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Optimisation of Process Parameters of Spot Welding of Mild Steel Joints Using Taguchi's Technique

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Abstract

The use of resistance spot welding for joining sheet metal pieces has increased in manufacturing industries because of its advantages like high speed, high-productivity in assembly lines and suitability for automation. However, it is important to choose the correct values of parameter for providing strong welds at correct positions. This paper reports for optimization of welding parameters in the Resistance Spot Welding (RSW) process for obtaining maximum possible weld strength.The experimental studies were conducted under varying welding pressure, hold timeand welding time. The settings of welding parameters were determined by using the Taguchi's L_9 orthogonal array. The percentage contribution of the welding parameters on the shear strength was determined by using analysis of variance (ANOVA) and S/N ratio determined the optimal combination of welding parameters. The validity of the Taguchi's method was confirmed through experiment, for enhancing the welding performance and optimizing the welding parameters in the resistance spot welding process.

Keywords

Spot Welding, Taguchi L_9 Method, ANOVA, S/N Ratio

I. Introduction

Nowadays, almost everything that is made by industry has component pieces and they have to be fixed together. Often mechanical joints are chosen, such as screws or rivets. But, in the automotive industry mainly Resistance Spot Welding (RSW) is applied because of its flexibility, robustness, speed, and low cost of operation.Resistance spot welding plays an important role in manufacturing and it is the simplest and most widely used form of the electric resistance welding process.

In this resistance spot welding process,faying surfaces are joined in one or more spots. Coalescence is produced in a relatively small area by the heat obtained from the resistance to the flow of electric current through the workpieces held together under pressure by electrodes. The main principle of RSW is that the resistance of the base metal to electrical current flow causes localized heating in the joint, and the weld is made.Maximum temperature is desired at the interface of the parts to be joined. Therefore, the resistance of the workpieces and the contact resistance between the electrodes and work should be kept as low as possible with respect to the resistance between the faying surfaces. This could be achieved by controlling the contact area, electrode materials, and dimensions, applied pressure, and surface quality of the workpieces [1-2].
The main advantages of spot welding from a production viewpoint are the suitability of the process for automation, and high level of productivity.Spot welding has been used successfully for many years to join mild steel components [3]. The quality of spot welds should quantify the ability to sustain the design load in the structure under normal service conditions without failure. The weld quality is assessed by measuring the load bearing capacity of the weld in a Universal Testing Machine, performing a tensile test.

The three main RSW parameters which determine the load bearing capacity of a spot weld are the welding current, welding time and electrode force. Variations in these parameters will result in changes in the values of the tensile shear strength, weld nugget diameter as well as weld indentation. It has been found by S. Aslanlar et al [4] that increase in welding currentincreases the weld nugget diameter and in turn the weld shear strength until the occurrence of expulsion [4]. Similarly the decrease in electrode force and increase in welding time increases the weld nugget growth and the shear strength until the occurrence of expulsion as stated by M. Pouranvari and S.P.H Marashi [5]. Each spot welding is not performed with the same parameters because of the variations of sheets and electrodes as well as the surface condition. Therefore, a spot welding process needs the optimum process condition for good quality welds [6].

UğurEşme [1] investigated the effect ofwelding parameters on the shear strength in theresistance spot welding (RSW) process. The experimentalstudies were conducted under varying electrode forces,welding currents, electrode diameters, and welding times. The results showed that the shear strength was increased by 2.03 and 1.20 times for 1mm and 2mm, respectively.

Thakur et.al [7-8] had used Taguchi's method to determine the optimum welding schedule to spot weld galvanized steel and austenitic stainless steel AISI304 on two separate works.Gulsah Akincioglu et al [9] performed Taguchi optimization of machining parameters in drilling of AISI D2 steel using cryo treated carbide tool and found out Taguchi Technique is a powerful method for optimisation. EyupBagci & SerefAykut [10] researched on Taguchi optimization method for identifying optimum surface roughness in CNC face milling of Cobalt Based alloy.

One of the simplest ways of optimizing the process parameters of RSW is achieved by using Taguchi's parametric optimization method. This method of conducting the experiments is based on well-defined guidelines, which use a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The crux of the orthogonal arrays method lies in choosing the level combinations of the input process variables for each experiment.

The present experimental work presents a systematic approach to determine the effect of different process parameters on weld quality and tensile strength of the weld. In order to achieve this important welding parameter like welding pressure, hold timeand welding timehave been selected in the present experimental work. On the basis of these parameters, experiments have been conducted using an L_9 orthogonal Array. Analysis of variance (ANOVA) is used to know the percentage contribution of different process parameters towards weld strength. S/N ratio has been used for determining the optimum set of process parameters.

II. Experimentation

Experimental work has been carried out using a spot welding machine that is used for welding thin sheet of metals. A Spot/ Projection welder (35 KVA, 1Φ, 50 Hz, 415 volts) was used is this work. The material used for the experiments is mild steel sheets of 3mm thickness. It is popularly used for car body panels, nuts and bolts, engine parts, and various other uses.

Each piece is 50 mm in length and 70 mm in width and each sample is made by lap welding two pieces. As the test samples will be used for the shear test to determine the shear strength of each weld, samples were prepared with an overlap of 20 mm.

The electrodes which have been used are RWMA Class II Cu-Cr alloy with tips of 8 mm diameter. Hold time, weld time and pressure have been used as the control factors with each having three levels as shown in Table 1. The electrode tip diameter and squeeze time were maintained constant. Hold time, weld times and pressure forces are identified by developing the weldability lobe for the machine.

A set of experiments has been carried out using L_9 orthogonal array. Orthogonal arrays are used to reduce the total number of experiments. Adoption of a suitable orthogonal array depends on the number of factors and their interactions the number of levels for the factors and their degree of freedom. In the present study L_9 orthogonal array has been used as there are three controllable welding parameters and each parameter has three levels. L_9 array is as shown in Table 2.

Using nine test samples experiments were conducted. Shear strengths for the samples were obtained from the universal testing machine in the laboratory.

III. Results

Table 3 shows the experimental results for hold time, weld time, and pressure. Shear strength is weld characteristics that will be maximized in the work.

Table 1: Parameter and its Levels

Parameter	Level 1	Level 2	Level 3
Hold time (A)	80	82	85
Weld time (B)	30	32	35
Pressure (C)	60	70	80

Table 2: L_9 Array

	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

A. S/N Ratio

Signal to Noise ratio is carried out in Taguchi method to determine the optimal welding parametric condition. MINITAB was used for S/N ratio calculation. In order to obtain optimal welding condition the larger the better principle is considered for shear strength.

B. ANOVA

Analysis of variance is performed to get the relative contributions of welding parameters in the spot welding process. The larger the value of sum of squares deviation the more influential the factor is for controlling the spot welding process. MATLAB codes were developed for calculation of ANOVA.

Table 3: Experimental Results

	Independent Variables			Results	
Sl No	**A**	**B**	**C**	**Avg SS**	**AvgC**
1	80	30	60	2.11	3.76
2	80	32	70	17.79	4.63
3	80	35	80	11.78	4.56
4	82	30	70	19.37	4.86
5	82	32	80	9.55	4.43
6	82	35	60	4.89	3.66
7	85	30	80	7.26	4.46
8	85	32	60	2.97	3.76
9	85	35	70	1.07	3.63

Table 4: Response Table for S/N Ratios

Level	A	B	C
1	17.637	16.482	9.909
2	19.710	18.020	17.111
3	9.087	11.932	19.414
Delta	10.622	6.087	9.505
Rank	1	3	2

Table 5: Response Table for Means

Level	A	B	C
1	10.560	9.580	3.323
2	11.270	10.103	17.743
3	3.767	5.913	9.530
Delta	7.503	4.190	9.420
Rank	2	3	1

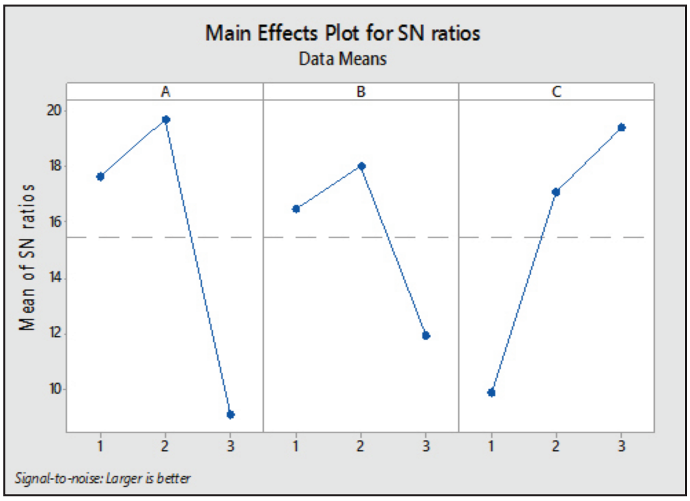

Fig. 1: Plot of Mean of S/N ratio v/s Process Parameters Level

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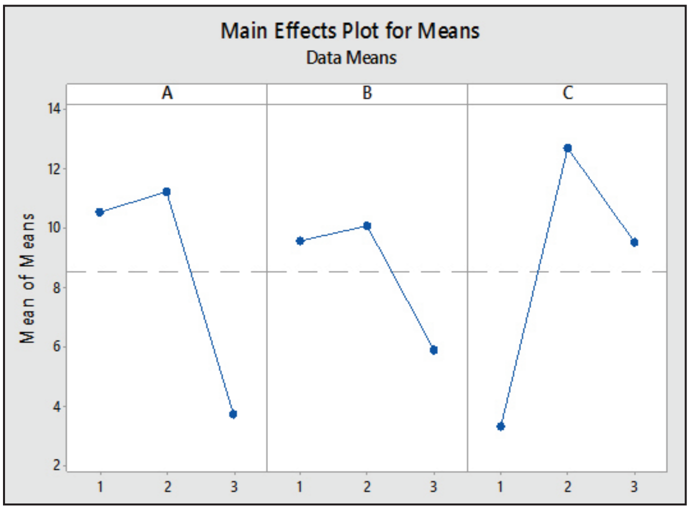

Fig. 2: Plot of Means v/s Process Parameters Level

Table 6: Analysis of Variance

Analysis of Variance					
	DOF	Sum of Square	Mean Square	F	P
A	2	102.95	51.48	1.20	0.454
B	2	31.27	15.64	0.36	0.733
C	2	137.58	68.79	1.61	0.384
Residual Error	2	85.69	42.84		
Total	8	375.50			

C. Optimized Parameters

Based on experimental results, new operation parameters were obtained through maximum level of each parameter. The optimised parameters for the shear strength from above experiment are:

1. Hold time: Level 2 (82)
2. Weld time: Level 2 (32)
3. Welding pressure: Level 2 (70)

ANOVA shows that as the p-value for hold time is less than the significance level selected hence its effect is statistically significant. Whereas that for weld time and weld pressure it is greater than the significance level so its effect is not statistically significant. From S/N ratio graph it is clear that the optimum parameters are of level 2 only. The S/N ratio for level 2 of C is lesser than level 3; it is due to experimental errors and improper alignment of the specimen during the test time because of environmental variables.

IV. Conclusion

From the present study the following conclusion are obtained:

1. The experimental results show that the welding parameters are the important factors for the strength of the welded joint, as they increase or decrease the strength of the welding joint. Thus, we can say that the combination of the suitable parameters is necessary for the maximum strength of the spot welded joint.
2. The parameter that influences the most to the weld strength is hold time and the parameter that influences the least is the weld time.
3. For each parameter the medium level yields the best result in the shear tensile strength of the welded joint.

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