National Journal of Multidisciplinary Research and Development
ISSN: 2455-9040; Impact Factor: RJIF 5.22
Received: 06-01-2019; Accepted: 09-02-2019
www.nationaljournals.com
Volume 4; Issue 1; January 2019; Page No. 87-90

Multi objective optimization of spot welding process parameters using composite desirability function method

Shweta Sharma[1], Raghav Singh Dhaker[2], Nidhi Sharma[3]
[1, 2] Department of Mechanical Engineering, RIET, Jaipur, Rajasthan, India
[3] Greater Noida Institute of Technology, Noida, Uttar Pradesh, India

Abstract
Spot welding is a process to joint two material using resistance heat developed by electrical resistance in these pieces. This method us generally used in automobile industry to improve its productivity. In present research study three process parameters are selected for optimization of response parameters developed by spot welding technique. The three factors are peak voltage, welding time and welding cycle. Each factor has three levels. The experiment table is generated using Taguchi method. The orthogonal array developed for this research work is L9. In present research work Al alloy (7475-T761) used for joining the two pieces. All pieces are cut as per standard provided by various research papers. Two response parameters are selected for this research study which is tensile strength and micro hardness of joint pieces. In present research work signal to noise ratio analysis is performed for both response parameters. After S/N ratio analysis, optimal solution calculation is performed using Taguchi analysis and Roy formulation technique. In present research work model equations are also developed and then Multi objective optimization is also performed for this research work.

Keywords: spot welding, DOE, taguchi method, ANOVA analysis, CD function optimization

Introduction (Literature Review)

The welds are finished utilizing the Resistance Spot Welding (RSW) process which is finished by a PC controlled mechanical welder. The utilization of RSW on lightweight aluminum composite is expanding [1, 2]. RSW is a rapid joining procedure broadly used to join thin shell congregations in car fabricating tasks. It is a vital process to guarantee solid auxiliary car bodies utilizing lightweight materials to spare both energy and normal assets [3]. The aluminum compound material is a low thickness material with high mechanical properties which is expected to be broadly utilized later on to somewhat supplant steel which is as of now the essential creation material in cars [4]. The 6061-T6 aluminum alloy is of light weight and has noteworthy mechanical properties which are of enthusiasm for this research.

The weld nature of the RSW process has been a critical issue for the car business. Manual computation of welding parameters, administrator experience, and expert aptitude in changing the parameter settings has not been reliably precise or right. The measurements have beforehand been not able be affirmed against ideal parameters [5]. The parameter settings of each welding machine have been troublesome on the grounds that there are numerous touchy variables. This has prompted the mind-boggling expense of requiring numerous examples of the development material to be tried to accomplish sufficient trial results to determine ideal parameter esteems. Each car body plant has in excess of 200 welding machines.

Objective of Research Study

The aim of present research study is to develop the optimum model for process parameters of spot welding method using Taguchi method. The material for joining the pieces is made of Al-alloy, which is kept constant for this research work. The response is measured parameters using computer contorted measuring devices.

CD based Multi objective optimization is performed for this research study using MINITAB software. Model equations for both responses tensile strength and micro hardness parameters respectively.

Experimental Setup

In present research work actual working model of SPOT welding is used which is show in Fig 1. This spot welding machine is installed at college welding shop. The maximum limit of this spot welding machine is lately termed as technical specifications of spot welding machine.

Fig 1: working model of spot welding machine

The standard design of cut for test piece made of Al-alloy is shown in Fig 2. These pieces are at initial stage and the final joined pieces of test pieces after spot welding is present in Fig 3.

Fig 2: Test pieces (After Spot welding)

Factor and Levels

In present research work three factors are selected which are voltage, welding time and welding cycle required for joining the two similar material test pieces. The factor and levels are present in table 1 for present research work.

Table 1: factor and Levels

Process Parameters	Symbol	Unit	Level 1	Level 2	Level 3
Voltage	A	Volt	220	225	227
Weld Time	B	Sec	2	3	4
cycle	C	NA	1	2	3

As seen in table 1, the levels are set as per machine technical specifications and pilot experiment done before the main experiments. After factor and levels selection time to generate experiment table. For this task design of experiment (DOE) method called Taguchi method is used which is present in next section of this research paper. Experiment table generated by Taguchi method is called orthogonal array. This method generates minimum experiments required for field analysis. So it is a robust technique for production importance.

Orthogonal Array

As discuss in previous section Taguchi method is used for present research study for three factor and three levels. So L9 orthogonal array is developed and present in table 2 for current research work.

Table 2: L9 orthogonal array

Exp. No.	A (Voltage)	B (Weld Time)	C (Weld Cycle)
1	220	2	1
2	220	3	2
3	220	4	3
4	225	2	2
5	225	3	3
6	225	4	1
7	227	2	3
8	227	3	1
9	227	4	2

As seen in table 2, total nine experiments are required for this research study. Each experiment has unique level combination and this is the quality of this method.

Result and Discussion

After development of experiment table using Taguchi method which is present in table 3 now time to require the response data recording which is present in table 3 for tensile strength and micro hardness respectively.

Table 3: Response strength and micro hardness for L9 experiment table

Exp. No.	A (Voltage)	B (Weld Time)	C (Weld Cycle)	Tensile Strength	Micro Hardness
1	220	2	1	33.5	88.02
2	220	3	2	44.00	61.95
3	220	4	3	65.18	101.87
4	225	2	2	49.65	90.70
5	225	3	3	62.27	137.71
6	225	4	1	69.35	188.81
7	227	2	3	28.58	84.22
8	227	3	1	57.55	84.75
9	227	4	2	63.56	86.25

Signal to noise ratio analysis

The results for S/N ratio analysis for both responses are present in table 4 and table 5 respectively. For both responses the option of S/N ratio is set “larger is better” due to their importance.

Table 4: S/N ratio result for Tensile Strength

Exp. No.	A (Voltage)	B (Weld Time)	C (Weld Cycle)	Tensile Strength	S/N ratio
1	220	2	1	33.5	30.5009
2	220	3	2	44.00	32.8691
3	220	4	3	65.18	36.2823
4	225	2	2	49.65	41.9312
5	225	3	3	62.27	35.8856
6	225	4	1	69.35	36.8209
7	227	2	3	28.58	29.1212
8	227	3	1	57.55	35.2009
9	227	4	2	63.56	36.0637

As seen in table 5 the S/N ratio analysis for tensile strength is present in this section. The best ranked factor for “larger is better” is set for voltage of spot welding process whereas least factor is set for welding time required to joint test pieces. The same results are present in Fig 3.

Table 5: Rank identification for tensile Strength using S/N ratio

Level	A	B	C
1	33.22	33.85	34.17
2	38.21	34.65	36.95
3	33.46	36.39	33.76
Delta	5.00	2.54	3.19
Rank	1	3	2

Table 6: S/N ratio result for Micro Strength

Exp. No.	A (Voltage)	B (Weld Time)	C (Weld Cycle)	Micro Strength	S/N ratio
1	220	2	1	88.02	38.8916
2	220	3	2	61.95	35.8408
3	220	4	3	101.87	40.1609
4	225	2	2	90.70	39.1521
5	225	3	3	137.71	42.7793
6	225	4	1	188.81	45.5205
7	227	2	3	84.22	38.5083
8	227	3	1	84.75	38.5628
9	227	4	2	86.25	38.7152

As seen in table 6 the S/N ratio analysis for micro hardness is present in this section. The best ranked factor for "larger is better" is set for voltage of spot welding process whereas least factor is set for welding time required to joint test pieces. The same results are present in Fig 4.

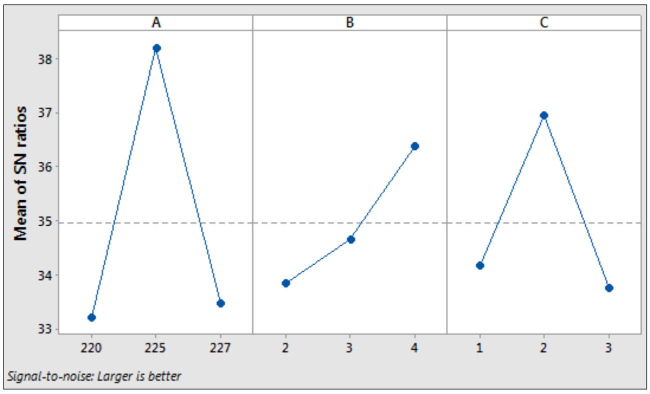

Fig 3: S/N ratio for Tensile Strength using Larger is better option

Table 7: Rank identification for Micro Hardness using S/N ratio

Level	A	B	C
1	38.30	38.85	40.99
2	42.48	39.06	37.90
3	38.60	41.47	40.48
Delta	4.19	2.61	3.09
Rank	1	3	2

Both ures 3 and 4 represent Signal to noise ratio analysis and the same ures are used for finding optimal solution for both responses using individual optimization techniques which is developed by Taguchi Method. The optimal solution is present in table 8.

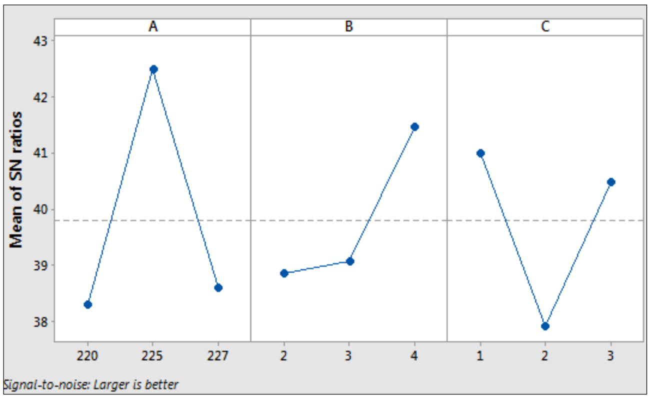

Fig 4: S/N ratio for Micro Hardness using Larger is better option

Table 8: Optimal solution for both responses

Response	A (Voltage)	B (Weld Time)	C (Weld Cycle)
Tensile Strength	225	4	2
Micro hardness	225	4	1

Multi Response Optimization (CD Function Optimization)

Two model equations are developed for both responses and present in this section after that Multi objective optimization is performed for both.

$$TS = -182831 + 1630\,A - 1641\,B + 3207\,C - 3.628\,A*A + 23.51\,B*B - 18.17\,C*C + 6.579\,A*B - 13.94\,A*C$$

$$MH = -271067 + 2428\,A + 1195\,B - 1963\,C - 5.432\,A*A + 3.676\,B*B + 29.32\,C*C - 5.277\,A*B + 8.166\,A*C$$

CD function optimization is performed and the values of this function are present in table 9.

Table 9: CD function values for both responses

Exp. No.	A (Voltage)	B (Weld Time)	C (Weld Cycle)	Tensile Strength	Micro Hardness	CD Function
1	220	2	1	33.5	88.02	0.102455
2	220	3	2	44.00	61.95	0.000000
3	220	4	3	65.18	101.87	0.345792
4	225	2	2	49.65	90.70	0.476054
5	225	3	3	62.27	137.71	0.457035
6	225	4	1	69.35	188.81	0.650597
7	227	2	3	28.58	84.22	0.000000
8	227	3	1	57.55	84.75	0.232499
9	227	4	2	63.56	86.25	0.263750

The optimum solution is present for both responses are present here and the one unique solution is following.

MH	TS	Composite				
Solution	A	B	C	Fit	Fit	Desirability
1	223.09	4	3	176.97	87.27	0.743329

Conclusion

It is observed that SN ratio analysis for both response show better analysis for factor rank which is preset for both responses in table 10.

Table 10: Rank identification for both responses

Response	A (Voltage)	B (Weld Time)	C (Weld Cycle)
Strength	1	3	2
Hardness	1	3	2

The optimal solution for both responses is present in table 11 for present research work.

Table 11: Optimal solution for both responses

Response	A (Voltage)	B (Weld Time)	C (Weld Cycle)
Tensile Strength	225	4	2
Micro hardness	225	4	1

The model equations for both responses are present here. The equations are verified by using ANOVA analysis.

$$TS = -182831 + 1630\,A - 1641\,B + 3207\,C - 3.628\,A*A + 23.51\,B*B - 18.17\,C*C + 6.579\,A*B - 13.94\,A*C$$

$$MH = -271067 + 2428\,A + 1195\,B - 1963\,C - 5.432\,A*A + 3.676\,B*B + 29.32\,C*C - 5.277\,A*B + 8.166\,A*C$$

CD function based optimization is present for this research work and the final results generated by using CD function is here

				MH	TS	Composite
Solution	A	B	C	Fit	Fit	Desirability
1	223.09	4	3	176.97	87.27	0.743329

References

1. Huh H, Kang W. Electrothermal analysis of electric resistance spot welding processes by a 3-D finite element method," Journal of Materials Processing Technology. 1997; 63(1-3):672-677.
2. Li W, Cheng S, Hu SJ, Shriver J. Statistical investigation on resistance spot welding quality using a two-state, sliding level experiment. Journal of Manufacturing Science and Engineering, Transactions of the ASME. 2001; 123(3):513-520.
3. Khan JA, Xu L, Chao YJ, Broach K. Numerical simulation of resistance spot welding process, Numerical Heat Transfer Part A: Applications. 2000; 37(5):425-446.
4. Zhu J, Li L, Liu Z. CO2 and diode laser welding of AZ31 magnesium alloy, Applied Surface Science. 2005; 247(1-4):300-306.
5. Lin HL, Chou T, Chou CP. Optimation of resistance spot welding process using Taguchi method and a neural network, Experimental Techniques. 2007; 31(5):30-36.
6. Weiss KD. Paint and coatings: a mature industry in transition, Progress in Polymer Science. 1997; 22(2):203-245.
7. Deng X, Chen W, Shi G. Three-dimensional finite element analysis of the mechanical behavior of spot welds. Finite Elements in Analysis and Design. 2000; 35(1):17-39.
8. Lin SH, Pan J, Tyan T, Prasad P. A general failure criterion for spot welds under combined loading conditions. International Journal of Solids and Structures. 2003; 40(21):5539–5564.