Optimization of Process Parameters for Resistance Spot Welding Process

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Abstract- *The automotive industries choose resistance welding for manufacturing. Because, of the great advantages this process has to offer. The first advantage is speed. When over 5000 welds need to be made in a typical car, a process where each weld takes less than a second is of great importance. The process is also adaptable to robotic manipulation so the speed is extremely fast. It is excellent for the sheet metals used in automotive construction and because no filler metal is needed. The complex wire feed systems in many arc welding processes are avoided. The contact resistance between the two pieces of sheet metal to be joined is much higher than the bulk resistance of the copper electrodes or of the sheet metal itself. Therefore, the highest resistive heating occurs between the two pieces of sheet metal. As current continues to flow, melting occurs and a weld nugget is formed between the two sheets. On termination of the welding current, the weld cools rapidly under the influence of the chilled electrodes. This causes the nugget to re-solidify, joining the two sheets of metal. Resistance spot welding is used extensively because it is a simple, inexpensive, versatile process.*

Hence, this paper is directed towards the optimization of process parameter of resistance spot welding process. After considering all the parameters this study represents the systematic approach the effect of process parameter (Electrode force, current and weld time) on the nugget diameter and Tensile shear strength of resistance weld joint of low carbon steel used in automobile car bodies for D-Grade as per IS 531 :1994.

Keywords- Resistance spot welding, mildsteel, Optimisation, Process parameters.

I. INTRODUCTION

Resistance spot welding is commonly used in the automotive industry for joining thin sheet metals. Compared with other welding processes such as arc welding processes, resistance spot welding is fast, easily automated and easily maintained. This welding is a complicated process which involves interaction of electrical, thermal, mechanical and metallurgical phenomena. In this process, the materials to be joined are brought together under pressure by a pair of electrodes and then a high electric current is passed through the work pieces between the electrodes. Due to contact resistance and Joule heating, a molten weld nugget is formed in the work pieces. The work pieces are joined as solidification of the weld pool occurs. Moreover, force is applied before, during and after the application Of electric current, to maintain the electric current continuity and to provide the pressure necessary to form the weld nugget. The total heat generation between two sheets per unit time is defined as the product of the current intensity squared, multiplied by the total Resistance and the welding efficiency. [1]

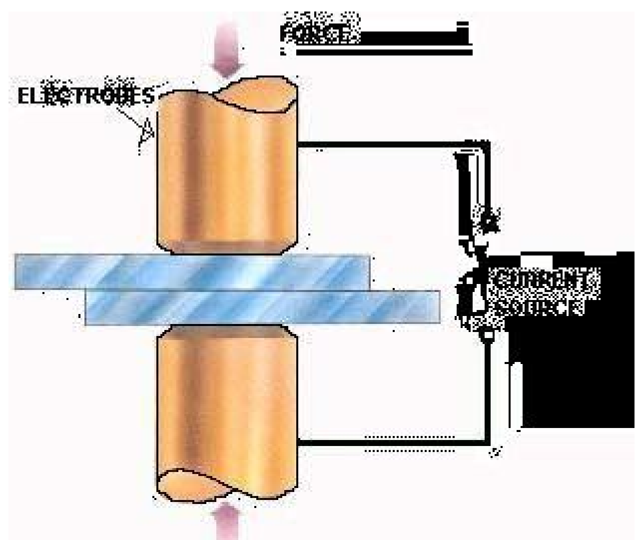

Figure 1. Diagrammatic Representation of spot welding machine

The heat generated is expressed by the equation, $E=I^2*R*t$

Where:- E is the heat energy, I is the current,
R is the electrical resistance
t is the time that the current is applied.

II. RESISTANCE SPOT WELDING PARAMETERS

A. Resistance Spot Welding Parameters:

There are three main parameters which control the quality of resistance spot welding. Diagrammatically shown in figure:

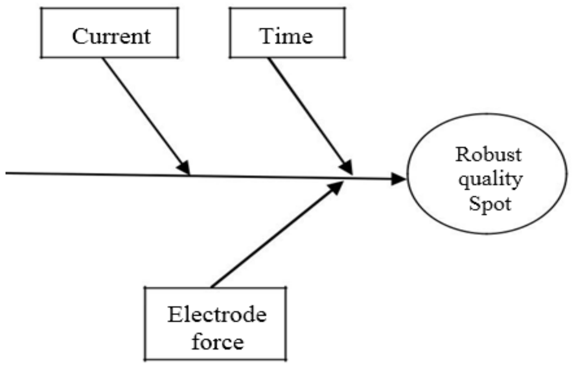

Figure 2. Cause and effect diagram of mainwelding parameter

A.Effect of Welding Current: Current controls the heat which generated according to the equation E =I2Rt.This shows that the current has more influence on the amount of heat generated. Tensile shear strength increases rapidly with increasing current density. Excessive current density will cause molten metal expulsion (resulting in internal voids), weld cracking, and lower mechanical strength properties. Typical variations in shear strength of spot welds as a function of current magnitude are shown in Figure 3.

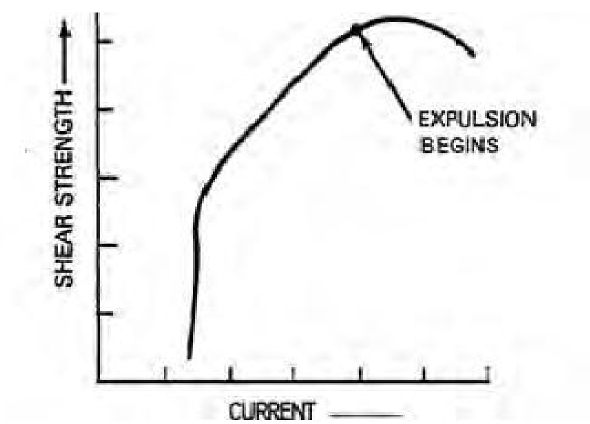

Figure 3. Effect of welding current on spot weld shear strength

B. Effect of Weld Time:

The rate of heat generation must be such that welds with adequate strength will be produced without excessive electrode heating and rapid deterioration. The total heat developed is proportional to weld time. During a spot welding operation, some minimum time is required to reach melting temperature at some suitable current density. Excessively long weld time will have the same effect as excessive amperage on the base metal and electrodes. Furthermore, the weld heat-affected zone will extend farther into the base metal. The relationship between weld time and spot weld shear strength is shown in Figure4.

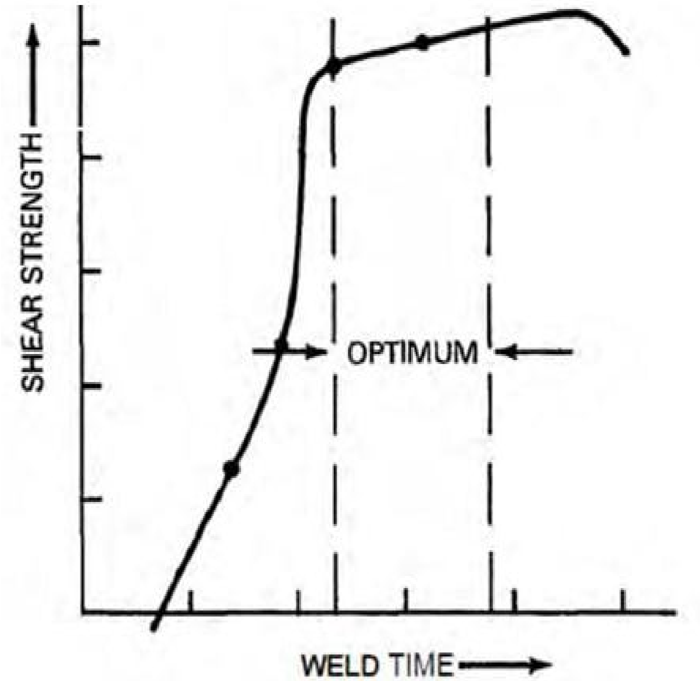

Figure 4. Tensile-shear strength as a function of weld time

C. Effect of Electrode Force:

Welding force is produced by the force exerted on the joint by the electrodes. Electrode force is considered to be the net dynamic force of the electrodes upon the work, and it is the resultant pressure produced by this force that affects the contact resistance. As the pressure is increased, the contact resistance and the heat generated at the interface will decrease. To increase the heat to the previous level, amperage or weld time must be increased to compensate for the reduced resistance. The surfaces of metal components, on a microscopic scale, are a series of peaks and valleys. When they are subjected to light pressure, the actual metal-to-metal contact will be only at the contacting peaks, a small percentage of the area.

III. PROBLEM DEFINITION

As there is no standard data for process parameter available from the resistance welding manufacturer's association, (American welding society) Every time with respect to thickness of material to be welded company does the trial and error basis experiment for optimizing the process parameter with reference lower thickness parameter from resistance welding manufacturer's association standard table.

1. Objectives-

(1) To study spot welding and factors affecting a good spot welding.

(2) Using Taguchi Method to estimate good parameter of the welding variables. The welding variables are Electrode force, current and time.

2. Scope and Limitation-

- The research is subjected to the following scope and limitation:
- The study is limited to resistance spot welding.
- The material of specimen is mild steel.
- The thickness of material is 0.8 mm and 1.2mm for mild steel.
- The machine used is spot welding machine.
- Others variables such as human element, type of machine, material and
- Surfaces are neglected.

IV. EXPERIMENTAL DATA

The experimental set up is shown in figure1.This Experiment was carried out on spot welding machine at Mahindra CIE Stamping Division, Nasik. A sheet metal Processing unit in MIDC Ambad, Nasik .Company is engaged in manufacturing of sheet metal sub assemblies and stamping of automotive parts for Mahindra and Mahindra Ltd. for car manufacturing company in India for model Bolero, Scorpio, Xylo, Verito , XUV500 and Quanto. In this study, copper was used as an electrode material and was kept constant during the experiment. The electrode was changed with non-used one for each experiment to prevent the effect of electrode damage on the nugget formed.

a. Dimensions of work pieces:

Thickness (t) mm	Length (L) mm	Width (W) mm	contact overlap mm
0.8	100	20	20
1.2	100	20	20

Overlap **Single spot weld**

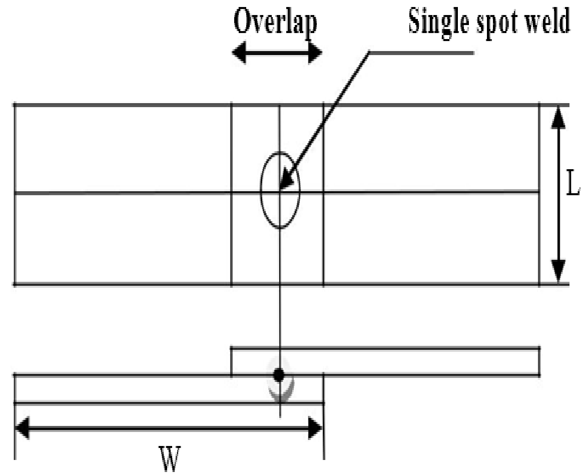

Figure 5. Diagrammatic representation of work-piece

Figure 6. Work piece after finished spot welding

V. ANALYSIS OF EXPERIMENTAL DATA

A. Analysis of S/N Ratio Based On Taguchi Method:

Taguchi recommends analyzing data using the S/N ratio that will offer two advantages; it provides guidance for selection of the optimum level based on least variation around on the average value, which closest to target, and also it offers objective comparison of two sets of experimental data with respect to deviation of the average from the target. The experimental results are analyzed to investigate the main effects. According to Taguchi method, S/N ratio is the ratio of

"Signal" representing desirable value, i.e. mean of output characteristics and the "noise" representing the undesirable value i.e., squared deviation of the output characteristics. It is denoted by η and the unit is dB. The S/N ratio is used to measure quality characteristic and it is also used to measure significant welding parameters. According to quality engineering the characteristics are classified as Higher the best (HB) and lower the best (LB). HB includes T-S strength which desires higher values. The summary statistics the S/N ratio (dB) is given by η. Larger is the best performance.

$\eta = -10\log [1/ns\ 1/yi2]$ Where i =1, 2, 3, 4….n.

The nugget diameter must be nominal for best performance of welding process. The Signal to Noise ratio was calculated as per η [db] =-10 log10 {σ2);

i =1, 2, 3, 4…n

Where σ is the standard deviation.

n is number of trials and yi is the ith trial

For multi-objective Taguchi method the a single overall S/N ration for both quality characteristics is computed. This overall S/N ratio is known as multiple S/N ratio and calculated as below for jth trial (ηej)

$$(\eta^{e}_{j}) = -10 \log 10(Y_j)$$

$$Y_j = \sum_{i=1}^{K} w_i y_{ij}$$

and $y_{ij} = L_{ij} / L_i^*$

Where

Yj is the normalized quality loss in jth trial, wi represent the weightage factor for ith quality characteristics and yij is normalized quality loss associated with ith quality characteristics at jth trial.Lij is the quality los or MSD for ith quality characteristics at jth trial, L* is the maximum quality loss for the ith quality characteristics among all the experimental run.

Table 1. Total Normalized Quality loss values for Nugget diameter and Tensile strength.

Exp. No.	Electrode force (kgf)	Current (KA)	Time (cycles)	ND Normalized Quality loss	TS Normalized Quality loss	Total Normalized Quality loss	MSNR (dB)
1	300	9	12	0.1885	0.3592	0.308	5.114
2	300	9	14	0.2124	0.7836	0.6122	2.131
3	300	9	16	**1.0000**	0.2387	0.4671	3.306
4	300	9.5	12	0.2186	0.8001	0.6257	2.036
5	300	9.5	14	0.1674	0.4289	0.3505	4.554
6	300	9.5	16	0.0993	0.5216	0.3949	4.035
7	300	10	12	0.1063	0.2199	0.1859	7.308
8	300	10	14	0.0925	0.2046	0.1709	7.672
9	300	10	16	0.1136	0.2394	0.2016	6.955
10	325	9	12	0.1115	0.3859	0.3036	5.178
S11	325	9	14	0.1357	0.0889	0.103	9.873
12	325	9	16	0.0637	0.5169	0.381	4.191
13	325	9.5	12	0.1585	0.801	0.6083	2.159
14	325	9.5	14	0.1648	0.6411	0.4982	3.026
15	325	9.5	16	0.3218	0.7923	0.6512	1.863
16	325	10	12	0.2124	0.4458	0.3757	4.251
17	325	10	14	0.2182	0.0924	0.1301	8.856
18	325	10	16	0.2346	0.1496	0.1751	7.567
19	350	9	12	0.1205	0.8011	0.5969	2.241
20	350	9	14	0.1168	0.3165	0.2566	5.908
21	350	9	16	0.1266	0.5133	0.3973	4.009
22	350	9.5	12	0.1212	**1.0000**	0.7364	1.329
23	350	9.5	14	0.0198	0.8825	0.6237	2.05
24	350	9.5	16	0.1597	0.642	0.4973	3.033
25	350	10	12	0.1392	0.1921	0.1762	7.54
26	350	10	14	0.1146	0.2801	0.2305	6.374
27	350	10	16	0.1233	0.3135	0.2565	5.91
						Average	**4.7581**

Sample Calculation for the Multi-objective Taguchi, Multiple S/N ratio (MSNR)

1) Quality loss values for nugget diameter and tensile shear strength

Exp. No.	Nugget Diameter				T-S Strength			
	ND1	ND2	MEAN	STANDARD DEVIATION	TS1	TS2	MEAN	STANDARD DEVIATION
1	3.028	3.582	3.305	=(ND1-MEAN)^2+ (ND2-MEAN)^2 =0.1535	3109.75	3108.80	3109.27	=(TS1-MEAN)^2+ (TS2-MEAN)^2 =0.4484

2) Normalized Quality loss values for nugget diameter and tensile shear strength

Standard Deviation-ND	Standard Deviation-TS	Normalized Quality Loss-ND	Normalized Quality Loss-TS
0.1535	0.4484	=0.1535/(0.8141)maximum quality loss for the i^{th} quality characteristic among all the experimental value.= 0.1885	= 0.4484/ (1.2482)maximum quality loss for the i^{th} quality characteristics among all the experimental value. =0.3592

3) Total Normalized Quality loss values for nugget diameter and tensile shear strength

ND Values	TS Values	TNQL
Normalized Quality Loss for ND =0.1885	Normalized Quality Loss for TS =0.3592	=(0.3* Normalized Quality Loss-ND)+ (0.7* Normalized Quality Loss-TS)) =0.3080

Figure 5 The output response of the raw material into the system

Where

The assigned to Tensile strength and Nugget diameter are 30% and 70% based respectively on importance of these parameter in the resistance spot welding process.

3. Multiple S/N ratio(MSNR) = -10*log10 (TNQL)

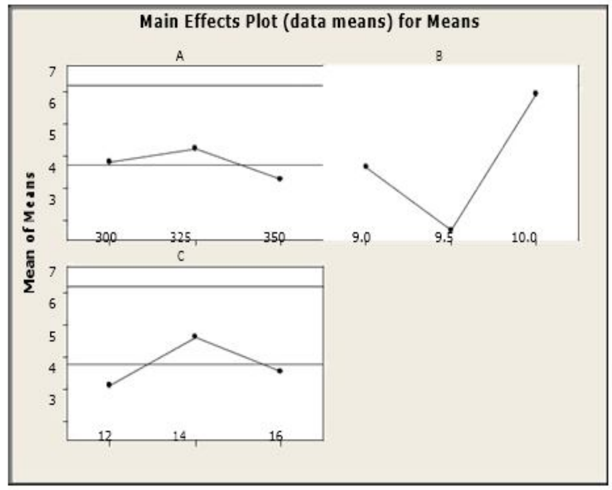

Figure 7. Main Effect Plot

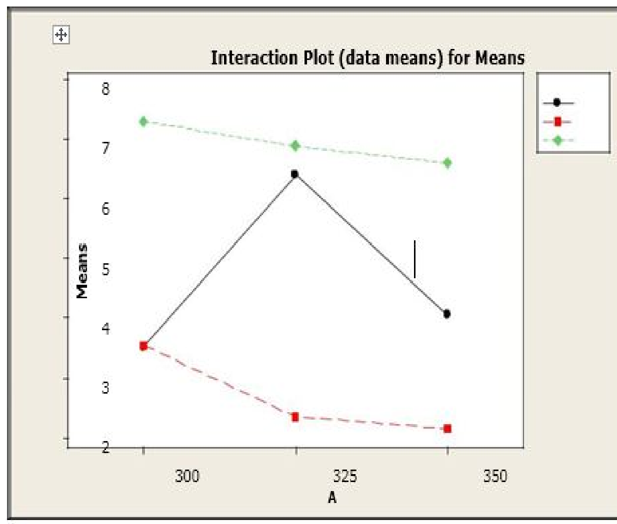

Figure 8. Interaction plot for A*B

VI. CONCLUSION

A Multi-objective Taguchi method has been applied for simultaneous consideration of multiple responses (nugget diameter and Tensile strength) to optimize multiple quality characteristics is resistance spot welding process it can be concluded that

1. From the result of ANOVA it is clear that the current is most important influencing parameter in resistance spot welding process with (% contribution 55.05%).The second influencing factor is Cycle with (% contribution 7.02%) and the third influencing factor is electrode force with (%contribution 2.75%) and interaction (A*B) is significant with (%contribution 9.65%).
2. Hence we obtained the optimum process parameter as A2 B3 C2 for nominal nugget diameter and maximum Tensile strength.

3. It means the maximum Tensile strength and nominal nugget diameter is obtained for the thickness of 0.8 mm and 1.2 mm with parameter Electrode force 325 kgf, welding current 10 KA and welding time 14 cycle.

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