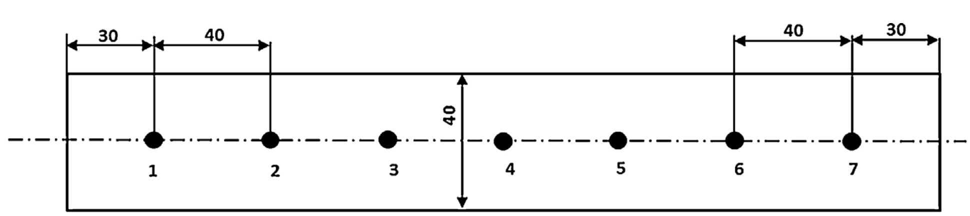

Fig. 1. Layout of spot locations in the test sample for spots surface quality evaluation (Dimensions in mm.).