Prediction of Spot Welding Parameters for Dissimilar Weld Joints

B. Vijaya Sankar, I. Daniel Lawrence and S. Jayabal

Abstract--- *Development of manufacturing systems are needed to invent new kind of methodology for joining process in current research and development. Spot welding technologies are widely applied in non-conventional joining process. In this investigation predicted the mechanical properties like tensile strength and Hardness. The hardness evaluated in different regions of the spot welded Stainless steel sheet and Mild steel sheet joints such as welded zone, heat affected zone and parent material subjected to different Welding Parameters. The Experimental procedures are developed by factorial design and the regression model developed from the experimental results through Response surface methodology. The variable parameters are Electrode force, Weld Current and the Weld time. The measurable parameters are Tensile strength and hardness. The optimization process is carried out by Response surface methodology and the optimized parameters are defined the quality of the welded steel joints. The optimized welded parameters are expressed the effective joining and improve the quality of the welded member.*

Keywords--- *Spotwelding, Response Surface Methodology, Electrode Force, Weld Current, Weld Time.*

I. INTRODUCTION

RESISTANCE Welding is a vital joining process for similar and dissimilar joints. To join two metals by resistance welding, it is necessary only to clamp them together under pressure and pass through them an electric current for a specific time. The heat generated creates a plastic state and produces fusion at the interface surfaces. Still huge no of engineering industries are used resistant welding for different engineering applications in different joining process.

Phoenician artisans “welded” metals together with forge and hammer over 3000 years ago. The blacksmith also used a forge and hammer, heat and pressure. It is an effective joining process broadly used for the production of sheet metal assemblies. Resistance spot welding is in use for over 120 years for joining of metals by the application of pressure, current and time. The resistance to flow of current concerning the materials that causes confined heating the parts to be merged is used in this process, as indicated in its name. [1] Determining the process–microstructure–performance relationship in resistance spot welding of AISI430 ferritic stainless steel .The phase transformation which occur during the weld thermal cycle were analyzed which shows that fusion zone exhibited a carbide precipitates with small amount of martensite the HTHAZ exhibited a martensite, the MTHAZ exhibiting the higher hardness, the LTHAZ exhibited Cr-carbide. The grain growth which occurred in FZ and HTHAZ is a major problem accompanied with fusion welding of FSSs. It shows that the peak load and energy absorption of the welds were improved as the welding current increases due to the formation of larger FZ size at higher heat input. [2] In their research, the effects of electrode force, weld nugget, and hardness of spot welded steel joints are examined based on observed values of the experiment. Mechanical properties and the microstructure of the welded joints are having significant impact on weld nudge. The significant values of difference are identified in the hardness due to the changes presence in weld nudge. The mechanical properties and the microstructure on the heat affected zone is preserve higher value compare with welded zone. [3] Weld nudges and weld time are investigated through Finite element methods by two dimensional models in resistant spot welding. This analysis defined the effect of nugget size and weld time on AISI304L stainless steel sheet. The experimental parameters are used for improving the result in simulation and comparison study. A rapid growth of nugget is caused to form while the welding current tends to exceed a critical value for nugget formation.[4]In this paper, the metallographic studies are carried out for the welded specimen with various weld current rates that will show relationship between the current intensity and nugget size. The investigation of phase transformation, mechanical properties and characterization of microstructure of AISI 316L austenitic stainless steel sheets of resistance spot welding were conducted. The micro hardness examination was also done to show that weld nugget has lower area than the area of heat affected zone. The maximum tensile strength and shear strength are observed for various current flow rates.[5] The behavior of fatigue in resistance spot welding (RSW) for aluminum 6061-T6 alloy was studied about three different levels such as nominal, low and high rates of different welding parameters. The various levels of welded joins are used to observe the microstructure. In addition to that different fatigue failure modes are observed different load ranges. The three different conditions are observed through Optical microscope images including different places such as base metal (BM), fusion zone (FZ) and heat affected zone (HAZ).[6] The effect of weld parameters on DP600 dual phase steel are evaluated by thermo coupled field finite element analysis in SYSWELD software package. Parameters optimization was done using ANOVA technique and found the optimized values, compared with simulation result and experimental setup. In this study the effect of the process parameters on the lap shear strength of

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AA618-T4/Ti6A14V single joints was investigated using full factorial design in design of experiment and analysis of variance sound joint with lap shear strength from 4769N to 6449 N were achieved and influence of the main process parameters on joint performance was evaluated. The Response Surface Methodology, mathematical model to predict lap shear strength was developed using second order polynomial function based on the experimental results. The RSM experiment results satisfactory agreement between the predicted and experimental values optimal, economic and efficient welds were achieved using the welding parameters (RS-2500 rpm DT-25) obtained from the numerical optimization for a sleeve plunge depth of 1.4mm and a clamping pressure of 12 KN.[7] Weld time and vibration amplitude are focused by the experimental process and the effects are identified from the experimental results. Experimental were conducted using lateral drive USW machine operating in time control mode. Weld quality of weld joint as analyzed based on the weld strength obtained lap shear tests and the fracture pattern subsequently characterized the peak failure load shifted to shorter welding time region for higher vibration amplitude level which indicates that a critical welding energy that yield good weld strength. Good bond density at weld interface of USWAL alloy joints was due to the combine effects of temperature rise around the horns tip and intensity of weld interface waviness.[8] The significant effect of weld parameters are analyzed on the resistant spot welding from developed linear response surface model. The prediction based on the nugget radius and the intention of the nugget radius justified for steel joints. Multi objective optimization method is enhancing the weld performance and described the contribution of different control factors such weld current, weld time and holding time. The generation of linear response surface model for prediction of radius of the weld nugget and width of HAZ has been found well fitted.[9] Optimization of welding parameters about tensile shear strength in the Resistance Spot Welding on mild steel. The experimental results were conducted by divergent level of electrode forces, welding currents, and welding times. The experimental design framed by L18 orthogonal design and the optimum parameters are identified for the mild steel joints. The appropriate combination of the optimum welding parameters were determined by the Signal-to-Noise (S/N) ratio technique. From the experimental results it is clear that the welding parameters are the important factors for the strength of the welded joint. The increasing or decreasing value of the weld strength is completely depends on the level of stated variable parameters.[10] The paper presents experimental investigation studies that were conducted under varying Resistance spot welding parameters such as electrode force, welding current and welding time in order to establish their influence on spot weld quality. Require weld characteristics of shear strength and tensile strength of spot welded joints identified between the lower and upper bound of the variable nugget parameters. The performance characteristics in RSW process is studied through the Taguchi method, the signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) approach. The experimental data was observed as per the pattern of L9 Orthogonal Array (OA).The confirmation tests indicated that it is possible to increase tensile shear strength significantly by using the proposed statistical technique. The variable parameters validated by optimization technique to enhancing the quality and performance of developing spot welding process. Further research is consider on different materials, different thickness and more factors (e.g. Electrode geometry, etc.) in the investigation of factors that would affect the present and other quality characteristics such as fatigue strength, peel strength etc.[11] This study describe the effect of weld current, Weld time and thickness of the materials on the three different steels such as Stainless steel, mild steel and Galvanized steel. The results highlighted better weld strength obtained from the stainless steel compared with other steel joints. [12] Experimental prediction of resistant spot welding parameters are done by L27 orthogonal design for Galvanized steel. The roles of weld parameters such weld current, welding time, electrode force and electrode diameter were evaluated and declared strength to noise ratio. The results showed that welding current was about two times more important than the second factor weld time for controlling the tensile shear strength. The confirmation tests indicated that it is possible to increase tensile shear strength significantly (13.43 %) by using the proposed statistical technique.

[13] The use of the Taguchi method to determine the optimum process parameters and other optimization techniques are reported. The Taguchi experimental design method was used to determine the welding parameter and their levels. The importance's of the measured parameters are defined by analysis of variance. Taguchi method of optimization process parameters is efficient, close to target and economical and thus, gives steady effect of process parameters which while optimizing and quickly identified its contribution of various response variables. It gives approximate results not confirm to its repeatability and consistency of operation.[14] Optimization of spot welding parameters are distinguishes by Gray theory for dissimilar materials and sheets thickness. The experimental procedure developed by using L9 orthogonal array with three factors with each factor having three levels. The welding current, weld time and electrode force are the selected input factors. The weld strength, weld nugget diameter and weld indentation are optimized by variable parameters.3 KN of electrode force, time of 15 cycles and 9 kA welding current are the optimized parameters for the dissimilar steel joints. ANOVA analysis shows that current flow playing most significant contribution on dissimilar weld characteristics.

II. METHODOLOGY

A. Material Selection

Table 1: Chemical Composition of Steels

Element	Content (%) in AISI 202	Content (%) in AISI 1018
Iron, Fe	68	98.81 - 99.26
Chromium, Cr	17-19	-
Manganese,Mn	7.50-10	0.60 - 0.90
Nickel, Ni	46	-
Silicon, Si	≤ 1	-
Nitrogen, N	≤ 0.25	-
Carbon, C	≤ 0.15	0.14 - 0.20
Phosphorous, P	≤ 0.060	≤ 0.040
Sulfur,S	≤ 0.060	≤ 0.050

Table 2: Mechanical Properties of AISI 202 & AISI1018

Property	Content @ 25^0C in AISI 202	Content @ 25^0C in AISI 1018
Poisson's Ratio	0.27 - 0.30	0.290
Elastic Modulus (GPa)	190 - 210	205
Tensile Strength (Mpa)	515	440
Yield Strength (Mpa)	275	370

In this work AISI 202 stainless steel and AISI 1018 mild steel with 2.0 mm thickness sheet selected for experimental work and its chemical compositions and mechanical properties are tabulated in table1 and table 2.

B. Experimental Procedure

AISI 202 and AISI 1018 steel sheets with 2mm thickness are selected for dissimilar joints on resistant spot welding process by KPW 250(SPM) spot welding machine.

The dimension of sheet is 100 mm length (L), 32 mm width (w) and 2.0 mm thick (t). Selected dissimilar steel sheets are chemically treated by astron to improve the material surface quality were to avoid the dust and impurities. A current and time controlled electric resistance spot welding machine was used for conducting tests. The electrodes material was Copper alloy with end diameter 8 mm. This machine was equipped with a pneumatic pressure system. Welding, squeezing and holding cycles were manually selected. Three process parameters are. Electrode Force, Current and Weld cycle time were selected as given in Table 3. The parameters which kept constant are electrode material and electrode diameter. Experiments were done respect to the test conditions indicated by the Taguchi L27 Orthogonal Array (OA). The parameters used in the resistance spot welding of the sheets are tabulated.

When current is passed through a conductor the electrical resistance of the conductor to current flow will cause heat to be generated that can be conveyed as follows,

$$V = IR$$

Where, R = Resistance offered by the work piece to the flow of current.

$$H = IVt$$

$$H = I (IR) t$$

$$H = I^2Rt$$

Where, H = Heat generated (Joules), I^2 = Welding Current Squared (Amperes), R = Resistance (Ohms) and t = Time of current flow (seconds).

III. RESULTS

Table 4 shows the experimental specimens that are tested for tensile strength and hardness, which according to L27 orthogonal array, totally 27 trails are done in spot welding and tabulated. The electrode weld tip with 8mm diameter and the Electrode material are taken as constant. The Tensile test values of the samples are measured as per ASTM E384-2011.

A. Results from Response Surface Methodology

From the test results the optimized values are tabulated in Table 3.

Figure 1: Welded Specimens

The experimental measured values observed for dissimilar weld joints and the measured parameters are tensile strength and hardness. From the measured values are used to predict the optimized weld parameters by Response surface methodology. The Experimental values and the optimized values are tabulated below in table 3 and table 4. The optimized results are displayed as per the value of desirability and the maximum desirability achieved by the variable parameters Electrode force, Weld current and Weld time are 3.66KN, 11.26 KA and 14.96Cycle respectively.

The relationship between weld current and electrode force are shown in Figure 2 with respect to the tensile strength. The relationship between weld current and Electrode force are shown with respect to the Desirability in figure 3.

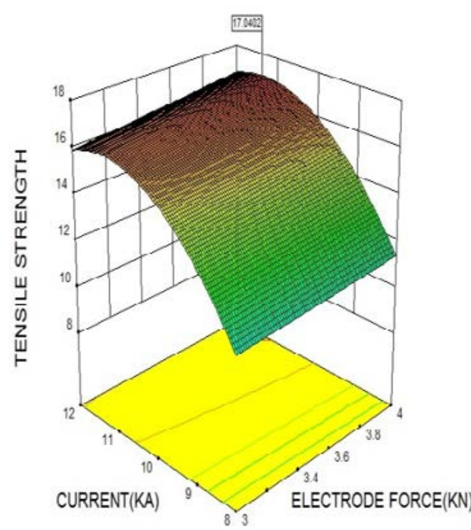

Figure 2: Weld Current Vs Electrode Forceon Tensile Strength

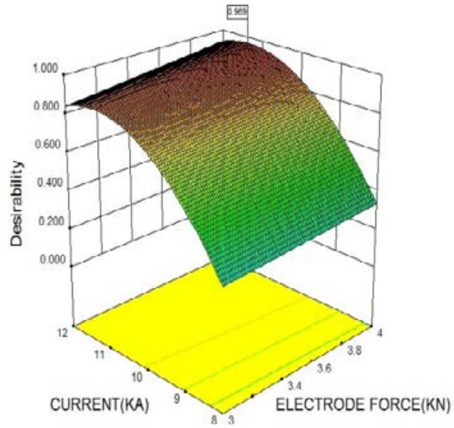

Figure 3: Weld Current Vs Electrode Force on Desirability

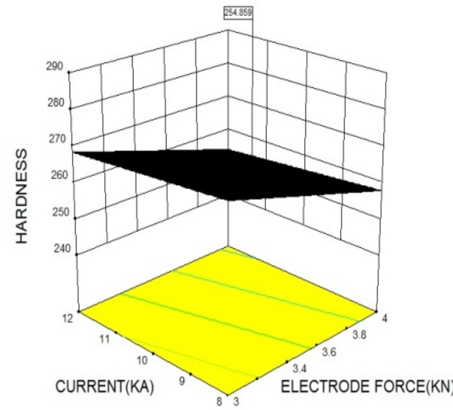

Figure 4: Weld Current Vs Electrode Force on Hardness

Table 3: Optimized Results by RSM

Trail No	Electrode Force(KN)	Weld Current(KA)	Weld Time(Cycle)	Tensile Load(KN)	Hardness	Desirability
1.	3.668	11.256	14.960	17.040	254.861	0.969
2.	3.668	11.257	14.942	17.040	254.875	0.969
3.	3.667	11.255	14.974	17.040	254.849	0.969
4.	3.667	11.249	14.996	17.040	254.833	0.969
5.	3.669	11.261	14.913	17.040	254.853	0.969
6.	3.669	11.234	14.977	17.040	254.891	0.969
7.	3.672	11.254	14.853	17.040	254.914	0.969
8.	3.674	11.215	14.864	17.040	254.905	0.969
9.	3.674	11.178	14.962	17.040	254.798	0.969
10.	3.662	11.252	15.137	17.040	254.875	0.969

Table 4: Experimental Results

Trails	Electrode Force (KN)	Weld Current (KA)	Weld Time (Cycle)	Tensile Load (KN)	Hardness Test (WM)
1.	3	8	12	9.01	249
2.	3	8	14	11.36	251
3.	3	8	16	11.55	254
4.	3	10	12	14.61	251
5.	3	10	14	15.26	243
6.	3	10	16	13.72	249
7.	3	12	12	15.45	246
8.	3	12	14	15.47	251
9.	3	12	16	16.56	249
10.	3.5	8	12	8.37	244
11.	3.5	8	14	10.10	249
12.	3.5	8	16	10.77	239
13.	3.5	10	12	14.69	252
14.	3.5	10	14	14.91	254
15.	3.5	10	16	16.37	254
16.	3.5	12	12	15.30	240
17.	3.5	12	14	17.00	243
18.	3.5	12	16	17.21	246
19.	4	8	12	8.54	247
20.	4	8	14	10.15	252
21.	4	8	16	12.30	242
22.	4	10	12	14.92	241
23.	4	10	14	15.82	253
24.	4	10	16	16.91	248
25.	4	12	12	15.81	249
26.	4	12	14	17.32	243
27.	4	12	16	14.88	251

The relationship between weld current and electrode force are shown in Figure 4. With respect to the Hardness and the normal percentage of probability is expressed in figure 5. The maximum response factor is obtained as 0.91 for the experimental results thorough Response surface methodology.

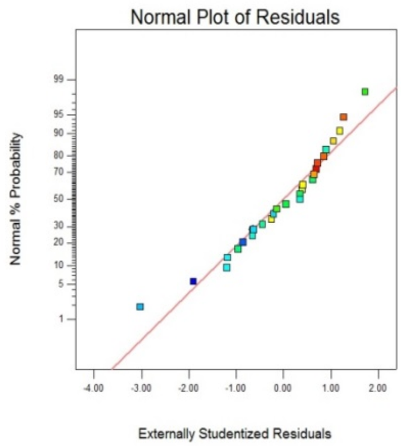

Figure 5: Normal Probability Plot of Residuals

IV. Conclusion

In this study the Resistance Spot Welding (RSW) process parameters were optimized for Dissimilar Mild steel and Stainless steel sheet joints to obtain desirable mechanical properties and the results were validated using Response surface methodology optimization technique. The Experimental design designed by using Design of Experiment as Taguchi's L27.

It has been observed that welding current and welding time are has more significant effect about the measured parameters.

The optimized values are observed from the experiments results. The optimal values of the measured parameters are tensile strength of 17 KN and hardness of 254.86 (HV10). The preserved values of the variable parameters are resistant force 3.66 KN, weld current 11.26 KA and weld time 14.96 cycles. The noted optimized values are expressed the ability of the individual parameters.

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