OPTIMIZATION OF RESISTANCE SPOT WELDING PROCESS PARAMETERS OF AISI 304L AND AISI 1020 WELDED JOINTS

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Abstract - *This dissertation report aimed on an optimization of resistance spot welding process by the effects of process parameters applying Taguchi methods to improve the quality of manufacturing goods and engineering development of designs for studying variation. A sound weld from spot welding is what most of the manufacturers desired and preferred for mechanical assemblies in their systems. The robustness is mainly relied on joining mechanism of mechanical parts. In this research, the effect of spot welding parameters on tensile strength (T.S.) and nugget diameter (N.D.) was investigated using Taguchi method. The main affecting welding parameters such as weld current, weld time, pressure and holding time were determined as the basis for quality evaluation. The welded samples are later undergone the tensile test and metallurgical test to characterize the spot weld growth. Taguchi quality design concepts of L9 orthogonal array has been used to determine Strength to Noise (S/N ratio), Analysis of Variance (ANOVA) and F test value for determining most significant parameters affecting the spot weld performance.*

Key Words: **Resistance spot welding, tensile strength, nugget diameter, ANOVA, grey relational analysis.**

1. INTRODUCTION

The quality and mechanical behavior of resistance spot welds (RSW) significantly affects durability and crashworthiness of vehicle. Dissimilar resistance spot welding can be more complex than similar welding due to different thermal cycle experienced with each metal. Despite of various application of dissimilar RSW, reports in the literature dealing with mechanical behaviors of them are limited.

2. LITERATURE REVIEW

Mehdi Mansouri et.al.[1] observed that compared to similar welds, weld nugget of dissimilar SS/CS RSWs has two distinct features: asymmetrical shape (FZ size of SS side is greater than that of for CS side due to its higher resistivity)and shifting of final solidification line from sheet/sheet interface into the SS side. Mahadzir Ishak et.al. [2] carried out resistance spot welding of AISI 301 stainless steel and AISI 1020 carbon steel. They reported that the optimum weld condition, (I=5 KA, WT 3 cycle and electrode force 40 psi) achieved highest tensile strength (200.71 MPa) and Charpy impact energy (46 J). Nachimani Charde [3] carried out spot welding of dissimilar materials with different thicknesses. He analyzed that hardness increments of welded side do exist because of heat treatment that happened during welding process. A.G. Thakur et.al. [4] investigated the effect of welding parameters on the tensile shear strength of spot welded galvanized steel sheets. Pirooz Marashi et.al. [5] concluded that in dissimilar RSW between low carbon galvanized steel and austenitic stainless steel, asymmetric fusion zone was obtained due to their different electrical resistivity and thermal conductivity. A.S. Panchakshari et.al.[6] carried out an optimization of process parameters in resistance spot welding using genetic algorithm. Oscar martin et.al. [7] observed that in resistance spot welding of 304 austenitic stainless steel of 0.8 mm thickness, the weld nugget grows at the expense of heat input that increases with increasing welding current and weld time. Nachimani Charade [8] invested spot weld growth on dissimilar joints of 304l austenitic stainless steel and medium carbon steel. He concluded that Force increment has caused diameters decrement which decreases bonding strength of weld pairs. Majid Pournavari et.al. [9] conducted experimentation on effect of weld nugget size on overload failure mode of resistance spot welds. Rajprasad Rajkumar et.al. [10] observed that hardness of welded zones of 304 austenitic stainless steel sheets with 2mm thickness is greater than hardness of unwelded zone and also heat affected zones.

3. EXPERIMENTAL WORK

The experimentation was carried out at 'KIRTI PRESSINGS PVT. LTD.' MIDC Waluj, Aurangabad, Maharashtra. Spot welding was performed using a calibrated 75 KVA 50Hz AC pedestal resistance spot welding machine, controlled by a programmable logic controller. Electrode with tip diameter 6mm used in this experimentation.

Table -1: Chemical composition of materials

Sr. no.	Elements	AISI 304L	AISI 1020
1	C	0.028	0.052
2	Mn	1.09	0.35
3	S	0.007	0.006
4	P	0.025	0.010

Table -2: Process parameters with their levels

Factor/Level	Notation	Level 1	Level 2	Level 3
Current(KA)	I	6	10	14
Pressure(bar)	P	2	3	4
Weld time(cycle)	W T	10	15	20
Hold time(cycle)	H T	20	25	30

As per the L9 orthogonal array for each combination of process parameters 18 rectangular work pieces of size about 200×30 mm are prepared and welded for both the materials AISI 304L and AISI 1020 and the results obtained included in tabular form.

Table -3: Design and experiments of resistance spot welding

Runs	Current (KA)	Pressure (BAR)	Weld time (CYCLES)	Hold time (CYCLES)	Tensile strength (N/mm²)	Nugget diameter (mm)
1	6	2	10	20	145.09	4.35
2	6	3	15	25	178.09	5.40
3	6	4	20	30	156.36	4.80
4	10	2	15	30	265.25	6.60
5	10	3	20	20	275.10	6.30
6	10	4	10	25	208.51	5.60
7	14	2	20	25	304.99	7.74
8	14	3	10	30	273.13	6.81
9	14	4	15	20	282.89	7.44

4. GREY RELATIONAL ANALYSIS

In this research work, normalization of tensile strength and nugget diameter is done between 0 and 1. Here for tensile strength, normalization equation larger-the-better and for nugget diameter smaller-the-better is used and is shown in table.

4.1 Data normalization

Table -4: Data normalization

Sr. no.	Tensile strength	Nugget diameter
Ideal sequence	1.000	1.000
1	0.4757	1.000
2	0.5839	0.8055
3	0.5126	0.9062
4	0.8697	0.6590
5	0.9019	0.6904
6	0.6836	0.7767
7	1.000	0.5620
8	0.8955	0.6387
9	0.9275	0.5846

$$Xi\ (k) = \frac{Yi(k)}{\max Yi(k)}$$ i.e. Tensile strength $= \frac{\text{Each value}}{\text{Max.value}}$,

$$Xi\ (k) = \frac{\min Yi(k)}{Yi(k)}$$ i.e. Nugget diameter $= \frac{\text{Min.value}}{\text{Each value}}$

4.2 Calculation of correlation coefficient

After normalization, a check has been made to verify whether the responses are correlated or not.

Table -5: Correlation coefficient

Sr. no.	Correlation between responses	Pearson correlation coefficient	Comment
1	Tensile strength and nugget diameter	-0.9676	Both are correlated

4.3 Calculation of principal component score

Table -6: Principal component score

	ψ_1	ψ_2
Eigen value	1.968	0.032
Eigen vector	0.707	0.707
	-0.707	0.707
AP	0.984	0.016
CAP	0.984	1.000

Table -7: Values of major principal components

Sr. no.	ψ_1	ψ_2
Ideal sequence	0.0000	1.4142
1	-0.3706	1.0433
2	-0.1566	0.9823
3	-0.2782	1.0000
4	0.1489	1.0807
5	0.1495	1.1250
6	-0.0658	1.0324
7	0.3096	1.1043
8	0.1815	1.0846
9	0.2424	1.0690

4.4 Quality loss estimate for principal component score

Table -8: Quality loss

Sr. no.	ψ_1	ψ_2
1	0.3706	0.3707
2	0.1566	0.4317
3	0.2782	0.4140
4	0.1489	0.3333
5	0.1495	0.2890
6	0.0658	0.3816
7	0.3096	0.3097
8	0.1815	0.3294
9	0.2424	0.3450

i.e. $\psi_1 = \Delta\theta i = \text{ABS}\ |0\text{-each value}|$,

$\psi_2 = \Delta\theta i = \text{ABS}\ |1.4142\text{-each value}|$

4.5 Calculation of grey coefficient and grey relational grades

From each column find Δ_{max}, Δ_{min} and $\Delta\theta i$

$$\Gamma i(k) = \frac{\Delta \min + \xi\, \Delta \max}{\Delta \theta i(k) + \xi\, \Delta \max}$$

Where, $\Delta\theta i$ – corresponding value of first column

ξ = Distinguishing coefficient, take $\xi = 0.5$ and similarly ψ_2 can be calculated.

Table -9: Grey relational coefficient and grey relational grades

	Grey relational coefficient				
Sr. no.	ψ_1	ψ_2	O.G.R.G.	S/N ratio	Orders
1	0.4516	0.8607	0.6561	-3.6605	9
2	0.7344	0.7796	0.7570	-2.4181	5
3	0.5417	0.8015	0.6716	-3.4573	8
4	0.7513	0.9193	0.8353	-1.5631	3
5	0.7501	1.0000	0.8751	-1.1598	2
6	1.0000	0.8450	0.9225	-0.7006	1
7	0.5073	0.9606	0.7339	-2.6872	7
8	0.6845	0.9259	0.8052	-1.8819	4
9	0.5870	0.9001	0.7435	-2.5743	6

Where, overall grey relational grade $\text{O.G.R.G.} = \frac{\psi 1 + \psi 2}{2}$

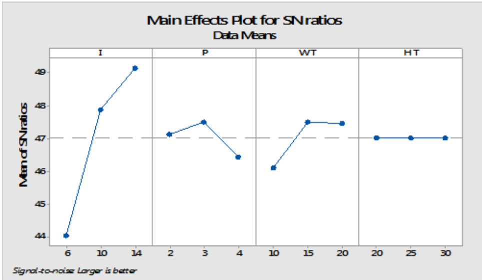
From Table 9 it is clearly observed, that the RSW parameters setting of experiment no. 6 has highest grey relation grade. Thus, the sixth experiment gives the best multi performance characteristics of the RSW process among the 9 experiments.

5. SUMMERY OUTPUT

Following statistical data generated using MINITAB-17 computer software.

Table -10: Response table for S/N ratios (T.S.)

Level	I	P	W T	H T
1	44.04	47.13	46.11	47.02
2	47.88	47.51	47.51	47.03
3	49.15	46.43	47.45	47.03
Delta	5.11	1.08	1.39	0.01
Rank	1	3	2	4



Graph 1: Main effect plot for S/N ratios (T.S.)

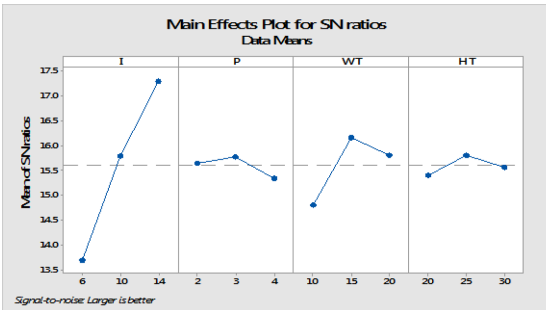
Table -11: Analysis of variance (T.S.)

Source	DF	Adj SS	Adj MS	F-value	P-value	% Contribution
Regression	4	27032.2	6758.0	11.89	0.017	
I	1	24253.2	24253.2	42.49	0.003	89.72
P	1	761.0	761.6	1.34	0.312	2.81
W T	1	2006.4	2006.4	3.53	0.133	7.41
H T	1	11.6	11.6	0.02	0.893	0.042
Error	4	2272.6	568.2			
Total	8	29304.8				

S = 23.8359, R-sq = 92.24 %, R-sq(adj) = 84.49 %

Table -12: Response table for S/N ratios (N.D.)

Level	I	P	W T	H T
1	13.68	15.65	14.80	15.40
2	15.78	15.77	16.16	15.80
3	17.29	15.34	15.80	15.56
Delta	3.61	0.43	1.36	0.40
Rank	1	3	2	4



Graph 2: Main effect plot for S/N ratio (N.D.)

Table 13: Analysis of variance (N.D.)

Source	DF	Adj SS	Adj MS	F-value	P-value	% Contibution
Regression	4	10.0695	2.52737	14.38	0.012	
I	1	9.2256	9.22560	52.71	0.002	91.62
P	1	0.1204	0.12042	0.69	0.453	1.19
W T	1	0.7211	0.72107	4.12	0.112	7.16
H T	1	0.0024	0.00240	0.01	0.912	0.017
Error	4	0.7001	0.17503			
Total	8	10.7696				

S = 0.418372, R-sq = 93.50 %, R-sq (adj) = 87.00 %

6. CONCLUSIONS

i. Tensile strength and nugget diameter are proportional to current, pressure and weld time.

ii. The higher tensile strength was due to an increase in the width of nugget diameter.

iii. Optimization technique revealed that the best combination of parameters for maximum tensile strength and minimum nugget diameter is current 10 kA, pressure 4 bars, weld time 10 cycles and hold time 25 cycles. The descending order of parameters that have most influence on the response in this research is I > W T > P > H T.

iv. Welding current is the most significant factor for tensile strength and nugget diameter.

v. Hold time does not have much more effect on tensile strength and nugget diameter.

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BIOGRAPHIES

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