Optimization of Process Parameter of Spot Welding by Multi Objective Taguchi

S.A.Jadhav[A], PG Student, SND COE &RC, Yeola Prof.. Dr. Venkatesh M. A[B]. , Principal Of SND COE &RC, Yeola

***Abstract*: The automotive industries choose resistance welding for manufacturing because of the great advantages this process has to offer. 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. Hence these papers is directed towards the optimization process parameter of resistance spot welding process and simultaneously consider multiple quality characteristics tensile strength and nugget dia. using Multi Objective Taguchi Method. The experiment is conducted with varying Electrode force, current and weld time. The optimum welding parameter is obtain using signal to noise ratio and significant level is analyzed using analysis of variance. After considering all the parameters this study represent the systematic approach the effect of process parameter (Electrode force, current and weld time) on the tensile strength of resistance weld joint D-Grade as per IS 531 :1994.**

***Keyword*:-Resistance spot welding, Optimization, Multi Objective Taguchi Method**

I. INTRODUCTION

Thousands of automobile products need sheet metal components in tremendous quantity world over. High volume of production at lowest possible cost is the driving potential of sheet metal technology which is undergoing technological transformations due to flourishing of automobile industry globally. Sheet metal components are of strategic importance especially in automotive industry. The tensile shear strength, nugget diameter, burr size, dimensional accuracy, profile correctness, surface smoothness etc. are of great concern as quality characteristics of the resistance spot welding products. Sheet thickness and process parameter is the key of increasing productivity of sheet metal welding process.

The resistance spot welding involves optimization of input process parameter and the product quality parameters. The obvious shear strength phenomena of resistance spot welding and development of process robustness with respect to tensile shear strength and nugget diameter formation is of technical importance. The challenge for manufacturing engineers is of determining the optimum process parameter for spot welding machine sheets without high tensile strength or internal defects at a lower manufacturing cost, depending on the material, the input process parameter, and the process

Current research on the control of spot welding operations aim is to improve the monitoring and control of the quality of components. The motivation is the reduction of rejected volume, the reduction of manual quality control, and the high cost of rejection. Correct parameter choice for a new product manufactured by sheet metal spot welding is determined empirically by performing a large number of expensive tests. The electrode force, current, time and the sheet thickness are the major factors that determine the shear strength and the quality of the work piece Spot welding has a large number of inputs. Each of these inputs has an associated variation that leads to variations in the final part. Optimizations of manufacturing processes and parameters control are known to have direct impact on the production line maintenance and operations. Among the most important tools for manufacturing processes optimization is the design of experiments (DOE) approach.

In Taguchi method, quality is measured by the deviation of a characteristic or attribute from its target value. A loss function is developed which is a measure of this deviation. Uncontrollable factors also known as noise factors, cause such deviation and thereby lead to loss. Elimination of these noise factors is impractical and often impossible. This study seeks to minimize the effects of noise and to determine the optimal level of the important controllable factors based on the concept of robustness. The objective of this study is to understand the creation of a product or process design that is insensitive to all possible combinations of uncontrollable noise factors and is at the same time effective and cost-efficient as a result of setting the key controllable factors at certain levels. The central purpose of this study is to understand and evaluate the impact of Taguchi methods in quality engineering and management for product or process parameters optimization. This study also presents a step by step approach to the optimization of a production process by the utilization of Taguchi methods of experimental design.

II.OBJECTIVE

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.
3. To perform Experiment on sheet metal with resistance spot welding machine

A.Jadhav Swati, SND COE&RC Yeola (swatijadhav510@gmail.com)
B.Vanktesh M.A.Principal SND COE&RC Yeola (mavenka@gmail.com).

4. Optimize the process parameter by multi objective Taguchi method.
5. To obtain the optimum welding parameter signal to noise ratio and significant level of welding parameter is further analysed using analysis of variance.
6. To take the conformation test to validate the project

III. PROBLEM STATEMENT

There are several variables to control like Electrode force (kgf),welding current(KA) and time(cycle).By automatic control of current, timing and electrode force, spot welds can be produced consistently at high rates and low labor costs with no defect.

Here the problem definition, as there is no standard data for process parameter is 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.

IV. METHODOLOGY

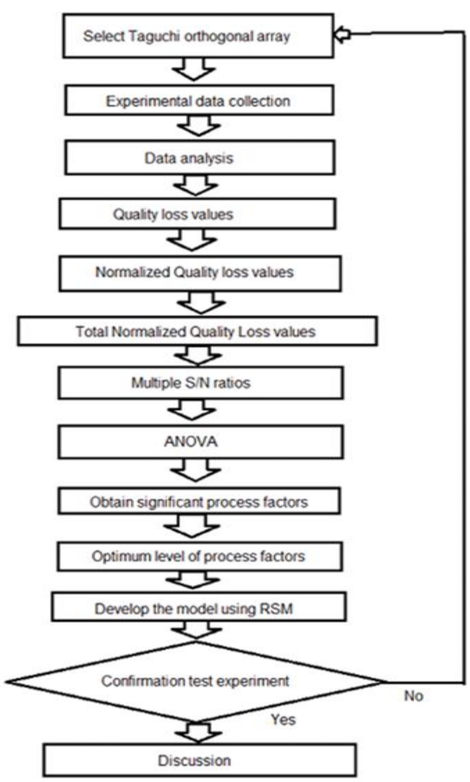

Fig 1 Flow Chart Of Research Methodology

Steps Involved in Taguchi method

a) Define the problem: Define the problem and set up the objective of the experiment. The objective is to identify those control factors settings which optimize the objective function.
b) Selection of factors and number of levels: List all possible factors contributing to the problem with help of brainstorming or cause-effect diagram and the levels which each would be tested.
c) Selection of appropriate Orthogonal Array (OA):The first step in selecting the standard Orthogonal Array (OA) involves counting of the total degrees of freedom (DOF) present in the study. This count fixes the minimum number of experiments that must be perform under study.
d) Performing the experiments: Conducting the experiments as per the Taguchi's orthogonal array design matrix and recording the responses or performance characteristics from each trial.
e) Statistical analysis and interpretation of experimental results: In this, the first step is to analyze the signal-to-noise (S/N) ratio, which measures the functional robustness of product or process performance in the presence of undesirable external disturbances. The following S/N ratios are used for optimization of design parameters setting:
The S/N ratios for nominal-the-best response is given by the following equation
The S/N ratios for nominal-the-best response is given by the following equation $S/N = 10\log\frac{y}{s^2}$
The S/N ratios for larger -the-better response is given by the following equation $S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$
The S/N ratios for smaller-the-better response is given by the following equation $S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}y_i^2\right)$
Using one of the above equations, the S/N ratio corresponding to each trial condition is computed. Now, the next step was to calculate the average S/N ratio at each level of each factor. In order to determine which of the factor/ interaction effects are statistically significant, a powerful statistical technique called analysis of variance (ANOVA) is used. Using ANOVA, one is able to identify the active and inactive factor/interaction effects with statistical confidence.
f) Determination of optimal condition: From the results of ANOVA, the optimal condition is obtained which yield the optimum performance. The optimal condition is obtained by identifying the levels of significant control factors which yield the highest S/N ratios. Thus, the process is optimized under these conditions.
g) Confirmation run or experiment: Finally, the confirmation experiment is to be performed using the optimum settings of the process parameters or factors obtained through the investigation. This is because a confirmation experiment or trial is necessary in order to verify the results from this investigation. This is to show that the factors or parameters and levels chosen from the experiment do provide the desired results.

V.EXPERIMENTATION

For conducting an experiment of a spot welding operation. One simple spot welding to produce spot weld for sheet metal. The experiments are proposed to done in nearby one large scale industry having spot welding process facilities. Material of appropriate thicknesses is selected to spot welding. The following readings are taken for Low Carbon Steel sheet. In all tests, the tensile shear strength is measured on Universal

Testing Machine and nugget diameter is measured with Digital Vernier Caliper. Based on literature and preliminary investigation the following parameters are selected and levels are decided on the basis of dimension of work piece from Resistance welder manufacturer association as shown in tableI
In our experiment, three 3-level factors (A, B, C). The degrees of freedom for this experiment are then computed as follows:

Factor/ interaction	Degrees of freedom
Overall mean	1
A, B, C	3 x (3-1) = 6
A* B, A*C and B*C	3 x (2x2) = 12
Total	19

Hence minimum numbers of experiments needed are nineteen. Considering the further need of data collection with respect to interactions and as once set the resources needed are not too costly, L27 was opted for experimentation
The experimental set up is shown in figure. This Experiment was carried out on spot welding machine at Mahindra Ugine Steel Co. ltd. Sheet metal processing unit in MIDC ambad, Nasik

Fig. 2 Experimental Setup

Table I. Process Parameter and Their Level

Factor	Units	Level 1	Level 2	Level 3
Electrode force	Kg f	300	325	350
Current	KA	9	9.5	10
Time	Cycle	12	14	16

Table II. 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

Table III. Experimental Design With Coded Value

Exp. No.	Electrode force (kgf)	Current (KA)	Time (cycle)
1	1	1	1
2	1	1	2
3	1	1	3
4	1	2	1
5	1	2	2
6	1	2	3
7	1	3	1
8	1	3	2
9	1	3	3
10	2	1	1
11	2	1	2
12	2	1	3
13	2	2	1
14	2	2	2
15	2	2	3
16	2	3	1
17	2	3	2
18	2	3	3
19	3	1	1
20	3	1	2
21	3	1	3
22	3	2	1
23	3	2	2
24	3	2	3
25	3	3	1
26	3	3	2
27	3	3	3

VI. RESULT AND DISCUSSION

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

The signal-to-noise concept is closely related to the robustness of a product or process design. Robustness has to do with a product's ability to cope with variation and is based on the idea that quality is a function of good design. A robust design or product delivers strong "signal". It performs its expected function and can cope up with variations ("noise"), both internal and external. Since a good manufacturing process will be faithful to a product design, robustness must be designed into a product before manufacturing commences. According to Taguchi, if a product is designed to avoid failure in the field, then factory defects will be simultaneously reduced. There is no attempt to reduce variation, which is assumed to be inevitable, but there is a definite focus on reducing the effects of variation. "Noise" in processes will exist, but designing a strong "signals" into a product can minimize their effect. The dimensionless signal-to-noise ratio is used to measure controllable factors that can have such a negative effect on the performance of a design. It allows for the convenient adjustment of these factors. Provided that a process is consistent, adjustments can be conveniently made using the signal-to-noise ratio to achieve the desired target.

The signal to noise ratio (S/N ratio) was used to measure the sensitivity of the quality characteristic being investigated in a controlled manner. In Taguchi method, the term 'signal' represents the desirable effect (mean) for the output characteristic and the term 'noise' represents the undesirable effect (signal disturbance, S.D) for the output characteristic which influence the outcome due to external factors namely noise factors. The S/N ratio can be defined as:

S/N ratio

$$\eta = -10 \log (MSD) \quad (1)$$

Where, MSD mean-square deviation for the output characteristic.

The aim of any experiment is always to determine the highest possible S/N ratio for the result. A high value of S/N implies that the signal is much higher than the random effects of the noise factors or minimum variance. As mentioned earlier, there are three categories of quality characteristics, i.e. the-lower-the-better, the higher-the-better, and the-nominal-the-better. To obtain optimal resistance spot welding performance, the-lower-the-better quality characteristic for burr height must be taken.

Nominal is best, $\eta = -10 \log_{10}\sigma^2$ (2)

Smaller is better, $\eta = -10 \log [1/n\sum_{i=1}^{n} yi2]$ (3)

Where yi mean and σ standard deviation

B. Analysis Of Variance:

The main aim of ANOVA is to investigate the design parameters and to indicate which parameters are significantly affecting the output parameters. In the analysis, the sum of squares and variance are calculated. F-test value at 95% confidence level is used to decide the significant factors affecting the process and percentage contribution is calculated. Larger F – value indicates that the variation of the process parameter makes a big change on the performance. The analysis of variance (ANOVA) is applied in order to test the equality of several means, resulting in what process parameters (factors) are statistically significant. The results of ANOVA are presented in a table that displays for each factor (or interaction) the values of: SS: sum of squared deviations from the mean. For *n* values of y_i and the mean value The analysis of variance (ANOVA) of the effects of factors on the response variable by using MINITAB software is given as below. The ANOVA analysis with general linear model for calculating F- test value and percentage contribution of process parameters for burr height of Low Carbon Steel is shown in Table The response table for mean burr height and mean S/N ratio for each level is summarized and shown in tables. The Result of ANVOA is as shown in table VIII

C .Multi Objective Optimization Result Using Taguchi Method

In multi objective the overall SN ratio is known as multiple SN ratio is given as

$$\eta j = -10 \log_{10}(Yj) \quad (4)$$

$$Yj=\sum_{i=1}^{k} wiYij \quad (5)$$

$$Yij=Lij/Li \quad (6)$$

Where Yj is total normalized quality loss value, wi is weighting factor k is total no of quality, Yij is NQL for ith quality for jth trail. Lij is MSD for ith quality at jth trail and Li is max. Quality loss for ith quality

From Table IV quality loss value is calculated using Eqs.2 and 3.These quality loss value are shown in Table.V.The normalized quality total loss value is calculated using eqn 5 and shown in Table VI. The MSNR is calculated using eqn 4 and shown in table VII.

Table IV. Experimental data for Nugget diameter and Tensile shear strength

	Electrode force (kgf)	Current (KA)	Time (cycle)	Nugget diameter (mm)		T -S Strength (N)	
				ND-1	ND-2	TS-1	TS-2
1	300	9	12	2.61	3.78	4308.8	4309.74
2	300	9	14	2.98	3.57	5384.02	5385.42
3	300	9	16	2.79	3.69	5595.17	5595.95
4	300	9.5	12	3.29	3.89	6494.1	6495.52
5	300	9.5	14	3.81	4.06	7573.25	7572.21
6	300	9.5	16	3.91	4.22	7884.15	7885.29
7	300	10	12	4.45	4.87	8231.81	8232.55
8	300	10	14	4.64	4.91	8676.27	8676.99
9	300	10	16	4.9	5.13	8809.13	8808.35
10	325	9	12	3.4	3.84	6277.39	6278.37
11	325	9	14	3.2	3.52	6608.18	6607.7
12	325	9	16	3.74	3.91	6890.93	6892.07
13	325	9.5	12	3.74	4.25	7322.15	7323.57
14	325	9.5	14	3.82	4.04	8294.09	8295.35
15	325	9.5	16	3.7	4.02	8416.19	8417.59
16	325	10	12	3.93	4.17	8698.1	8697.04
17	325	10	14	4.23	4.68	9018.49	9018.01
18	325	10	16	4.46	4.96	9352.82	9353.44
19	350	9	12	4.91	5.36	5113.96	5115.38
20	350	9	14	5.24	5.68	7507.39	7508.27
21	350	9	16	5.76	6.42	7898.07	7899.21
22	350	9.5	12	6.23	6.57	4236.96	4238.54
23	350	9.5	14	6.28	6.48	6767.05	6768.53
24	350	9.5	16	6.82	7.13	6934.27	6933.01
25	350	10	12	7.03	7.41	7434.07	7434.77
26	350	10	14	7.38	7.61	8747.62	8748.46
27	350	10	16	7.57	7.9	8898.34	8897.46

Table V.Quality loss values for Nugget diameter and tensile shear strength

ExNo.	Nugget Diameter				Tensile Shear Strength			
	ND1	ND2	Mean	S.D	TS1	TS2	Mean	S.D
1	2.61	3.78	3.195	0.685	4309	4310	4309	0.448
2	2.98	3.57	3.275	0.174	5384	5385	5385	0.978
3	2.79	3.69	3.24	0.405	5595	5596	5596	0.298
4	3.29	3.89	3.59	0.18	6494	6496	6495	0.999
5	3.81	4.06	3.935	0.031	7573	7572	7573	0.535
6	3.91	4.22	4.065	0.048	7884	7885	7885	0.651
7	4.45	4.87	4.66	0.088	8232	8233	8232	0.275
8	4.64	4.91	4.775	0.037	8676	8677	8677	0.255
9	4.9	5.13	5.015	0.026	8809	8808	8809	0.299
10	3.4	3.84	3.62	0.097	6277	6278	6278	0.482
11	3.2	3.52	3.36	0.051	6608	6608	6608	0.111
12	3.74	3.91	3.825	0.015	6891	6892	6892	0.645
13	3.74	4.25	3.995	0.13	7322	7324	7323	1
14	3.82	4.04	3.93	0.024	8294	8295	8295	0.8
15	3.7	4.02	3.86	0.051	8416	8418	8417	0.989
16	3.93	4.17	4.05	0.029	8698	8697	8698	0.556
17	4.23	4.68	4.455	0.101	9018	9018	9018	0.115
18	4.46	4.96	4.71	0.125	9353	9353	9353	0.187
19	4.91	5.36	5.135	0.101	5114	5115	5115	1
20	5.24	5.68	5.46	0.097	7507	7508	7508	0.395
21	5.76	6.42	6.09	0.218	7898	7899	7899	0.641
22	6.23	6.57	6.4	0.058	4237	4239	4238	1.248
23	6.28	6.48	6.38	0.02	6767	6769	6768	1.102
24	6.82	7.13	6.975	0.048	6934	6933	6934	0.801
25	7.03	7.41	7.22	0.072	7434	7435	7434	0.24
26	7.38	7.61	7.495	0.027	8748	8748	8748	0.35
27	7.57	7.9	7.735	0.055	8898	8897	8898	0.391

Table VI. Normalized Quality loss values for Nugget diameter and Tensile shear strength.

Exp No.	Electrode force (kgf)	Current (KA)	Time (cycle)	ND Standard Deviation	TS Standard Deviation	ND Normaliz Quality loss	TS Normalzed Quality loss
1	300	9	12	0.6845	0.4484	1	0.3592
2	300	9	14	0.1741	0.978	0.2543	0.7836
3	300	9	16	0.405	0.298	0.5917	0.2387
4	300	9.5	12	0.18	0.9987	0.263	0.8001
5	300	9.5	14	0.0312	0.5354	0.0457	0.4289
6	300	9.5	16	0.048	0.6511	0.0702	0.5216
7	300	10	12	0.0882	0.2745	0.1289	0.2199
8	300	10	14	0.0365	0.2553	0.0533	0.2046
9	300	10	16	0.0264	0.2988	0.0386	0.2394
10	325	9	12	0.0968	0.4817	0.1414	0.3859
11	325	9	14	0.0512	0.111	0.0748	0.0889
12	325	9	16	0.0145	0.6452	0.0211	0.5169
13	325	9.5	12	0.1301	0.9999	0.19	0.801
14	325	9.5	14	0.0242	0.8002	0.0354	0.6411
15	325	9.5	16	0.0512	0.989	0.0748	0.7923
16	325	10	12	0.0288	0.5564	0.0421	0.4458
17	325	10	14	0.1013	0.1153	0.1479	0.0924
18	325	10	16	0.125	0.1868	0.1826	0.1496
19	350	9	12	0.1013	0.9999	0.1479	0.8011
20	350	9	14	0.0968	0.3951	0.1414	0.3165
21	350	9	16	0.2178	0.6408	0.3182	0.5133
22	350	9.5	12	0.0578	1.2482	0.0844	1
23	350	9.5	14	0.02	1.1016	0.0292	0.8825
24	350	9.5	16	0.048	0.8014	0.0702	0.642
25	350	10	12	0.0722	0.2398	0.1055	0.1921
26	350	10	14	0.0265	0.3496	0.0386	0.2801
27	350	10	16	0.0545	0.3913	0.0796	0.3135

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

Ex. 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	1	0.3592	0.5515	2.585
2	300	9	14	0.2543	0.7836	0.6248	2.043
3	300	9	16	0.5917	0.2387	0.3446	4.626
4	300	9.5	12	0.263	0.8001	0.639	1.945
5	300	9.5	14	0.0457	0.4289	0.314	5.031
6	300	9.5	16	0.0702	0.5216	0.3862	4.132
7	300	10	12	0.1289	0.2199	0.1926	7.153
8	300	10	14	0.0533	0.2046	0.1592	7.982
9	300	10	16	0.0386	0.2394	0.1791	7.468
10	325	9	12	0.1414	0.3859	0.3125	5.051
11	325	9	14	0.0748	0.0889	0.0847	8.721
12	325	9	16	0.0211	0.5169	0.3682	4.339
13	325	9.5	12	0.19	0.801	0.6177	2.092
14	325	9.5	14	0.0354	0.6411	0.4594	3.378
15	325	9.5	16	0.0748	0.7923	0.5771	2.388
16	325	10	12	0.0421	0.4458	0.3247	4.886
17	325	10	14	0.1479	0.0924	0.1091	9.623
18	325	10	16	0.1826	0.1496	0.1595	7.971
19	350	9	12	0.1479	0.8011	0.6051	2.181
20	350	9	14	0.1414	0.3165	0.264	5.784
21	350	9	16	0.3182	0.5133	0.4548	3.422
22	350	9.5	12	0.0844	1	0.7253	1.395
23	350	9.5	14	0.0292	0.8825	0.6265	2.031
24	350	9.5	16	0.0702	0.642	0.4705	3.275
25	350	10	12	0.1055	0.1921	0.1661	7.796
26	350	10	14	0.0386	0.2801	0.2077	6.826
27	350	10	16	0.0796	0.3135	0.2433	6.138

Table VIII. Result of ANOVA

Source	DF	Seq SS	Adj SS	Adj MS	F-ratio (F)	P-value (P)	% contribution (%C)
A	2	7.687	7.687	3.843	1.39	0.304	4.42
B	2	91.527	91.527	45.763	16.53	0.001	52.69
C	2	18.694	18.694	9.347	3.38	0.087	20.76
A*B	4	18.56	18.56	4.64	1.68	0.248	10.68
B*C	4	3.264	3.264	0.816	0.29	0.873	1.88
A*C	4	11.834	11.834	2.959	1.07	0.432	6.81
Error	8	22.154	22.154	2.769			
Total	26	173.721					97.25
S = 1.66409 R-Sq = 87.25% R-Sq(adj) = 58.55%							
All F-ratios are based on the residual mean square error.							

C. Confirmation Test

The final step is verification experiment to validate that the optimum conditions suggested by the matrix experiment gives the projected improvement. The confirmation experience is performed by conducting a test with specific combination of factors and levels previously evaluated.

After determining optimum the conditions, a new experiment was conducted by optimum level of the welding parameter. (A2B3C2).

The improvement in multiple S/N ratio from initial parameter (A2B3C2.) setting to the optimal a parameter (A2B3C2) is found to be 9.623dB.

The result shows considerable improvement in both the quality characteristics with multi response optimization used, as compared the initial value of radius weld Nugget and Tensile Strength. Confirmation experiments are also compared with predicted values.Result of confirmation test compared to predicted values Tensile strength and nugget diameter. using developed model and percentage error are also shown in table. Percentage error for Tensile strength is 11.55% and Nugget diameter is 1.16%. Respectively

Table IX Result of confirmation experiment

	Optimal Process Parameter		
	Prediction	Experimental	Percentage
Level	A2B3C2	A2B3C2	Error
Tensile Strength(N)	7976.885	9118.25	11.55%
Nugget Diameter (mm)	4.4031823	4.403	1.16%

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

From the result of ANOVA it is clear that the current is most important influencing parameter in resistance spot welding process with (% contribution 52.69%).The second influencing factor is time in Cycle with (% contribution 20.76%) and the third influencing factor is electrode force with (%contribution 4.42%) and interaction (A*B) is significant with (%contribution 10.68%).

Hence we obtained the optimum process parameter as A2 B3 C2 for nominal nugget diameter and maximum Tensile strength.

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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REFERENCES

[1] A. K. Panday, M. I. Khan, K. M. Moeed"Optimization of resistance spot welding parameter by using Taguchi method"International Journal of Engineering and Technology,Vol.5,No 02,2013,pp234-239

[2] Norasiah Muhammad, Yupiter HP Manurung, Mohammad Hafidzi, Sunhaji Kiyai Abas, Ghalib Tham,M.RidzwanAbd.Rahim"A Quality Improvement Approach for Resistance Spot Welding using Multi-objective Taguchi Method and Response Surface Methodology, International Journal on Science and Engineering, Vol.02,2012,No.3 pp17-22

[3] Hamid Eisazadeh,MohsenHamedi, AyobHalvaee"New Parametric study of nugget size in resistance spot welding process using FEM".Advanced Welding & Joining Department, Korea Institute of Industry technology, 2011,pp925 – 930

[4] A.G.Thakur, V.M.Nandedkar, Application of Taguchi Method to Determine Resistance spot welding conditions of Austenitic Stainless Steel AISI 304, Journal of Scientific& Industrial Research ,vol 69,Sept 2010, pp 680-683

[5] UgurEsme,"Application of Taguchi method for Optimization of resistance spot Welding process" The Arabian journal of science and Engineering, Vol34, No 2B, 2009, pp521-52

[6] AslanlarS,OgurA,Ozsarac U, Ilhan E" Welding time effect on mechanical properties of automotive sheets in electrical resistance spot welding" Materials and Design 2008, 29,pp1427–1431.

[7] Sumit Chaudhary, Vipin Kumar Sharma, "Taguchi Analysis Of Tensile Strength Of Resistance Spot Welding " International Journal on enhanced research in science technology & engineering,vol.3 No.10,2014 ISSN 2319-7463 pp 217-221

[8] F.Khodabakhshi M.Kazeminzhad ,A.H.Kokadi" Mechanical Properties And Microstructure Of Resistantly Spot Welded Deform Low Carbon Steel"Material Science and Engineering,2011 pp 237-245

[9] P.S.Wei T.H.Wu" Electrical Contact Resistance Effect On Resistance Spot Welding" International Journal On Heat And Mass Transfer 2012 pp3316-3324

[10] S.Alsandar A.Ogur U Ozsarac"Welding Time Effect On Mechanical Properties Of Automotive Sheet In Electric Resistance Spot Welding "Material And Design 2008,pp1427-142

Swati A Jadhav was born in nashik City, in 1991.She received the B.E. degree in mechanical engineering from the University of Pune, Maharashtra, in 2013 and pursuing ME Design degree in mechanical engineering from Pune University at SNDCOE&RC, Yeola, Maharashtra.

Dr. Venkatesh M. A. received B.E in Mechanical. and M.Tech. in production, & Ph.D. in Mechanical.

He has been working as Principal of S.N.D.C.O.E &R.C, Yeola, Maharashtra. He has 30 years of teaching experience. He has published 10 national papers and 5 international paper.