International Journal of Emerging Engineering Research and Technology
Volume 2, Issue 5, August 2014, PP 60-66
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Optimization of Geometrical Parameters of Resistance Spot Welding Process for Strength of Welded Joints

Nilesh T.Mohite[1], Prof.Jaydeep S. Bagi[2]

[1]Student, K.I.T.'s College of Engg, Dept of Production Engg. Kolhapur.Maharashtra, India
[2]Professor, K.I.T's College of Engg. Dept of Production Engg. Kolhapur.Maharashtra, India

Abstract: *The objective of this work is to optimize geometry parameters of resistance spot welding process for AISI 1008 material In order to study the significance of the geometry parameters i.e. Distance between welds, Overlapping length, Distance of weld from the edge towards the percentage improvement in tensile strength. It is clear from the results that parameters significantly affect both the mean and the variation in the percentage improvement in tensile strength values of the AISI 1008 material. The S/N ratio analysis suggests third level of Distance between welds, first level of Overlapping length and second level of Distance of weld from the edge as the best levels for maximum percentage improvement in tensile strength of AISI 1008 work-piece in spot welding operation. This study helps us to find out the optimum values for three parameters for Resistance Spot Welding for 1.2mm thickness of AISI 1008 sheet. The average value of the response characteristic obtained through the confirmation experimentations lies within the 95% confidence level.*

Keywords: *Resistance Spot Welding (RSW), Analysis of variance (ANOVA), S/N ratio*

1. Introduction

Resistance welding is the most commonly used method for joining steel sheets. No filler metal is needed and the heat required for the weld pool is created by means of resistance when a high welding current is directed through the welded workpieces. An electro-conductive contact surface is created between the workpieces by pressing them together. Contact is made using the shape of either the welded surfaces of the workpieces or the shape of the electrodes. Water-cooled electrodes made of alloyed copper are used in resistance welding. Electrodes convey a pressing force to the joint and direct the welding current to the joint in the appropriate manner. After welding, the electrodes rapidly cool down the welded joint. Resistance welding is a highly efficient production method that is particularly well-suited for automated production lines and mass production. Resistance Welding is also suitable for small batch production, because the method is flexible, equipment simple and the welding process is easy to control. In addition, an important advantage of the method is that it can be used for joining a great number of metallic materials. Resistance welding is also suitable for the welding of the most common metal coated steel sheets.

2. Material Specification

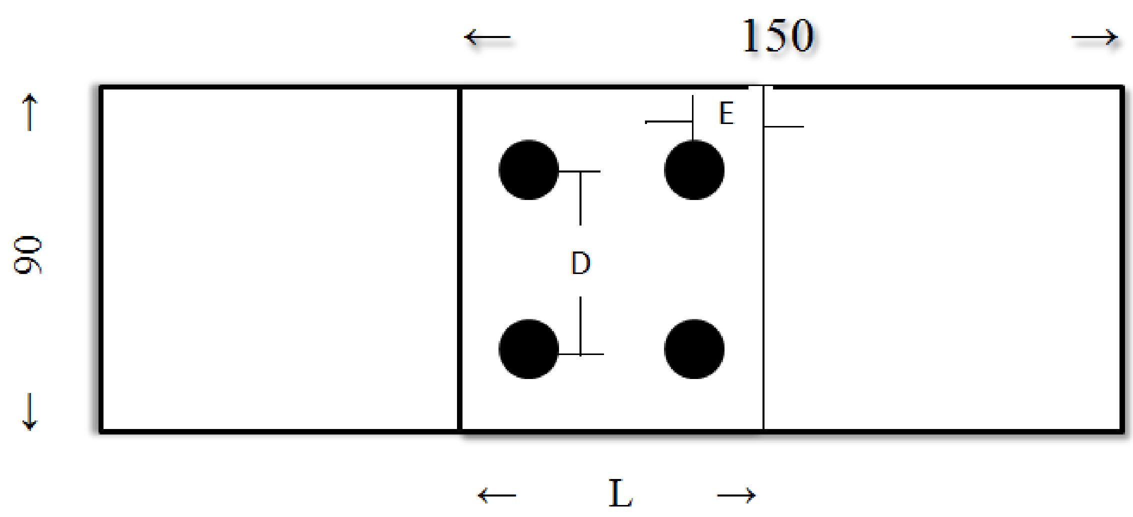

Fig2.1. *Dimensions of Specimen (all dimensions in mm)*

Table2.1. *Material AISI1008 Composition*

ELEMENT	WT. %
c	0.0709
Si	.00393
Mn	0.375
P	0.00500
S	0.0136
Cr	0.0161

2.1. Experimentation

The three geometry parameters viz. Distance between welds, Overlapping length, Distance of weld from the edge were selected as given in Table 2.3.1. The parameters which were kept constant are also listed in this Table. Experiments were conducted according to the test conditions specified by the L9 (Table 2.3.2). Each experiment was repeated five times in each of the trial conditions. Thus, twenty 135 work-pieces were selected of thickness 1.2mm. In each of the trial conditions and for every replication, the tensile strength characteristics were measured.

2.2. Response Characteristics

The effect of selected geometry parameters was studied on the tensile strength response characteristics for the material AISI1008. Tensile strength was measured using Universal Testing machine.

2.3. Design of Experiments

Table2.3.1. *Selected Process Parameters and Their Range*

SR. NO.	PROCESS PARAMETERS	RANGE	UNIT
1	Current	5-65	Amp
2	Thickness of AISI1008 sheet	1.2	mm
3	Electrode Type	straight	Nil
4	Electrode Tip Diameter		
5	Shape of Electrode Tip	circular	Nil
6	Electrode Material	Copper chromium	Nil

Table2.3.2. *parametric combinations for experimentation*

EXPT.NO.	D(MM)	L(MM)	E(MM)
1	23	38	6
2	23	75	11
3	23	113	19
4	45	38	11
5	45	75	19
6	45	113	6
7	68	38	19
8	68	75	6
9	68	113	11
EXPT.NO.	D(MM)	L(MM)	E(MM)
10	23	38	11
11	23	75	23
12	23	113	38
13	45	38	23
14	45	75	38
15	45	113	11
17	68	75	11
18	68	113	23
19	23	38	19
20	23	75	38
21	23	113	56
23	45	75	56
24	45	113	19
26	68	75	19
27	68	113	38

The experiments were designed to study the effect of some of parameters on response characteristics of resistance spot welding process. Taguchi parametric design methodology was adopted. The experiments were conducted using appropriate orthogonal array (OA).

Where,

D- Distance between welds

L- Overlapping length

E- Distance of weld from the edge.

Parameters and their levels are given in Table 2.3.2 Each three level parameter has 2 degree of freedom (DOF = Number of levels-1), overall mean has a degree of freedom of 1, and the total DOF required for three parameters each at three levels is 7 =1+ [3 x (3-1)]. As per Taguchi's method the total DOF of selected OA must be greater than or equal to the total DOF required for the experiment. So an L9 (a standard 3-level OA) having 8 = (9-1) degree of freedom was selected for the present analysis.

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1. Experimental Results

Experiments are conducted to study the effect of geometry parameters over the output response characteristics with the geometry parameters assigned to columns as given in Table 2.3.2 and each experiment is repeated five times for obtaining S/N values. All response outputs are 'Larger the Better'; accordingly S/N ratio for each experiment is calculated.

Table3.1. *Experimental results for tensile strength*

EXPT.NO.	TENSILE STRENGTH(N/MM^2)						S/N RATIO
	1	2	3	4	5	Avg.	
1	108.102	105.231	105.463	105.37	105.787	105.9906	40.50404
2	110.741	98.472	104.028	103.981	104.815	104.4074	40.35657
3	98.241	106.852	109.213	109.074	110.278	106.7316	40.54215
4	107.231	109.583	106.389	113.843	107.917	108.9926	40.74051
5	107.176	104.167	98.009	101.667	93.241	100.852	40.04284
6	96.713	97.315	103.704	99.12	106.528	100.676	40.04019
7	97.222	107.222	108.889	110.509	106.574	106.0832	40.48617
8	101.991	110.741	98.75	109.537	96.889	103.5816	40.26786
9	105.093	108.148	112.963	107.13	111.62	108.9908	40.7386
10	107.222	106.944	102.269	109.074	103.796	105.861	40.48757
11	98.889	98.519	98.75	97.222	100.278	98.7316	39.88786
12	95.88	103.843	97.083	96.713	96.898	98.0834	39.82106
13	128.278	125.444	105.093	111.25	105.602	115.1334	41.13136
14	105.648	104.444	105.741	98.704	102.917	103.4908	40.28951
15	102.546	107.315	108.472	108.796	97.593	104.9444	40.39629
17	105.185	110.972	104.907	105.741	115	108.361	40.68032
18	104.398	112.176	111.343	110.972	109.861	109.75	40.79938
19	102.083	106.759	107.13	105.88	108.287	106.0278	40.50305
20	107.731	97.083	105.37	101.204	99.583	102.1942	40.17003
EXPT.NO.	TENSILE STRENGTH(N/MM^2)						S/N RATIO
	1	2	3	4	5	Avg.	
21	100.509	92.083	104.444	96.944	80.787	94.9534	39.44453
23	97.824	110.37	100.694	101.065	105.093	103.0092	40.23501
24	100.37	108.426	106.019	109.352	99.213	104.676	40.37618
26	112.13	105.648	106.991	111.25	94.491	106.102	40.46448
27	95.139	106.204	109.352	104.074	105.556	104.065	40.31667

$S/N = -10 \, Log_{10} \, (MSD)$

MSD = Mean squared deviation from the target value of the quality characteristic.

$$= \frac{\left(\frac{1}{y_1^2}+\frac{1}{y_2^2}+\frac{1}{y_3^2}+\cdots+\frac{1}{y_n^2}\right)}{n}$$

Where y_i is result of observation

n = number of repetitions

3.2. Determination of Significant Geometry Parameters for Tensile Strength by Anova Method

Average S/N ratio for tensile strength for each level of geometry parameters is plotted as in figure .It can be observed from the figure, tensile strength increases as distance between welds increases. With increase in overlapping length tensile strength tends to decrease till middle level and then increases for higher value of parameters. With increase in edge length tensile strength tends to increase till middle level and then decreases for higher value of parameters

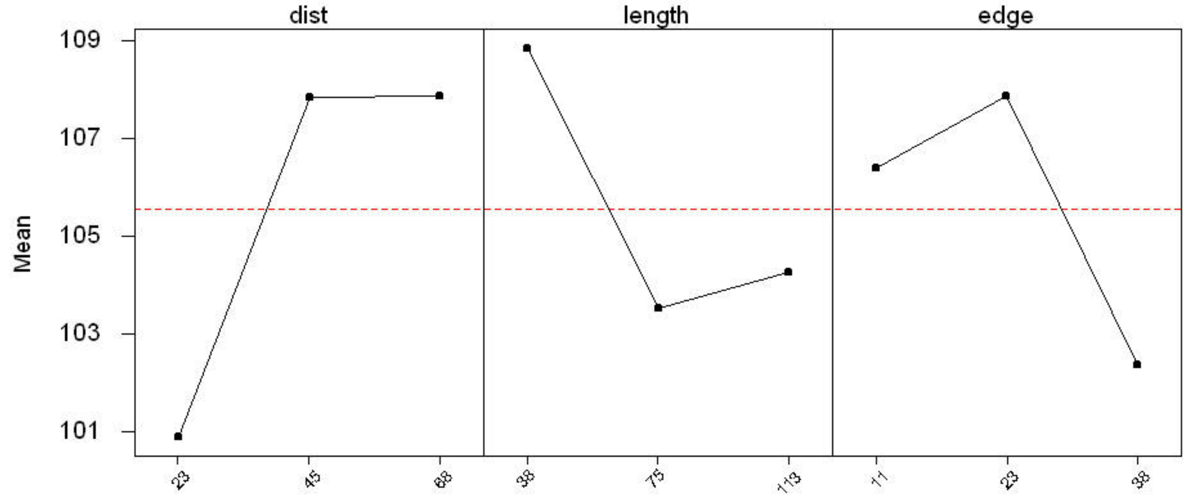

Fig3.2.1. *Main effect plot for means for average tensile strength*

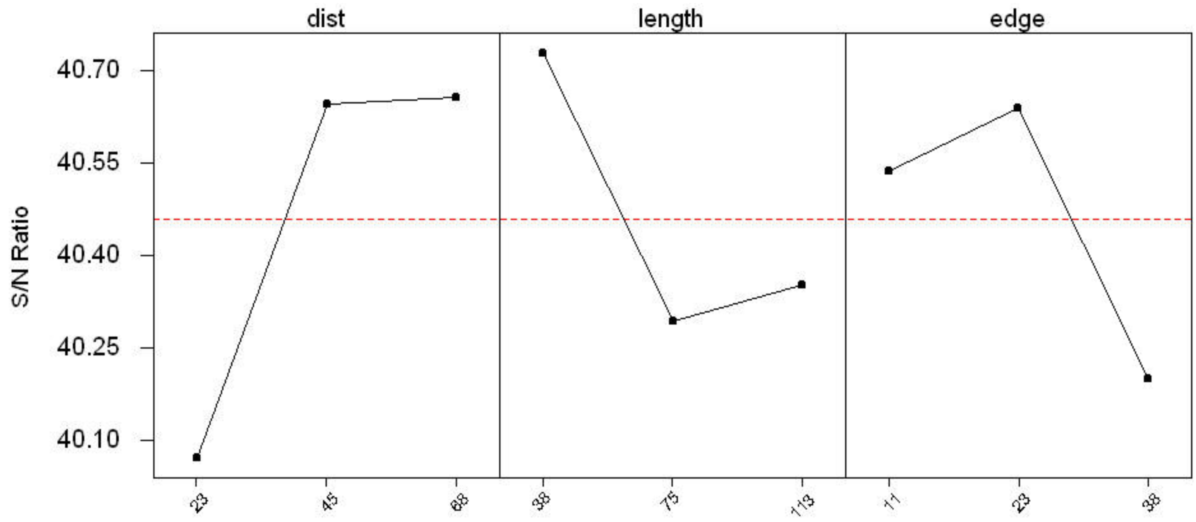

Fig3.2.2. *Main effect plot for means for average tensile strength*

Analysis of variance (ANOVA) is performed to find out the significant parameters which affect the tensile strength as shown in table. It is found that distance between welds and overlapping length are significant parameters for tensile strength and edge distance is less significant parameter. As tensile strength is the "Larger the better" characteristic, from figure 3.2.2 it can be observed that the third level of Distance between welds, first level of Overlapping length and second level of Distance of weld from the edge **(A3-B1-C2)** result in maximum value of tensile strength.

Table3.2.1. *Analysis of variance for tensile strength (S/N ratio), using adjusted SS for tests*

SOURCE	DF	SEQ. SS	ADJ.SS	ADJ.MS	F	P	% CONTRIBUTION	REMARK
dist	2	97.40	97.40	48.70	3.42	0.226	49.78	Most significant
length	2	49.86	49.86	24.93	1.75	0.364	25.47	significant
edge	2	48.57	48.57	24.28	1.70	0.370	24.74	significant
Error	2	28.50	28.50	14.25				
Total	8	224.33						

Table 3.2.2 *Response Table for Signal to Noise Ratios for tensile strength larger is better*

LEVEL	DISTANCE	LENGTH	EDGE
1	40.0719	40.7291	40.5371
2	40.6471	40.2949	40.6404
3	40.6581	40.3531	40.1995
Delta	0.5862	0.4343	0.4409
Rank	1	3	2

3.3. Predicted Result by Taguchi Method

Once the optimal level of the geometry parameters is identified, the final step is to predict and validate the improvement of the performance measures using the optimal level, i.e. for tensile strength A3-B1-C2. The purpose of the confirmation experiment is to verify the conclusions drawn during the analysis phase. The S/N ratio η_{pre} for tensile strength can be predicted as follows.

$$\eta_{pre} = \eta_{om} + (\eta_{dist} - \eta_{om}) + (\eta_{length} - \eta_{om}) + (\eta_{edge} - \eta_{om}) \quad (1)$$

Where η_{om} is the overall mean S/N ratio and η_{dist} , η_{length} , η_{edge} are the S/N ratios of the significant individual control factors at their optimum levels.

3.3.1. The Optimal S/N Ratio for Tensile Strength

From Table 3.1

η_{om} =40.4366, η_{A3}= 40.7398, η_{B1}= 40.8094, η_{C2}=40.6061

Putting these values in equation (1) we get

$\therefore \eta_{pre}$ = 41.2821 dB

Predicted optimal tensile strength is = $\sqrt{10^{\frac{\eta_{pre}}{10}}}$ =115.90 N/mm^2

Experiments are conducted by using optimal level for each parameter. Table 6.3.1 shows the comparison of the predicted and the actual responses obtained during experimental trial. The predicated and actually measured response for both surface roughness and machining forces are in good agreement, indicating that optimization of the control parameters was appropriate.

Table 3.3.1 *Confirmation experiments for tensile strength*

	PREDICTION	EXPERIMENT
Level	A3-B1-C2	
Tensile strength	115.90	116.335

4. CONCLUSION

The following conclusions are drawn from the study.

1) The geometry parameter distance between two welds is most significant factor affecting tensile strength followed by overlapping length and distance of weld from edge.
2) From response table it is found that distance between welds has greatest effect on tensile strength and it followed by dist of weld from edge and overlapping length.

3) From Taguchi's DOE, it is observed that third level of distance between welds, first level of overlapping length and second level of distance of weld from the edge (A3-B1-C2) result in maximum value of tensile strength.
4) For this parametric combination prediction of tensile strength is done according to Taguchi and it is 115.90 N/mm^2. For this experiment tensile strength is 116.335 N/mm^2. This is very close to predicted value, indicating that the use of Taguchi Design for analysis and optimization of control parameters is appropriate.

REFERENCES

[1] Al-Bahkali Essam A. Et.Al. "Stresses Distribution In Spot, Bonded, And Weld-Bonded Joints During The Process Of Axial Load" World Academy Of Science, Engineering And Technology,Vol.67, (2012),Pp.347-352

[2] Alam Shahnawaz Et.Al. "Prediction of Weld Bead Penetration For Steel Using Submerged Arc Welding Process Parameters" International Journal of Engineering Science And Technology,0975-5462, Vol. 3 No.10 ,October (2011),Pp.7408-7416

[3] Choa S.K. Et.Al. "Fatigue Strength In Laser Welding Of The Lap Joint" Finite Elements In Analysis And Design,Vol.40, (2004),Pp.1059–1070

[4] Dalvi M.V.Et.Al. "FEA Based Strength Analysis Of Weld Joint For Curved Plates (Overlap) Specially For Designing Pressure Vessel Skirt Support" International Journal Of Recent Technology And Engineering,2277-3878,(2012),Pp.17-23

[5] Darwish S.M. "Weld Bonding Strengthens And Balances The Stresses In Spot-Welded Dissimilar Thickness Joints" Journal of Material Processing Technology, Vol.134, (2003),Pp.352-362

[6] Diaye A. N Et.Al. "Stress Concentration Factor Analysis For Notched Welded Tubular T-Joints" International Journal Of Fatigue,Vol. 29, (2007),Pp.1554–1570

[7] Guo S.Et.Al. "Numerical Analysis And Experiment Of Composite Sandwich T-Joints Subjected To Pulling Load" Composite Structures,Vol. 94,(2011),Pp. 229–238

[8] Jose Lavado Rodrıguez Et.Al. "Study of The Distribution Of Tensions In Lap Joints Welded With Lateral Beads, Employing Three Dimensional Finite Elements" Composite And Structures,Vol.82, (2004),Pp.1259–1266

[9] Kassab Rabih Kamal Et.Al. "Experimental And Finite Element Analysis Of A T-Joint Welding" Journal Of Mechanics Engineering And Automation,Vol.2, (2012),Pp. 411-421

[10] K.Ashok Kumar Et.Al. "Thermo-Mechanical Analysis Of A Corner Welded Joint By Finite Element Method " International Journal Of Engineering Research & Technology ,2278-0181, Vol. 1 Issue 7, September (2012),Pp.1-8

[11] Krscanski S.Et.Al. "Fem Stress Concentration Factors For Fillet Welded Chs Plate T-Joint" Engineering Review,Vol. 32,(2012),Pp.147-155

[12] Labeas G. Et.Al. "Laser Beam Welding Residual Stresses Of Cracked T-Joints" Theoretical And Applied Fracture Mechanics,Vol.63–64,(2013),Pp.69–76

[13] Lima Jaesong Et.Al. "Estimation Of The Fatigue Life According To Lap Joint Weld Profiles For Ferritic Stainless Steel" Procedia Engineering, Vol.10 (2011),Pp. 1979–1984

[14] Meneghetti Giovanni "The Use Of Peak Stresses For Fatigue Strength Assessments Of Welded Lap Joints And Cover Plates With Toe And Root Failures" Engineering Fracture Mechanics, Vol.89 (2012),Pp.40–51

[15] Moraitis G.A. Et.Al. "Residual Stress And Distortion Calculation Of Laser Beam Welding For Aluminum Lap Joints" Journal Of Materials Processing Technology, Vol.98, (2008),Pp. 260–269

[16] Padmakumari.T Et.Al. "Finite Element Analysis Of EBW Welded Joint Using SYSWELD" International Journal Of Emerging Technology And Advanced Engineering Volume 3, Issue 2, (February 2013),Pp.335-340

[17] Pandey A. K. Et.Al. "Optimization Of Resistance Spot Welding Parameters Using Taguchi Method" 0975-5462,Vol. 5 No.02, February (2013),Pp.234-241

[18] Pilare S.N.Et.Al. "Fe Modeling And Analysis Of Arc Welded T Joint", International Journal Of Engineering Science And Technology,0975-5462,(2012),Pp.2774-2783

[19] Reddy Sathyanarayana B. N. Et.Al. "Influence Of Groove Angle In V-Groove Butt Joints On Transverse Shrinkage In CO2 Arc Welding Process" International Journal Of Engineering Science And Technology,0975-5462, Vol. 5 No.02, February (2013) Pp. 410-412