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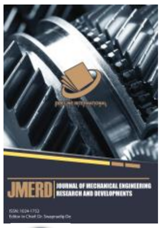

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RESEARCH ARTICLE

USING BRASS FOIL INTERLAYER TO IMPROVE THE RESISTANCE SPOT WELDING AA5451 WITH APPLY TAGUCHI METHOD

Osamah Sabah Barrak[1], Mohammed Helan Sar[2], Mursal Luaibi Saad[3], Abbas Khammass Hussein[4], Sabah Khammass Hussein[2]*

[1]Institute of Technology - Baghdad, Middle Technical University, Baghdad, Iraq
[2]Engineering Technical Collage Baghdad, Middle Technical University, Baghdad, Iraq
[3]Technical Institute - Suwaira, Middle Technical University, Baghdad, Iraq
[4]University of Technology, Middle Technical University, Baghdad, Iraq
****Corresponding Author Email: sabah.kh1974@yahoo.com***

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ABSTRACT

The aim of this work was to investigate the effect of resistance spot welding (RSW) parameters on the quality of AA5451 joint with brass foil interlayer. Three welding parameters were used; welding current: 12750 and 13500 Amp, electrode pressure: 40 and 45 Bar, welding time: 1.2, 1.4 and 1.6 sec. The squeeze and hold time were kept constant with 1.98 sec for each case. A sheet of AA5451 of 1 mm thickness with brass foil (C26800) of 0.1 mm thickness as interlayer was used. A shear test was used to determine the sheer force of the welded specimen. The results of shear force were analyzed statistically using a Taguchi method with the aid of a Minitab program. The results indicated that the applied pressure and welding current decreased and increased the sheer force of joint respectively. Increasing the welding time decreased and increased the shear force for the intervals 1.2 – 1.4 and 1.4 – 1.6 sec respectively. The presence of the foil increased the shear force of joint by 16 %. The optimum values of parameters that found using the brass foil were; welding current: 13500Amp, electrode pressure: 40Bar, welding time: 1.6sec. A theoretical model of shear force as a function of welding parameters was derived.

KEYWORDS

resistance spot welding, foil, AA5451, C26800, Taguchi

1. INTRODUCTION

RSW is the process of connecting sheet metal in the several of industries, such as the automobile industry, aircraft and space craft manufacturing and the household appliances. It is the effective process of joining which widely used for sheet metal assembly. There are 3000-6000 spot welds in any modern vehicle, which indicates the importance of the resistance spot welding level. RSW has an excellent technological benefit, such as low cost, the rate of high production and adaptability for automation, making it an attractive choice for car assemblies, rail vehicles, truck cabins, and home appliances [1]. Simplicity, low cost, high speed (low process time) and the possible of automation are among the advantages of this process [2]. RSW is a process in which two or more pieces of metal are combined to make it work as a single piece. It is used to join most types of metals and its alloy [3].

The RSW process was achieved by two or more metal plates are joined together by electrodes and an electric current pass through. An electric current flow through the workpiece to generate heat of resistance and the force is applied simultaneously to press the two components together to form a single connected part. The resistance heat depends on the applied electric current, the resistance of the workpiece materials and the time for which the current is applied [4,5]. The control function of the welding machine expresses the welding cycle. The specific steps that are controlled are squeeze, welding, and hold time [6]. The welding current and the pressure force are applied to the sheets through the electrodes of copper alloy. When the metal is reached to the temperature of melting, the fuse of metal will begin, RSW features are the speed of operating and the suitable to automation [7].

Aluminum and its alloys were used as a lightweight material for the automotive industry to reduce fuel consumption and control the pollution [8]. In the RSW of the aluminum alloy joints, three zones were observed: base metal (BM), weld nugget and the heat affected zone (HAZ). The BM region is far enough away and is not affected by generated heat during the process. In the boundary of weld nugget, the peak temperature was reached. All materials were melted within the weld nugget, and then solidified rapid. Between the limits of the weld nugget and the BM, there is a region of HAZ. Thermal input of the welding process has changed the microstructure of metal and the properties, resulted a HAZ as transition zone traditional [9-11]. The problems of aluminum welding in the RSW are high consumption of energy, short life of electrode, and unstable welding quality [12]. Adjusting welding parameters such as; holding time, electrode shape, squeeze time, welding current, welding time and electrode force are important to improve the weld quality. When using unsuitable parameters for an aluminum it may lead to some welding defects, such as columnar grains, porosity and composition segregation. Increasing both the welding time and welding current generated the more resistance heat which caused the melted nugget volume increased [13-16]. The strength and hardness of aluminum alloys of 5000 series is annealed during the treatment of RSW [17-19]. The AA5451 has higher conductivity of thermal, and lower resistance of electrical. Both low resistance and high conductivity may result in lower generation of heat, higher dispel of heat. It has previously studied the viability of using interlayers as a foil such as Cu, Fe, Ti, Ni and Zn-based alloys to joining aluminum \ aluminum. The results indicated that the strength of joint was improved in the case of using such interlayers [20]. Despite the importance of the interlayer in achieving an efficient joint, an excessive growth in the interlayer leads to joint brittleness [21].

The aim of this work is to obtain the optimum sheer force of resistance spot welding of similar AA5451sheets by studying the effect of the welding parameters (welding current, Electrode Pressure & Welding time) and the use interlayer foil type C26800 on the shear force. In addition, a Minitab software was used to apply the design of experimental (DOE) method to identify the effect of those parameters and modeling the sheer force of joint in term of welding parameters.

2. EXPERIMENTAL WORK

2.1 Materials Selection

Aluminum alloy AA5451 of 1 mm thickness was used in the RSW process. The chemical compositions were experimentally investigated and listed in table 1. A brass foil type C26800 with 0.1 mm thickness was used as interlayer foil between the aluminum specimens. The chemical compositions of this foil were listed in table 2.

Table 1: Chemical Composition of AA5451

	Element wt %									
Material	Si	Mn	Mg	Ti	Cr	Cu	Fe	Ni	other	Al
Actual	0.161	0.058	2.31	0.02	0.255	0.025	0.37	0.007	0.077	Remainder
Standard [22]	0.25	0.1	1.8 - 2.4	0.05	0.15 -0.35	0.1	0.4	0.05	0.05	Remainder

Table 2: Chemical Composition of alpha brass C26800

	Element wt %			
Material	Zn	Pb	Fe	Cu
Actual	18.27	0.059	0.02	Remainder
Standard [23]	33	0.15	0.05	Remainder

2.2 Specimens Preparation

2.2.1 RSW Specimens

Standard dimensions of RSW samples were used according to the standard specification of the AWS [24]. Table 3 lists the dimensions of aluminum specimen and foil. A flat sample was cut from a sheet metal into two parts according to the previous dimensions as shown in figure 1.

Table 3: Dimensions of the sample

Material	Thickness (t), mm	Width (W), mm	Length (L), mm	Contacting Overlap, (mm)
AA5451	1	25	100	25
C26800	0.1	25	25	25

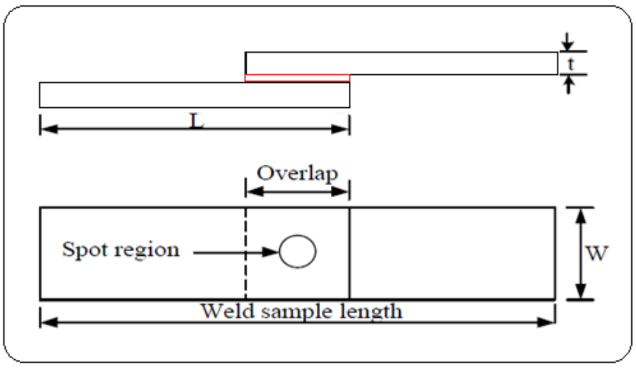

Figure 1: Schematic of the RSW specimen

2.2.2 Machine Electrode

The electrodes of machine were made from zirconium-chromium-copper alloy according to the AWS specification with a higher electrical and thermal conductivity. The face diameter of electrode was 15.9 mm according to RWMA GROUP class 1 with 3mm radius of concave as shown in Figure 2.

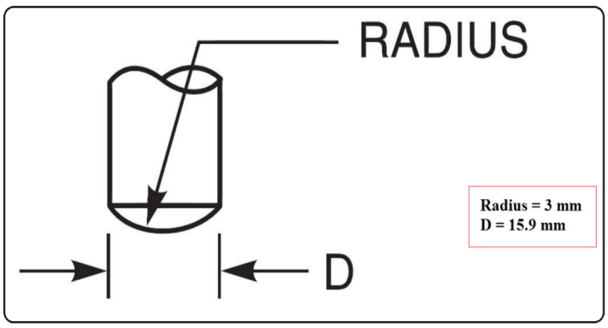

Figure 2: Schematic of machine electrode

2.2.3 Welding parameters

The welding process parameters have an important part in determined the welded joint quality, a design of experiments method was used determine the welding parameters of machine for each specimen. The following RSW parameters were used: [Welding current (Amp.), Electrode Pressure (Bar) & Welding time (sec)]. The squeeze and hold time of machine were kept constant with a value of 1.98 sec.

2.2.4 Design of Experiments method

Two values of the electrode pressure, two value of the welding current and three values of the welding time were used to welding the aluminum specimens. The boundaries conditions of each welded specimen were designed experimentally according to the Taguchi method and as shown in table 4.

Table 4: Taguchi Method for Welding Machine Parameters

Specimen No.	Parameters		
	Pressure (Bar)	Welding Current(A)	Welding Time (sec)
1	40	13500	1.6
2	40	13500	1.4
3	40	13500	1.2
4	40	12750	1.6
5	40	12750	1.4
6	45	12750	1.2
7	45	13500	1.6
8	45	13500	1.4
9	45	13500	1.2
10	45	12750	1.6

Ten specimens were welded using RSW machine according to the boundary conditions for each specimen such that the hold and squeeze time were constant, figure 3 illustrates the welded specimens.

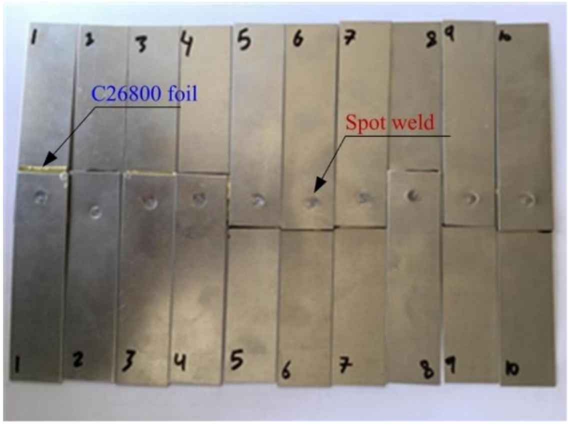

Figure 3: The welded specimens

2.3 Mechanical Tests (Shear Test)

The welded specimens were mechanically tested by shear test. Each specimen was fixed at each edge to prevent the sliding and fixed by means of a shim to prevent the bending during the test as shown in figure 4. The linear speed of shear test was 10 mm/min [25]. The internal surface of joint exhibited that the welded foil either remains welded or it was dislocated from the spot welding during the shear test as shown in figure 5. The appearance of the fracture specimens in the shear test exhibited three types of fracture; button pullout, thickness and interfacial failure as shown in figure.

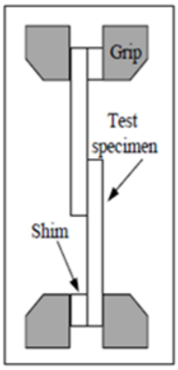

Figure 4: Schematic of Tensile Strength Test

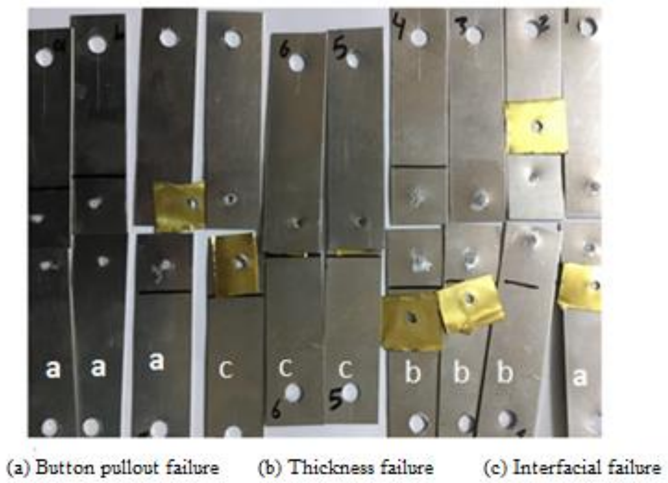

Figure 5: The tested shear force specimens

3. RESULTS

3.1 Taguchi analysis

A Minitab program was used to analysis the results data from the shear test with the aid of Taguchi method. The boundary conditions of all specimens mention in table 4 were considered as input data in this program. The shear force was considered as output data which has been statically analysed by Taguchi method by the main effect and interaction plot.

3.1.1 Main Effect Plot

Figure 6 illustrates the main effect plot of RSW parameters; electrode pressure, welding current and time on the sheer force of the welded specimens. The results indicated that all parameters have an effect on the sheer force of joint. The sharp effect was found in the welding current as compared with the other parameters. Increasing the electrode pressure resulted in decreasing the sheer force of the welded specimens. On the other hand, it was found that shear force increased with increasing the welding current of the RSW machine. A fluctuating effect was found in the welding time; hence increasing the welding time decreased the shear force for the interval time 1.2-1.4 sec. The other interval of time (1.4-1.6 sec) increased the sheer force of the welded specimens.

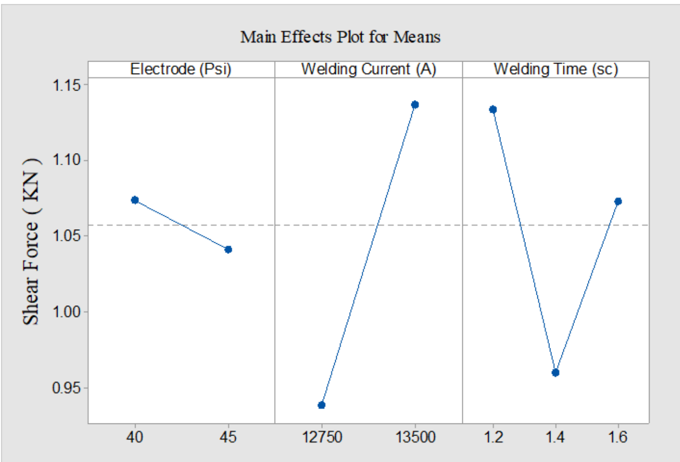

Figure 6: Main effects plot for means of shear force

3.2 Interactions Plot

The input welding process parameters were statically analyzed to determine the effect of each two parameters on the output response (shear force) by means Minitab program. An interaction plot was used to identify the effect of those parameters on the shear force as shown in figure 7. Table 5-7 summarized the description of figure 7.

Table 5: Current and pressure parameters that effect on shear force

current 12750	current 13500
• The pressure 40 Bar gave lower values of shear force. • The pressure 45 Bar gave highest values of shear force.	• The pressure 40 Bar gave highest values of shear force. (this better state) • The pressure 45 Bar gave lower values of shear force.

Table 6: Current and welding time parameters that effect on shear force

current 12750	current 13500
• The weld time 1.2 second gave highest values of shear force. (this better state) • The weld time 1.4 second gave lower values of shear force. (this worst state) • The weld time 1.6 second gave medium values of shear force.	• The weld time 1.2 second gave lower values of shear force. • The weld time 1.4 second gave medium values of shear force. • The weld time 1.6 second gave highest values of shear force.

Table 7: Pressure and Welding time parameters that effect on shear force

Pressure 40 Bar	Pressure 45 Bar
• The weld time 1.2 second gave highest values of shear force. (this better state) • The weld time 1.4 second gave lower values of shear force. (this worst state) • The weld time 1.6 second gave medium values of shear force.	• The weld time 1.2 second gave highest values of shear force. • The weld time 1.4 second gave medium values of shear force. • The weld time 1.6 second gave lower values of shear force.

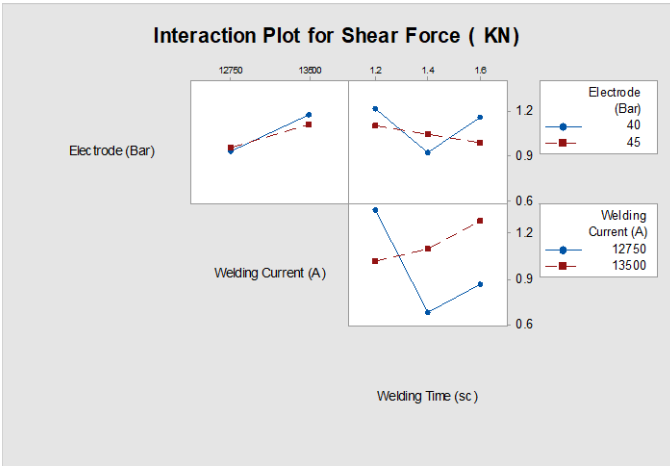

Figure 7: Interactions plot of shear force

3.3 Response Optimizer

The response optimizer method was used to show which welding parameters that effects on the shear force, moreover, which give the best value for the shear force. Table 8 illustrated the analysis of optimizer response from the DOE for shear force: -

Table 8: Shear force optimizer response

Welding current (Amp.)	Electrode force (Bar)	Welding time (sec)	squeeze time (sec)	Hold Time (sec)	Shear force (KN)
135000	40	1.6	1.98	1.98	1.436

It was found that the optimum shear force in welding of similar aluminum with interlayer is F = 1.436 KN. Also, the optimum value of shear force without interlayer was F = 1.234 KN. Therefore, the improvement of shear force was 16 %.

3.4 The Regression Equation

The regression equation has been obtained which can use to deduction how much the shear force value being at each welding parameter. This equation is used only in this work, the following results are reached:
Shear Force (KN) = 0.000261 Current (A) - 0.0069 Pressure electrode (Bar) - 0.047Welding time (sec) - 2.02

4. CONCLUSION

AA5451 sheets were weld by RSW with the aid brass foil interlayer. The following conclusions were recorder:

1. The sheer force of joint was increased with increasing the welding current until 13500 A.
2. The sheer force of joint was decreased with increasing the applied pressure of machine above 40 bar.
3. The joint with interlayer foil has a higher shear force than that are welded without interlayer foil.
4. According to result analyzed using the DOE of interlayer foil was found joint efficiency have improved by 16 % percent compare with the specimens without interlayer foil.
5. The welding time have an alternating effect on the sheer force of joint.
6. According to the DOE analysis, the optimum shear force with using the interlayer foil were produced by (welding current 13500 Amp, applied pressure 40 Bar, welding time 1.6 sec) as the values of welding parameters.

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