OPTIMIZATION RESISTANCE SPOT WELDING PARAMETERS BY TAGUCHI METHOD TO IMPROVE WELD QUALITY

M.Narsimha
Asst.Prof, Dept of Mechanical, Mahaveer Institute of Science and Technology Hyderabad.

Faiz Ali
Asst. Prof, Dept. of, Dept of Mechanical, Mahaveer Institute of Science and Technology Hyderabad.

Abstract:
Almost a hundred years ago, the resistance spot welding process was introduced. Since then, in almost all industries that need to unite sheet metal parts together, it has found extensive use. Resistance spot welding (RSW) is commonly used in the car industry for its low cost, high speed, simple mechanism and automation applicability.

In particular, its use is of great significance in the automotive industry, as each vehicle requires approximately 5000 spot welds in its assembly process. This project work discusses the optimization of different resistance spot welding parameters in order to increase the efficiency of welds. The experimental studies to be carried out for the joining of two DPs under different welding power, welding current and welding timeIn this investigation the quality characteristics (direct tensile strength and shear tensile strength) has been considered. D.P(dual phase) steel is used in this analysis as a sheet metal works piece.

In order to extract the experiment data in a controlled way for Taguchi statistical analysis, L9 Orthogonal Array is to be used. In this study, three levels are considered for each process parameter. The experiments will be conducted as per the pattern of L9 Orthogonal Array. The optimum welding parameter combination was obtained by using analysis of signal to noise(S/N) ratio. Analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments to determine the percentage contribution of each parameter against a stated level of confidence

The experiment results reveal that the most significant spot-welding parameters that are affecting the strength of the spot-welded joint both in 1.5mm and 2mm.The optimum spot-welding parameters were established, and they are confirmed by using validation experiments.

INTRODUCTION

Resistance spot welding (RSW) is widely used for joining purposes due to its robustness, speed, flexibility and low cost operation, especially in the automotive industry. These benefits come from its operating theory, which uses the idea of electrical resistance. Between two electrodes, the metal to be joined is positioned and pressure applied and the current turned on. Basically, the RSW process consists of four stages: the squeeze cycle, the welding cycle, the hold cycle and the off cycle. The squeeze cycle is a phase in which the upper electrode is brought into contact with the sheets to be welded and the welding area is exerted by force. While the weld cycle is a phase during which the current is switched on and the sheet interface is immune to current flow, creating a nugget. The hold period is when the current is shut off and allows the fully grown nugget to cool slowly and solidify under constant pressure. The final time during which the electrode is raised from the welded sheets is the off-stage. Present, time electrode power, contact resistance and sheet material are major variables regulating this process. The performance is best measured by nugget size and joint strength. The regulation of welding parameters plays an important role in welding efficiency. It is therefore necessary to select the parameters of the welding process to obtain the optimum weld nugget size. The unique welding machine and setting, however, does not guarantee this Different optimization methods can be implemented to define the desired output variables by creating mathematical models to determine the relationship between the input parameters and output variables in order to solve this problem.

Almost a hundred years ago, the Resistance spit welding process was introduced. Since then, in almost all industries that need to join sheet metal components to get in, it has found extensive use because of its low cost, high speed, simple mechanism, and automation applicability. In particular, its use is of great significance in the automotive industry, as each vehicle requires approximately 5000 spot welds in its assembly process. Taguchi methods are statistical methods developed by Genichi Taguchi to increase the quality of manufactured products and, more recently, have applied to engineering (Rosa et al. 2009), biotechnology (Rao et al. 2008, Rao et al. 2004), marketing and development (2004), The aim and improvements brought about by Taguchi techniques were welcomed by professional statisticians, especially by Taguchi's creation of models for studying variation. The Taguchi technique is an important method for developing structures of high quality. The L18 mixed orthogonal table in the Taguchi quality design(Ross1988) has been used to assess the experimental efficiency in order to improve the experimental effectiveness. significant factors.In the experiments , we select three influential welding parameters, such as welding current, welding force, welding time , welding time, each of which has three different levels(high, medium and low levels). His concepts produced a unique and powerful quality improvement technique that differs from traditional practices. He Manufacturing processes have been produced that are "robust" or indifferent to daily and seasonal environmental changes, machine wear, and other external variables. As the primary means of improving efficiency, the Taguchi approach to quality engineering puts great emphasis on mixing variability. The concept is to design products and processes whose performance is not impacted by external conditionsVia the use of experimental design, and to build this in during the development and design process. The approach requires a collection of tables that allow the analysis of key variables and interactions in a minimal number of trials. The Taguchi approach uses the principle of Fundamental functionality, which will make it simpler for individuals to define the common objective because it will not vary from case to case and will provide a robust standard for circumstances that change widely and regularly. It is also pointed out that the Taguchi Process is also very consistent with the approaches to human-centered quality assessment that are coming up.

It involves the use of a strategically constructed experiment to evaluate the best design, exposing the method to varying degrees of design parameters. In the early years of the 20th century, experimental design techniques were developed and have since been widely studied by statisticians, but they were not easy for clinicians to use (Phadke 1989). The approach of Taguchi to the design of experiments is easy to follow and apply to users with minimal statistical knowledge; it has therefore gained broad popularity in the engineering and science community.

Some work has been done in the RSW framework on different aspects of modeling and process optimization. An investigation into the optimization and impact of welding parameters on the tensile shear strength of spot-welded SAE 1010 steel sheet using the Taguchi method was reported by Ugur Esme, A.G.Thankur and V.M.Narndedkar proposed a systematic approach to evaluating the effect of process parameters on tensile shear SAE 1010 steel sheet spot-welded strength using Taguchi technique, A.G.Thankur and V.M.Narndedkar proposed a systematic method to assess the impact of process parameters on RSW tensile shear strength of RSW austenitic stainless AISI 3040 steel, using the Taguchi process. For the effect of spot welding parameters on the strength of spot-welded aluminum sheets, S.M.Darwish and S.D.AL-Dekhial proposed Response Surface Methodology (RSM); and Hefin Rowland and Jiju Antony presented the use of Taguchi's loss function analysis and In order to discover the key process parameters that affect the tensile strength of welded joints, RSM to a Spot welding process.

Optimization of welding parameters on tensile shear strength and direct tensile strength in the method of resistance spot welding (RSW) in the current research. Under varying welding current, welding time and electrode force, experimental studies were performed. Most of the studies centered on the modeling and optimization of single quality characteristics based on past analysis, which may be Simultaneous Production of deterioration of other features. In the study of the S/N ratio, there are three types of consistency characteristics that are lower-the-better, higher-the-better and nominal-the-better. The higher-the-better is selected in this study.

LITERATURE REVIEW

Optimization of welding parameters in the resistance spot welding (RSW) process in the current research on tensile shear strength and direct tensile strength. Under varying welding current, welding time and electrode force, experimental studies were performed. Most studies focused on modeling and improving single quality characteristics based on previous research, which could deteriorate other characteristics. Because the main goal of the production process is often to increase a product's overall quality, many quality characteristics need to be optimized simultaneously. In the study of the S/N ratio, there are three types of consistency characteristics that are lower-the-better, higher-the-better and nominal-the-better. The higher-the-better is chosen in this study,

Project work deals with the Resistance spot welding, which has been carried out in order to test the properties of the weld of D.P Steel. In the automotive industry, resistance spot welding is a very common joining procedure. It is cost-efficient and offers a very high rate of output of components of the automotive body. Spot welds are very prone to different types of loading conditions, despite this advantage. They are also prone to failure, if not correctly built, During their period of service. The actions of spot welds and their failure characteristics are therefore very important to understand. This project work deals with the optimization of different resistance spot welding parameters to improve the efficiency of welding. The experimental studies to be performed to connect two DP steel sheets under varying welding power, welding current and welding time. The consistency characteristics (direct tensile strength and shear tensile strength) were taken into account in this investigation.

In this study, DP (Dual Phase) steel is used as a piece of sheet metalwork. Because of its strong mechanical properties, DP steel has been commonly used in the automotive industry to minimize weight and improve safety. Due to high performance and low costs, RSW is still the first choice to join DP steel in the auto body assembly 7 rows. For the extraction of the experimental For Taguchi statistical analysis, L9 Orthogonal Array data should be used in a managed manner. There are levels considered for each parameter of the method in this analysis. The experiments will be carried out according to the L9 Orthogonal Array pattern. By using signal to noise(S/N) ratio analysis, the optimum welding parameter combination was obtained. Variance Analysis (ANOVA) is the most widely used statistical treatment to assess the percentage contribution of each parameter against the defined level of trust in the results of the experiments.

Ugur Esme(1) Study on the influence and optimization of welding parameters on tensile shear strength in the process of RSW (Resistance Spot Welding). Various electrode forces, welding currents, electrode diameters, and welding times were used to perform the experimental tests. By using variance analysis (ANOVA), the degree of significance of the welding parameters on the tensile shear strength is calculated. The optimal combination of welding parameters was obtained. By using signal-to-noise(S/N) ratio analysis. The confirmation tests suggested that by using the Taguchi system, it is possible to increase tensile shear strength significantly. The experimental results demonstrated the validity of the Taguchi method used in the resistance spot welding process for improving welding efficiency and optimizing welding parameters.

Research by Norasiah Muhammed et al(2) deals with an approach developed by resistance spot welding to optimize the weld region (RSW). At the same time, this approach considers the multiple quality function (weld nugget and heat affected area) using the Multi-objective Taguchi Method (MTM). The experimental research was carried out under various currents of welding, Welding, and holding times for joining two 1.0 mm low carbon steel sheets. The welding parameter setting was calculated using the experimental design method of Taguchi and the orthogonal array of L9. Using multi-signal to noise ratio (MSNR) and the essential level of welding parameters, the optimum welding parameter for multi-objective was obtained. was further analyzed using analysis of variance (ANOVA). A confirmation experiment was conducted at an optimal condition for observing the accuracy of the developed response surface model. Based on the confirmation test results, it is found out that the developed model can be effectively used to predict the size of the weld zone, which can improve the welding quality and performance is RSW.

H-L Lin et al. (3) The efficiency of the resistance spot welding (RSW) process is influenced by several parameters. In the low-carbon welding process, The Taguchi method was used for the initial optimization of the RSW process parameters of the sheet steels of the auto body. To improve the interactions between the welding process parameters and the tensile shear strength of each specimen, a neural network with the Levenberg-Marquardt back-propagation algorithm was then adopted. The optimal parameters of the RSW process were calculated using welding current, hold time and weld time to simulate the process parameters..

Thanks, et al. (4) presents an experimental analysis using the Taguchi method to maximize the Tensile Shear (T-S) strength of RSW for Galvanized Steel. Due to the propensity of zinc coating electrode alloying, RSW of galvanized steel is often difficult. The experimental studies were performed under various welding currents, Period of welding, electrode diameter and force of the electrode. In order to determine strength to noise (S/N ratio), analysis of variance (ANOVA) and F test value, Taguchi quality design principles of the L27 orthogonal array were used to determine the most relevant parameters affecting the performance of the spot weld. The experimental results verified the validity of the Taguchi system used in the RSW process to boost welding efficiency and optimize welding parameters. The confirmation test suggested that it is possible to substantially increase tensile shear strength.

S.V. The Sapakal et al (5) effect of welding parameters such as welding current, welding voltage, welding velocity during welding on MS C20 material penetration depth. To acquire the data, a plan of experiments based on the Taguchi technique was used. An Orthogonal series, a ratio of signal to noise (S/N) and review Variance (ANOVA) is used to investigate and refine the welding parameters of the MS C20 material's welding characteristics. Finally, the conformance tests were carried out In the study of penetration, comparing the predicted values with the experimental values confirms its efficacy.

D.S.Sahota, et al (6) on the effects of parameters on ASS316 material resistance spot welding. To study the significance of process parameters, i.e., current, electrode force and weld cycles, to improve material hardness percentage. From the results, it is clear that parameters significantly affect both the mean and the variation in the percentage improvement of the ASS316 material hardness values. The S/N ratio analysis suggests that the third weld current level, the third weld cycle level and the third electrode force level are the best levels for the maximum percentage.

Improvement in ASS316 work-piece hardness in spot welding operation. This research helps us to find the optimum values for the three Resistance Spot Welding parameters for the ASS316 sheet thickness of 0.5 mm. The average value of the response feature obtained through the confirmation experiment is within the confidence level of 95 percent.

A.K.Pandey, et al. (7) Optimization of different resistance spot welding parameters. Under varying pressure, welding current, pressure, and welding time, the experimental studies were done. The quality characteristic (tensile strength) was considered using the Taguchi method in this investigation.

Joseph I. Achebo (8) by suggesting alternative, uniquely crafted and improved process parameters to replace its existing signature welding protocol, the inadequacies of existing GMAW welding process parameters used by the investigated industrial firm in its signature welding protocol,, Achieving greater UTS by doing so. Thereafter, these proposed process parameters were subjected to reported literature, after which optimization was achieved using the Taguchi Method. An optimal process parameter of A3BC1D1, which consists of welding current, from the analysis carried out by applying the Taguchi Method 240A, 2.0 mins of welding time, 0.0062m/s welding speed, and 33V welding voltage were suggested. These optimum parameters have been found to improve the S/N ratio by 2.32dB and the existing process parameters by 1.11 times over the UTS. This research clarifies a step-by-step approach to the application of the Taguchi Method. The study also shows that the use of the Taguchi method has improved successfully on existing process parameters, giving a more efficient signature welding protocol to the industrial firm.

Norasiah Muhammad, et al (9) Resistance Spot Welding (RSW) weld zone development focusing on weld nuggets and heat-affected zones (HAZ). Using a general 24 factorial design augmented by five center points, the effects of four variables, namely weld current, weld time, electrode force and hold time, were studied. The results of the analysis showed that all the variables selected except hold time exhibit a significant effect on weld nugget radius and HAZ size. In Response Surface Methodology (RSM), the optimization of the welding parameters (weld current, weld time and electrode force) to normalize weld nuggets and to minimize HAZ size was then carried out using Central Composite Design (CCD) and the optimal parameters were determined. A regression model was developed for weld nugget radius and HAZ size, and its adequacy was assessed. The experimental results obtained under optimal operating conditions were then compared with the expected values and were found to agree with each other satisfactorily..

A systematic approach to evaluating the effect of process parameters on indentation as a primary & initial measure of weld quality and subsequently tensile strength nugget diameter and penetration is used by Niranjan Kumar Singh et al (10). An attempt has been made to select essential welding parameters such as welding current, welding current, and welding Update to achieve the goal. Using quality instruments, credible literature and on scientific grounds, loop, keep time & cool cycle. Experiments were carried out on the chosen parameters according to the Taguchi method and the levels for the parameters were set. There are four considerations in the experiment, and all variables are at two stages. In order to provide a broad range of study and variability over time, L32 Orthogonal Experiments are performed on collection (OA). Optimum welding parameters established by the Taguchi method have improved indentation, confirming the nugget size, tensile strength and penetration value in turn. Variance analysis (ANOVA) and the F-test were used to determine the most critical parameters influencing the parameters of spot welding.

"Mustafa Kemal Bilici (11) "Use of the Taguchi method to optimize polypropylene friction stir spot welding parameters. In accordance with the Taguchi orthogonal table L9, the experimental tests were carried out on the basis of combinations of process factors such as instrument rotation speed, plunge depth and dwell time at the beginning of weldingAnd in a randomized manner. In various cases of weld power, the findings indicate coherence between the numerical prediction and experimental observations. To obtain the effect of the friction stir spot welding parameters on the weld power, this signal-to-noise ratio and the study of variance were used. Finally, from the initial welding parameters to the op, the increase in the weld power

Hefin Rowland, (12) 'Application of experimental design for process optimization' also shows the use of the Taguchi technique in the UK industry in December 200. The paper also explains the use of the Taguchi system for optimizing the manufacturing process to maintain a spot welding process..

'Optimization of various welding processes' K.Y.Benyounis (13) The welding input parameters play a very important role in deciding the efficiency of the welding joint. In general, all welding methods are used to obtain a welded joint with the desired parameters of the weld bead, with excellent mechanical properties and minimal distortion. In order to decide the welding input parameters that contribute to the desired weld quality, a mathematical relationship between the welding process input parameters and the output variables of the weld joint is now commonly used for a few days in the application of experiment design (DOE), evolutionary algorithms and computational network. A systematic literature analysis of the application of these techniques in the field of welding has been presented herein. This analysis was categorized according to the weld performance characteristics, i.e., the geometry of the bead and the mechanical properties of the welds..

EXPERIMENTAL PROCEDURE

Spot welds' mechanical properties, particularly strength under quasi-static, impact, and fatigue loading conditions, are of paramount importance for vehicle design and manufacturing. A considerable amount of effort has been placed on predicting spot weld performance under idealized, lab- testing conditions. Because of the combination of high strength and ductility, for future automotive applications, dual-phase steels are being actively investigated. In the ferrous microstructure, the term 'dual-phase steel' refers to the predominance of two phases, the relatively soft body-centered-cubic alpha-ferrite, and the relatively hard body-centered-tetragonal martensite. The beneficial ferrite+ martensite mixture in dual-phase steels is usually produced after annealing in the so-called intercritical temperature range, where ferrite and austenite are stabilized. Annealing is immediately followed by rapid cooling (or quenching) to affect a displace transformation Austenite to Martensite.

Chemical composition of steel DP600 in *weight percentage*

C	MN	Cr	Mo	Ni	Ti	V	Al	Si	S	P	B	N	O
0.11	1.5	0.27	<0.005	0.02	<0.005	0.06	0.06	0.01	<0.003	0.02	<0.001	0.007	0.0028

3.2 SELECTION OF SPOT WELDING PARAMETERS AND THEIR RATE OF RESISTANCE

Resistance spot Welding parameters	Units	symbol	levels		
			Level 1	Level 2	Level 3
Welding current	KA	A	3.0	3.5	4.0
Welding force	KN	B	2	3	4
Welding time	Sec	C	1	2	3

Table 3.2. selection of resistance spot welding

3.3 ORTHOGONAL ARRAY (OA) COLLECTION FOR THE EXPERIMENT

Once the degrees of freedom required are known, selecting a suitable orthogonal array to match the particular task is the next step. Basically, for the orthogonal array, the degrees of freedom should be greater than or at least equal to those for the parameters of the operation. The L9 orthogonal array of three columns and 9 rows was used in this analysis.

This array has 8 degrees of freedom and can handle parameters of three-level processes. Each welding parameter is assigned to a column and 9 combinations of welding parameters are available. Therefore, to research the entire parameter space using the L9 orthogonal array, only 9 experiments are needed.

The experiments are planned using Taguchi's orthogonal array in the design of experiments (DOE), which helps in reducing the number of experiments

EXPERIMENT NO	FACTOR		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	1
7	3	1	2
8	3	2	3
9	3	3	1

Table3.3 Pattern of L9 Orthogonal Array

4.1EXPERIMENTAL RESULT AND DISCUSSION

The material that is used in the this project work is Dp600 steel sheet metal, with a thickness of 1.5mm and 2.0mm for both the thicknesses the length of the coupon is 100mm and width of the coupon is 40mm and the contacting overlap of the sheets is 35mm, the The details are shown in Table 4.1 below. The experiments included the joining of two sheet metal layers. Squeezing time was constant throughout the study in this experimental study of the electrode size.

Thickness (t) Of sheets mm	Width (w) Of sheets mm	Length (L) of sheets mm	Contacting overlap of sheets mm
1.5	40	100	35
2.0	40	100	35

Table4.1:Dimensions of the sheet metal coupons

The experiments were carried out under various welding conditions specified in the L9 orthogonal array for DP600 steel sheets of both 1.5 mm and 2.0 mm thickness for both shear tensile strength specimens and direct tensile strength specimens separately..

SPOT WELDING MACHINE

In making a resistance spot weld, the machine used must deliver the correct amount of current, localize it at the point where welding is desired and apply the At the correct time, proper strain. Due to the heat generated by the high current in resistance welding, the transformer and electrode system must also be cooled. The resistance welding machine is therefore composed essentially of the following systems:

Electrical system

Mechanical system

Control system

Cooling system

A.C. RESISTANCE WELDING MACHINE

Most resistance welding machine are single-phase AC machines. This is the type of machine most commonly used, because it is the simplest and least expensive in initial costs, installation and maintenance. The electrical circuit is shown in Fig4.4 and Fig5. The power from the single phase of main power from the single phase of main power is applied to the primary side of the welding transformer through a switch (annti-phase dual silicon-controlled rectifiers), converted by the transformer and output high current (low voltage) on the secondary side.

In AC resistance welding, the welding current flows with positive and negative half-cycles, there is zero heat or current between these two half cycles. This is called cycling, which can cause some undesirable effects in welding smaller and thinner parts, where the weld time is typically under 3 cycles, because the weld may cools effectively between the half cycles, this will result in loss of the heat required to make a good weld.

Another negative effect of cycling is that when the heat is not applied constantly throughout the duration of the weld, the nugget growth can be irregular. Variations in the weld nugget are directly related to the quality and strength of a weld. Other AC disadvantages are unbalanced line loading and lower power factors due to the inherent inductive reactance in the machine.

RESISTANCE WELDING MACHINE

For the spot welding process, a spot welding machine with rated configuration of rated capacity 15KVA, the maximum short circuit secondary-18kAmps, with a supply voltage of 415V and the rated frequency 50/60 Hz, control panel for the welding current, welding time and squeeze time controller was used. The maximum electrode force is 3000N (pneumatic loading). The welding electrodes were made of copper alloy with a conical shaped tip surface geometry. All the welding parameters were set to obtain a reasonably good spot weld nugget. It should be noted here that the weld lobe was not constructed in this study by varying the welding current and welding time during the spot welding process.

Experiment Number	Process parameter level		
	Electrode	Welding	Weld

	Force	Current	Time
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 4.2Experimental layout pattern Used in an L9 (3^3) Orthogonal Array

Thickness	Symbol	Process parameter	Unit	Level 1	Level 2	Level 3
1.5mm	A	Electrode Force	KN	2	3	4
	B	Welding Current	KA	3.0	3.5	4.0
	C	Welding Time	Sec	1	2	3

Table 4.3: process parameters with their values at three levels for 1.5mm thickness of sheets

Thickness	Symbol	Process parameter	Unit	Level 1	Level 2	Level 3
2.0mm	A	Electrode Force	KN	2	3	4
	B	Welding Current	KA	3.0	3.5	4.0
	C	Welding Time	Sec	1	2	3

Table 4.4: process parameters with their values at three levels for 2.0mm thickness of sheets

4.2S/N RESPONSES FOR THE SHEAR AND DIRECT TENSILE STRENGTH

Thickness	Process parameter	Units	Level 1	Level 2	Level 3	Total mean S/N (dB)	Max - Min
1.5mm	Electrode force	kN	22.659	22.113	23.306	22.69	1.19
	Welding current	kA	23.486	26.933	17.659		9.274
	Weldin	Sec	22.11	22.43	23.52		1.14

	g times		6	6	6		

Table4.9S/N Responses for the Direct Tensile strength for 1.5mm thickness

Thickness	Process parameter	Units	Level 1	Level 2	Level 3	Total mean S/N (dB)	Max - Min
1.5mm	Electrode force	kN	12.723	15.313	10.25	12.76	5.063
	Welding current	kA	15.353	10.199	12.733		5.154
	Welding times	Sec	15.203	12.776	10.306		4.897

Table4.10S/N Responses for the shear Tensile strength for 1.5mm thickness

Thickness	Process parameter	Units	Level 1	Level 2	Level 3	Total mean S/N (dB)	Max - Min
2.0mm	Electrode force	kN	19.846	13.693	15.380	16.30	6.153
	Welding current	kA	18.159	14.266	16.493		3.893
	Welding times	Sec	13.599	20.073	15.246		6.474

Table4.11S/N Responses for the Direct Tensile strength for 2 mm thickness

Thickness	Process parameter	Units	Level 1	Level 2	Level 3	Total mean S/N (dB)	Max - Min
2.0mm	Electrode force	kN	13.05	14.25	10.633	12.64	3.617
	Welding current	kA	15.666	9.883	12.389		5.783
	Welding times	Sec	14.849	13.100	9.99		4.859

Table4.12S/N Responses for the shear Tensile strength for 2 mm thickness.

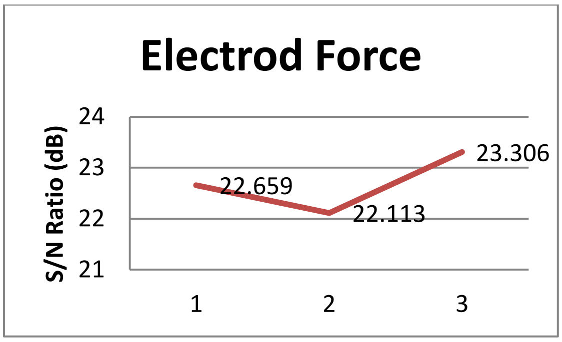

Fig4.10 S/N Ratio graph of 1.5mm Direct Tensile Strength Electrode force

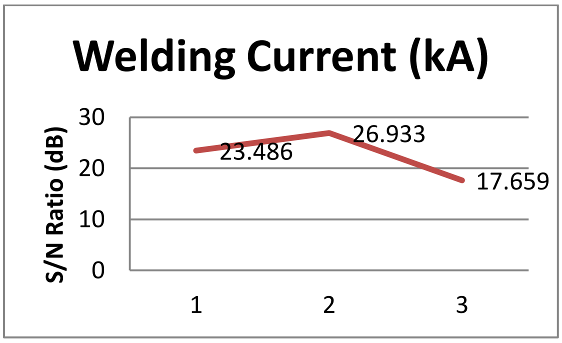

Fig4.11 S/N Ratio graph of 1.5mm Direct Tensile Strength Welding current

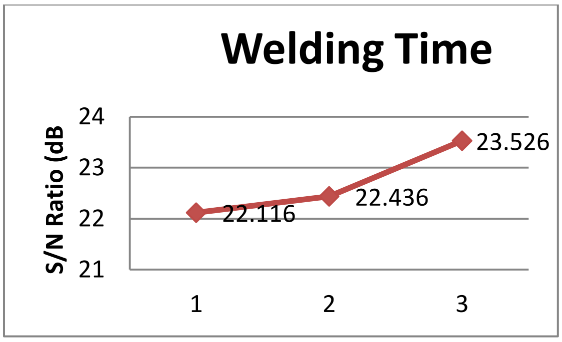

Fig4.12 S/N Ratio graph of 1.5mm Direct Tensile Strength Welding Time

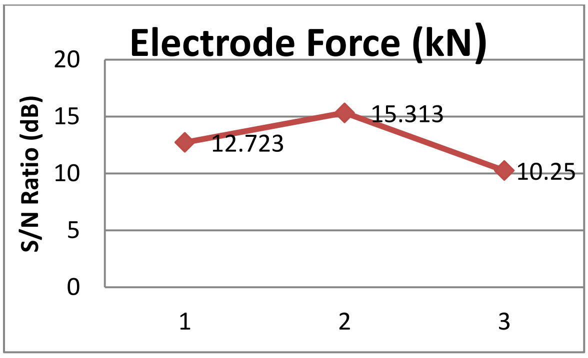

Fig.4.13.S/N Ratio graph of 1.5 Shear Tensile Strength Electrode Force

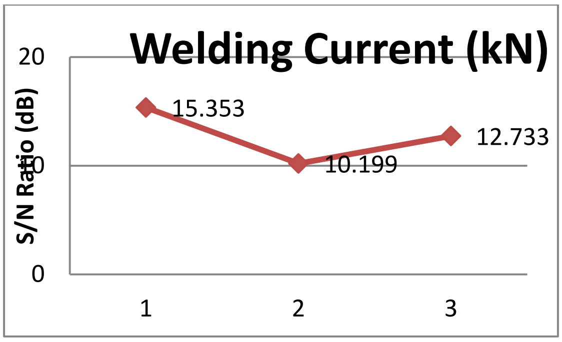

Fig.4.14 S/N Ratio Graph of 1.5mm Shear Tensile Strength Welding Current

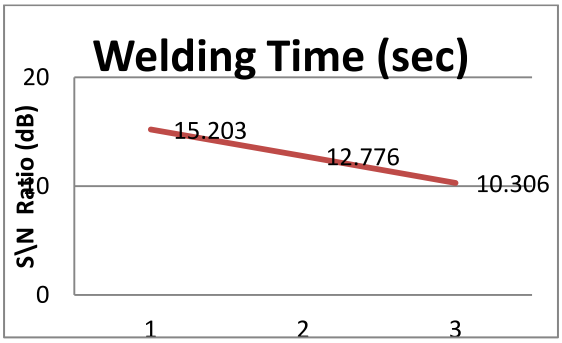

Fig.4.15 S/N Ratio Graph of 1.5mm Shear Tensile Strength Welding Time

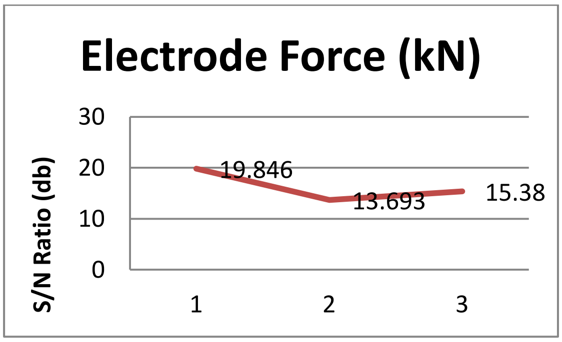

Fig.4.16 S/N Ratio Graph of 2mm Direct Tensile Strength Electrode Force

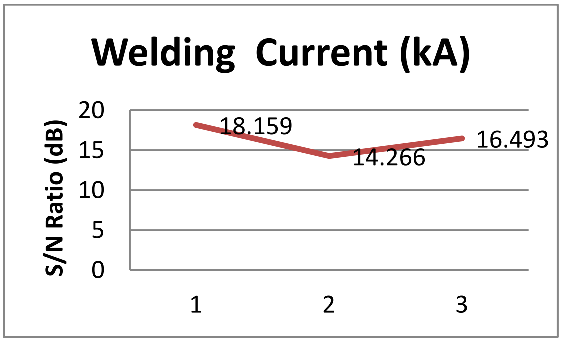

Fig.4.17 S/N Ratio Graph of 2mm Direct Tensile Strength welding Current

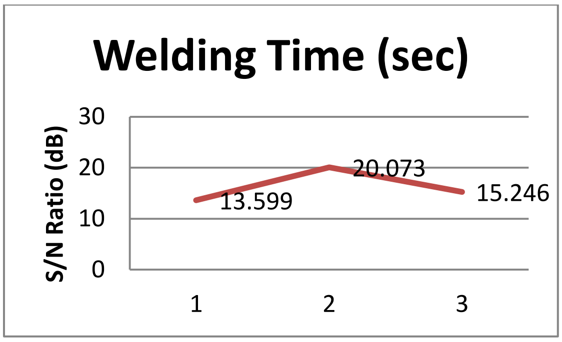

Fig.4.18 S/N Ratio Graph of 2mm Direct Tensile Strength welding Time

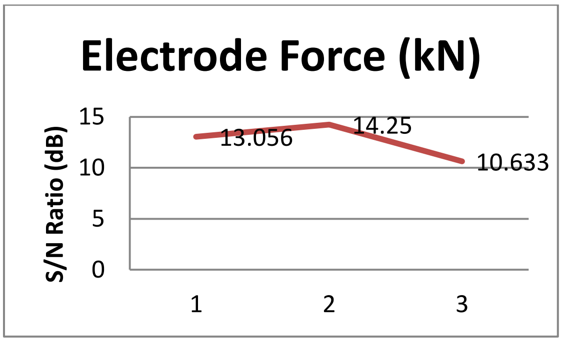

Fig.4.19 S/N Ratio Graph of 2mm Shear Tensile Strength Electrode Force

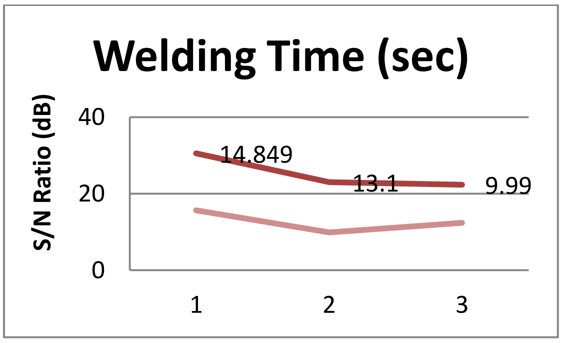

Fig.4..20 S/N Ratio Graph of 2mm Shear Tensile Strength Welding current

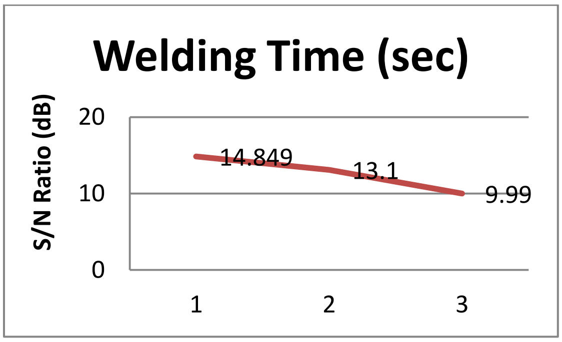

Fig.4..21 S/N Ratio Graph of 2mm Shear Tensile Strength Welding Time

parameter	process parameters`	degree of Freedom	Sum of square	Variance	F	contribution percentage
A	Electrode Force	2	2.14	1.07	0.282	0
B	Welding current	2	131.823	65.911	17.42	85.806
C	Welding Time	2	3.278	1.639	0.433	0
Error		2	7.566	3.783		14.194
Total		8	7.566			100

Table 4.13 Results of ANOVA of Direct Tensile Strength for 1.5mm Steel sheet

parameter	process parameters`	degree of Freedom	Sum of square	Variance	F	contribution percentage
A	Electrode Force	2	38.462	19.231	599.114	33.584
B	Welding current	2	39.838	19.919	620.548	34.788
C	Welding Time	2	35.967	17.983	560.237	31.401
Error		2	0.064	0.032		0.227
Total		8	114.33			100

Table 4.14 Results of ANOVA of Shear Tensile Strength for 1.5mm Steel sheet

CONCLUSION

The experimental results confirmed the validity of the predicted values by the Taguchi method for enhancing the spot welding performance and optimizing the welding parameters in order to improve the spot welded joint quality in resistance spot welding operation.

The following conclusion could be drawn from the present investigation.

1. The experimental results show that the right sections of the input parameters are : HIGH current , medium electrode force and medium welding time.
2. The response of S/N ratio with respect to direct tensile strength and direct tensile strength indicates the welding current to be the most significant parameter that controls the weld tensile strength where's the welding time and electrode force are comparatively less significant in this regard.
3. Optimum results have been found by the Taguchi method using tensile shear strength is 8.741KN and direct tensile strength is 17.5KN. This paper represents the optimization of various parameters of resistance spot welding. The experimental studies have been conducted under varying electrode force, welding current and welding time. In this investigation, the quality characteristic (tensile strength) has been considered using Taguchi Method. The experimental studies

have been carried out varying welding currents, weld and hold times for joining two sheets.

4. The confirmation test validated the use of multi-objective Taguchi method for enhancing the welding performance and optimizing the welding parameters in resistance spot welding process.

SCOPE OF WORK FUTURE

The experimental studies can be conducted under varying electrode diameter, tool rotation speed, plunge depth, dwell time and different electrode material etc to see how the factors would affect the strength of spot weld joint. Also, further study could consider the outcomes of Tauchi parameter design when it is implemented as a part of management decision –making processes. It is recommended to use Taguchi statistical tool for studying the quality of the spot-welded joints made of different materials and also are with different thickness.

REFERENCES

1. *Ugur Esme,Mersin University, tarsus technical education, faculty department of machine education, 33400 Tarsus/Mersin,Turkey*
2. *Norasiah Muhammad,Yupiter HP Manurung, Mohammed Hafidizi, Sunhaji Kiyai Abas, Ghalib Tham, M.Ridzwan Abd.Rahim, Faculty of Mechanical Engineering University Technology MARA (UiTM),40450 Shah Alam, Selangor, Malaysia*
3. *HL-Link,T chou2 and C-p Chou Department of Vehicle Engineering, Army Academy R.O.C, Jungli, Taiwan, Republic of China, Department of Mechanical Engineering, National Chiao Tung University, Taiwan, Republic of China. The manuscript was received on 1 February 2006 and was accepted after revision for publication on 18 March 2008.*
4. *Thanks, A.G.Rao, T. E. Mukhedkar, M.S.Nandedkar, V.M.SOURCE,Journal of Engineering &Applied Sciences 2010, Vol.5 Issue11,p22*
5. *S.V.Sapakal,M.T.Telsang Post Graduate student, professor, Mechanical Engineering, Rajarambapu Institute of Technology, Sakharale-415414, Maharashtra, India*
6. *D.S.Sahota, Ramandeep Singh,Rajesh Sharma, Harpreet Singh Indo Global Engineering College, Assistant Professor, Departement of Mechanical Engineering, Punjab,India. CT Engineering College, associate professor, Departement of Mechanical Engineering, Punjab,India. CCET,Sec-26,Chandigarh, Assistant Professor, Departement of Mechanical Engineering, Punjab,India. REBT, Professor, Departement of Mechanical Engineering, Punjab,India.*
7. *A.K.PANDEY,M.I.KHAN,K.M.MOEED akpandey@engineer.com, mikyh_20@yahoo.com, kmoeed@yahoo.com, Integral University, Lucknow, India*
8. *Joseph I.Achebo lecture at university of Benin, Nigeria*
9. *Norasiah Muhammad and Yupiter HP Manurung Faculty of Mechanical Engineering, University Technology MARA (UiTM) Malaysia Associate professor Dr-lng of mechanical engineering UITM Shah Alam, Malaysia*