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TECHNICAL PAPER

Converting the pneumatic- to servo-based system in resistance spot welding: analyzing the dissimilar weld joints for two welding schemes

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Abstract

This experimental investigation analyzes the performance of two types of electrode-actuating systems, pertaining to welding current increments in resistance spot welding. Alternating current (AC) waveform, 75 kVA apparent power and C-typed body frame of a welding machine are engaged to undertake the entire experiment. Initially, the pneumatic-supported compression technique is employed to weld the dissimilar combinations of metal sheets; the carbon steel and stainless steel in this case. Since the pneumatic cylinder consumes reasonable amount of time to operate, it is limited to handle the single-periodic AC waveform which is designated as the single current and single force (SISF) welding scheme. As the pneumatic-based system is mechanically redesigned and refitted for the servo-supported compression, thereafter it paved ways to manipulate the compression variables as to support the dual current and dual force (DIDF) welding scheme in addition to the original SISF welding scheme. After the successful attempts for both schemes, the welded samples underwent the tensile test, hardness test, post-crack pattern recognition and finally subjected to the metallurgical observation to characterize the differences and anomalies. The result shows that the weld formations have been greatly improved in servo system for the SISF and DIDF compared to the pneumatic SISF welding scheme.

Keywords Spot welding · Electrode actuation system · Servo and pneumatic system

1 Introduction

As the reliability of the force profiles is always debated in resistance spot welding, a novel approach has been carried out in this research study [1–3]. This attempt is a timely needed to clarify the doubt among researchers as it can obviously benefit the mass production of spot welds. Automotive industries such as BMW, Ford EU, Opel and few other companies are still using the pneumatic cylinders meanwhile the Asian automotive manufacturers such as the Honda, Toyota, Nissan and some others have already started to use servo-based systems to produce spot welds. What are the distinguishable and pertinent improvements between these two compressing system are the primary quest of this research. Hence, dissimilar welds have been welded using common machine with two different compressions. An AC-waveform, 75 kVA of apparent power with pneumatically-fitted welding machine was redesigned to fit the servo-based electrode-actuating mechanism. The regulation of welding current against the welding time is again and again analyzed for both systems under the single current and single force (SISF) welding scheme and subsequently the dual current and dual force (DIDF) welding scheme is introduced after the conversion for better performance. Figure 1 illustrates the basic setup of SISF versus DIDF welding schemes. With the electrode actuation performance in mind, dissimilar steels of carbon steels and stainless steels are welded to characterize the weld growth [4, 5]. As such the regular tests such as the tensile test, hardness test, post-crack pattern recognition and metallurgical tests have been carried out to distinguish the profound changes.

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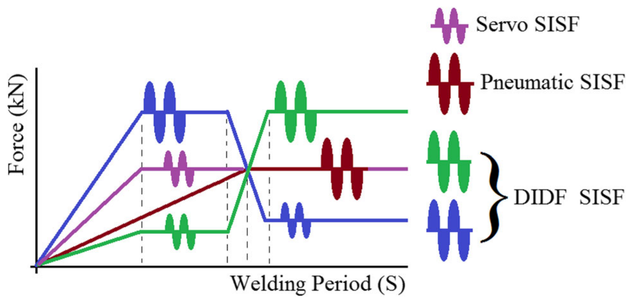


Fig. 1 Welding schemes

2 Experimental

Welding samples are prepared by carbon steel and 304L stainless steel materials separately, with a rectangular-shape sheet of sizes, that of 200 mm in length by 25 mm in width using 1 mm thickness sheet. Initially the welding processes are held using pneumatic-controlled cylinder with which the welding lobe limits are established for welding current against welding time in SISF welding scheme; see Fig. 2 for picture representation. Similar welding scheme is carried out after the up-gradation of servo-based system and consequently Fig. 3 is illustrated. Moreover, the dual current and dual force (DIDF) welding scheme is introduced after the up-gradation as to improve the weld growth relatively. So the Fig. 2 should be compared with Fig. 3 while both figures should be concurrently compared with the Fig. 4 as to see the improvement, respectively. As can been seen from Figs. 2, 3 and 4 that the acceptable weld regions are marked with green circles to denote the round tips while color represents good quality. Thus, it has been enclosed with continuous line to represent the limit of working window. Detailed explanations about the colors' representation and circles are given in Figs. 2, 3 and 4 legends, respectively. With the use of these welding lobes' limits, three welding combinations of welding time, welding current, constant compressing force and unchanged electrode tips are, therefore, selected.

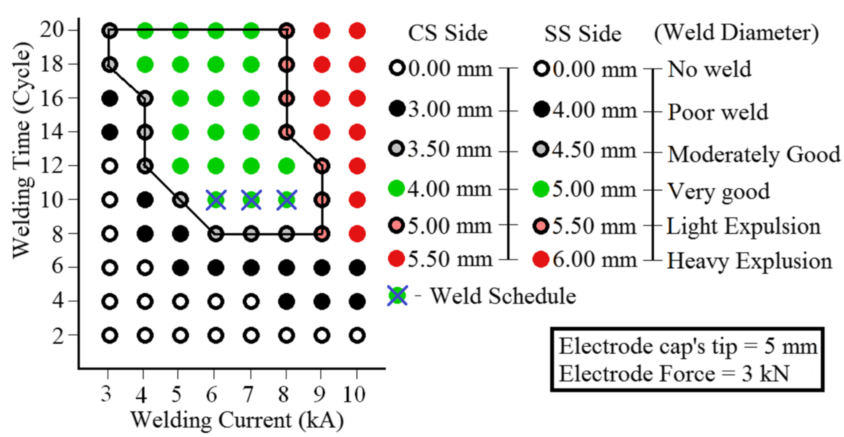
The entire welding process is accomplished in accordance with the combinations of process-tuning parameters, which are marked with '*X*' on the spot in the welding lobes. Seven welded pairs are developed for each weld schedule as the first five pairs being allocated to the tensile test, sixth one is used for hardness test and the final one is used for metallurgical observation. As for the hardness test and tensile test, the Rockwell hardness tester using scale B and 100 kN tensile test machine are engaged to complete the experiments. The V2A etchant which contains 100 ml of water, 100 ml of hydrochloric acid and 10 ml of nitric acid is applied to etch the well-prepared and weld-polished bakelite samples.

3 Results and discussion

3.1 Working windows of the welding lobe diagrams

While assessing the acceptable weld combinations of welding lobe diagrams, it is found that the servo-based DIDF welding scheme has improved the working regions remarkably. Literally the working window has been widened up for good welds while shifting the linear patterns for lower possible combinations of process parameters. Look at the green-colored circles in the welding lobe diagrams of both systems (Figs. 2, 3, 4) with respect to its columns and rows for basic pattern. In pneumatic-based system, the welding current against welding time set has produced 21 good welds, whereas in the servo-based system, it has produced 22 good welds for the SISF welding scheme. In the servo-based DIDF welding scheme, the welding current against welding time set has produced 41 good welds. There is a noticeable and profound improvement for good welds in servo-based system as it increases 42% of the overall performance. There are discernible increments of weld diameters as listed in Table 1,

Fig. 2 Welding lobe diagram (pneumatic SISF welding scheme)



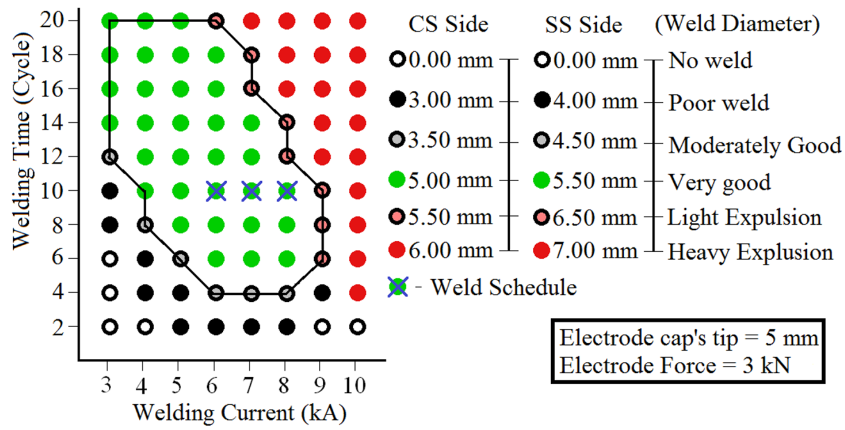


Fig. 3 Welding lobe diagram (servo SISF welding scheme)

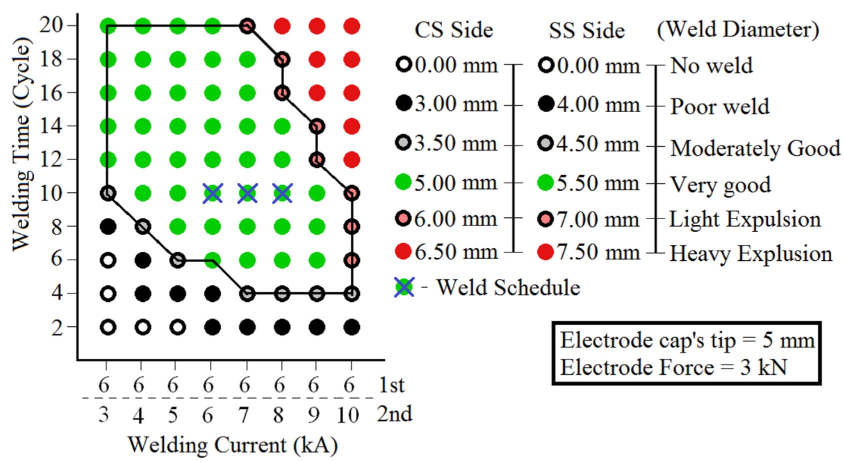


Fig. 4 Welding lobe diagram (servo DIDF welding scheme)

Table 1 Parameter sets and corresponding average diameter

	Moderately good weld			Good welds			Expulsion welds		
	No	Diameter (mm)		No	Diameter (mm)		No	Diameter (mm)	
		CS	SS		CS	SS		CS	SS
Pneumatic SISF	9	3.50	4.50	21	4.00	5.00	7	5.00	5.50
Servo SISF	6	3.50	4.50	32	5.00	5.50	8	5.50	6.50
Servo DIDF	7	3.50	4.50	41	5.00	5.50	8	6.00	7.00

including the moderately good welds and also the light expulsion welds.

It should be noted here that the critical weld growth of stainless steel starts at $4\sqrt{t}$ and carbon steel starts at $3\sqrt{t}$; where t stands for the thickness of base metal [6, 7]. Although the critical weld growth of stainless steel starts at 4.00 mm for 1 mm thickness and carbon steel starts at 3.00 mm for 1 mm thickness of two sheets, the servo-based system has successfully extended the light expulsion limit until it attains a wider length about 6.00 mm on CS side and 7 mm of SS side. This factor has to be also seen in another corner because the electrode tip's original diameter was just 5 mm, as a matter of fact. If the electrode tip is 5 mm of diameter and then the possibility of weld indentation has to be higher enough if the molten area is diffused up to 6 mm. This factor has been predominantly handled in the servo-based system due to force profiles' consistencies and also a pre-solidified process.

3.2 Weld growth of different welding schemes and dissimilar electrode systems

Weld growth is an important factor in resistance spot welding as it establishes the bonding strength between the welded counterparts [8]. Thus, if bigger the fused areas then better the bonding strength will be. Increment of the electric current will proportionally enlarge the molten areas because heat generation ($Q = I^2Rt$) will directly be