Optimization of Spot Welding Using Taguchi Method

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Abstract— **The aim of this project is to obtain an optimum setting of spot welding process parameters (Electrode diameter, Pressure, Weld Time, Current) resulting in maximum strength of joint when welding of dissimilar metals SS304 (stainless steel with 1% nickel) with Galvanized steel and welding of similar metals Galvanized steel. The effects of the selected welding parameters on tensile strength & subsequent optimum setting of parameters have been accomplished using "Taguchi parameter design approach". Results are analysed by using response surface method.**

The results indicate that selected process parameters significantly affect the selected welding characteristics. The results are confirmed by further experiments.

Keywords— **Electrode diameter, SS304, Galvanized ion, Taguchi technique, Response surface method.**

I. Introduction

For a typical automotive body construction, the Spot Welding (SW) is a widely used joining technique for sheet metal parts. The SW process is easy to operate, automate, and control; thereby making it an ideal joining technique for mass production. However, the SW of aluminium alloys has some unique problems due to their high thermal and electrical conductivity. These problems include weld porosity, fast electrode wear, and inconsistent failure modes.

As a result, the automotive industry has switched to structural adhesives, rivets, and toggle-locks to join aluminium panels. Rivets offer better strength and quality compared to SW, but the added material, in turn, adds weight and cost. Adhesives are expensive and require long cycle time for dispensing and curing. Toggle locks are cheaper than RSW, but they are also weaker in fatigue than RSW. Recently, Mazda and Toyota have introduced Spot Friction welding (SFW) technology to join aluminium sheet metal body panels.

There is lot many parameters involved in the spot welding process (normally 5 to 7). Optimizing these parameters to get a good weld strength and proper HAZ diameter is a tough task. These are the outputs obtained from spot welding process and should be optimum. So, to optimize these parameters a well-known and effective methodology proposed by Sir Genichi Taguchi known as Taguchi Method is used.

Taguchi Method is a powerful tool proposed by Genichi Taguchi for design of experiments. This tool gives a better flexibility to control and optimize the input parameters involved in spot welding process to get desired result (higher weld strength and HAZ diameter) in minimum number of trails

II. Review of Papers

The study of different research papers gave us a lot of information about the spot welding process, Taguchi method as well as its use in the optimization of parameters involved in spot welding. We have discussed them in short in the coming pages.

A. Spot Welding

It is a process which is being widely used for the joining of metal sheets in the automobile and aviation industry. In this process, two metal sheets are joined by using electric current. Electric current of high amplitude is passed through the metal sheets by using electrodes concentrating the current on the joint area. The current generates a high temperature which results in the melting of the metal near the area where the current is concentrated using the electrodes. Further, adequate amount of pressure is applied for required time by the electrodes to complete the joining process.

B. Taguchi Method

Taguchi techniques for quality engineering is intended as a guide and a reference source for industrial practitioners (managers, engineers and scientists) involved in product or process experimentations and development. Taguchi philosophy provides 2 tents: -

1. The reduction in variations (improved quality) of a product or process represents a lower loss to society, and
2. The proper development strategy can intentionally reduce variations.

It is hoped that Taguchi techniques for quality engineering will bridge the gap for industrial user, eventually making the companies more competitive with their products in the world market. World class quality will be requirement for corporations to remain lucrative, let alone highly competitive, as more and more companies embrace the Taguchi methods.

C. Use of Taguchi Method In Optimization Of Spot Welding Parameters

The Taguchi method provides a lot of conveyance in the optimization of spot welding process variables. There are a number of variables associated with this process and are 5 to 7 in number. Value of every variable puts an adverse effect on the output of the welding process that is weld strength and nugget or HAZ diameter.

So, there is a need to investigate the effect of change of values of each and every parameter involved in the process on the output. Since the output required should be as per the desire of the application, result of the values of different process variables on the output is required to be investigated.

The effect of process variables can be studied only by performing the experiments on different material sheets of different thicknesses. Now, performing the experiments on a hit and trail basis is a tough task and very expensive also. So, a proper model of experimentation is required to be formulated.

Taguchi techniques help a lot in the formulation of an effective experimental model for these types of problems. Use of this technique not only reduces the number of experiments but also gives a proper optimization of the values of process variables to get an effective weld strength and nugget or HAZ diameter.

III. Proposed Methods

A number of methodologies are present for the optimization of input process variable for getting a desired output. But, the experimental analysis shows that the method proposed by Sir Genichi Taguchi known as Taguchi Method is the best among all.

This method not only reduces the number of experiments but also gives a better optimization of the values of input process variables to get a desired output. The process formulates an effective experimental model with minimum number of experiments to get proper optimized values of process variables for the best results. The different tools for the effective use of this method are: -

1. Analysis of variance (ANOVA)
2. Factorial design experiments
3. Taguchi design experiments
4. Orthogonal arrays
5. Regression model
6. F-Test

IV. REVIEW OF PAPERS

The study of different research papers gave us a lot of information about the spot welding process, Taguchi method as well as its use in the optimization of parameters involved in spot welding. We have discussed them in short in the coming page minimum HAZ diameter) in minimum possible number of trails by using Taguchi Technique for the Design of Experiment.

The parameters involved in the process are weld current, weld time, electrode pressure etc. values of which, pays a adverse effect on the output that is weld strength and nugget or HAZ diameter. By the formulation of experiment model using Taguchi method we correlate the values of these input variables with the output and a proper value of each parameter is decided to get the desired output.

Every parameter involved in the process of spot welding has its own and vital role in the output of welding. Welding current, weld time, electrode pressure, weld energy, cool time etc. are the different parameters involved in the process. Each parameter is having its own impact and plays its own role for the output of the process that is weld strength and HAZ or nugget diameter.

Increment and decrement of every parameter's value while the welding process varies the strength as well as nugget diameter either increasing or decreasing its value depending on its impact on the process output. Each parameter value change gives a particular value of strength and nugget diameter.

Our work is to make the use of Taguchi technique to identify the parameters putting a great influence on the output and then to optimize them for the maximum weld strength and nugget diameter.

V. MATERIAL SPECIFICATION

The work material, electrode and other machining conditions are as follows:

1. Sheet Metal either Stainless Steel 304(1% nickel) or Galvanized steel
2. Sheet Metal Dimension-100x30x1 mm
3. Electrode used – Cu Cr having diameter 6mm and 8 mm.
4. Applied Pressure- Pneumatic

Different Input Parameters considered are Pressure, Current, Weld time and Electrode diameter.

Different Output Parameters considered are Breaking Strength, Nugget Diameter, and Heat affected zone

VI. EXPERIMENTATION PHASES

Phase – A

Similar Metals: - Galvanized Steel + Galvanized Steel

Total samples: - 5 (3 for Nugget diameter and HAZ and 2 for Weld strength)

Phase – B

Similar Metals: - Galvanized Steel + Stainless Steel

Total samples: - 5 (3 for Nugget diameter and HAZ and 2 for Weld strength)

VII. ANALYSIS OF TAGUCHI DESIGN MATRIX

After feeding the data in MINITAB 15 worksheet, the data is analysed .The Analysis gives the signal to noise (S/N) ratio for weld strength, nugget dia. and heat affected zone. The table below gives the result output that is values of weld strength, nugget dia., HAZ with run order.

A. Signal-To-Noise Ratio

The control factors that may contribute to reduce variation (improved quality) can be quickly identified by looking at the amount of variation present as a response. All past analyses in this text have addressed which factors might affect the average response, but now there is interest in the effect on variation as well. Taguchi has created a transformation of repetition data to another value which is a measure the variation present. The transformation is the signal-to-noise (S/N) ratio. The S/N ratio consolidates several repetitions (at least two data points are required) into one value that reflect amount of variation present. There are several S/N ratio available depending on the type of characteristic; lower is better (LB), Nominal is best (NB), or higher is better (HB).

B. Different S-N Ratios

Higher is better: -

S/N ratio = -10*log (sum (y^2)/n)

Nominal is best: -

S/N ratio = -10*log (s^2)

S/N ratio= -10*log ((y bar) ^{2}/s^2)

Lower is better: -

S/N ratio = -10*log ((1/y^2)/n)

TABLE I

VALUES OF PARAMETERS AT DIFFERENT LEVELS

Parameters	Level 1	Level 2	Level 3
Electrode Diameter (mm)	6	8	-
Pressure (kg/cm^2)	2	3.5	5
Current (Kamp)	8	10	12
Weld Time (cycles/sec)	8	12	16

TABLE III

TAGUCHI DESIGN MATRIX (L18 OA)

Sr. No.	Electrode Diameter (mm)	Pressure (bar)	Current (kA)	Weld Time Cycle (cycles/sec.)
1	1	2	8	8
2	1	2	10	12
3	1	2	12	16
4	1	3.5	8	12
5	1	3.5	10	16
6	1	3.5	12	8
7	1	5	8	16
8	1	5	10	8
9	1	5	12	12
10	2	2	8	8
11	2	2	10	12
12	2	2	12	16
13	2	3.5	8	12
14	2	3.5	10	16
15	2	3.5	12	8
16	2	5	8	16
17	2	5	10	8
18	2	5	12	12

VIII. GRAPH FOR SIMILAR MATERIALS

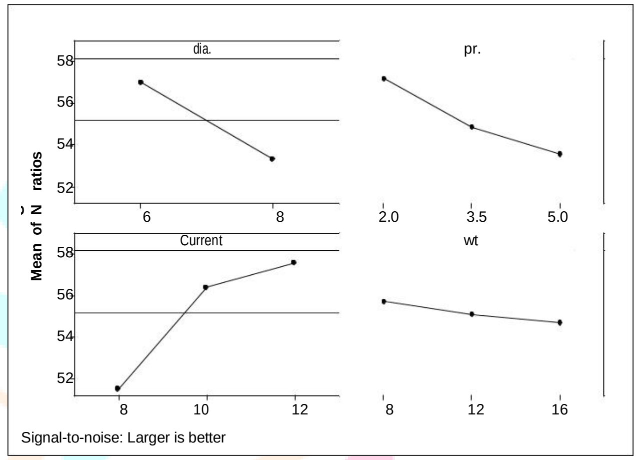

Fig. 1 Main Effect plot for S/N ratio for WS

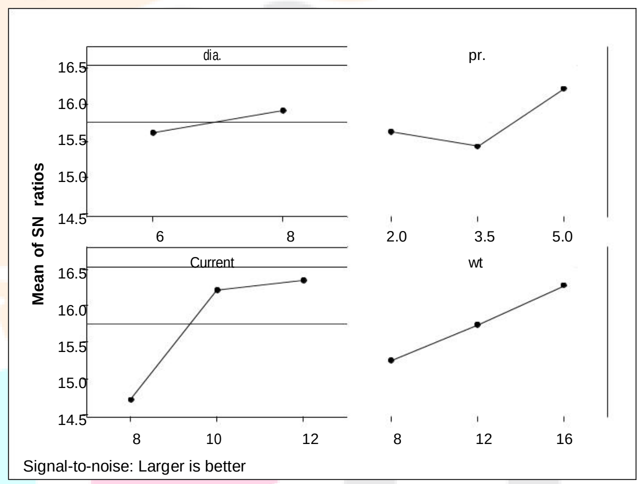

Fig. 2 Main Effect plot for S/N ratio for Nugget Dia.

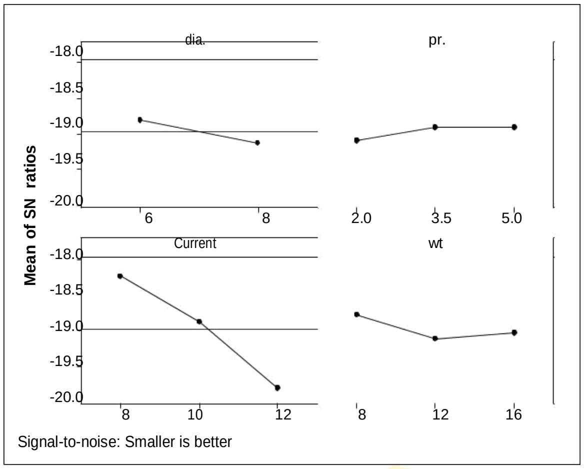

Fig. 3 Main Effect plot for S/N ratio for HAZ

IX. GRAPH FOR DISSIMILAR MATERIALS

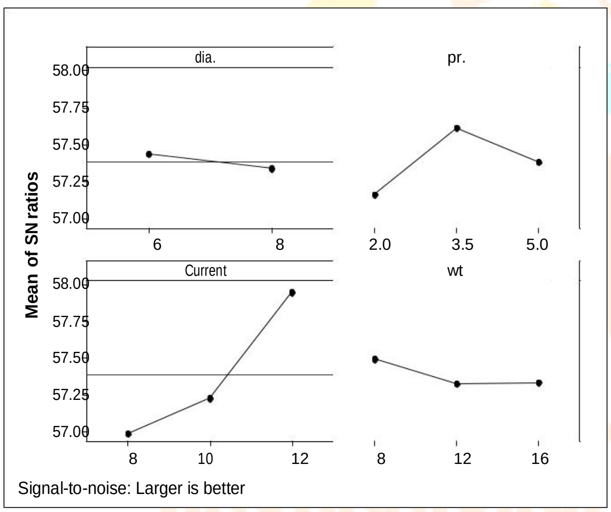

Fig. 4 Main Effect plot for S/N ratio for WS

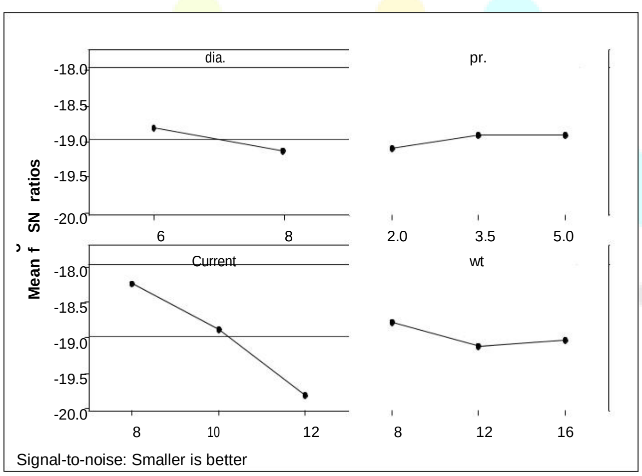

Fig. 5 Main Effect plot for S/N ratio for Nugget Dia.

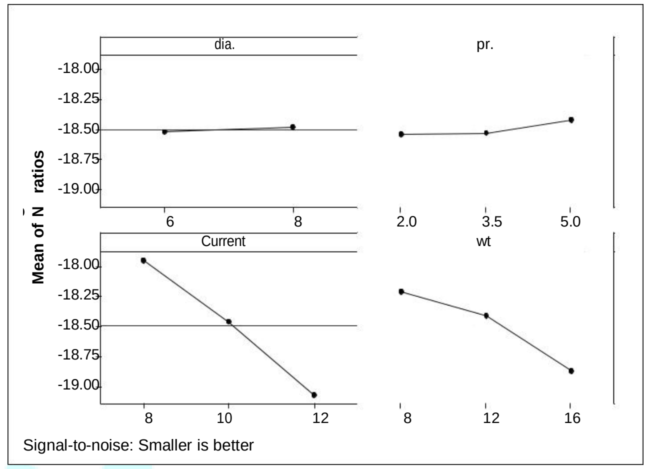

Fig. 6 Main Effect plot for S/N ratio for HAZ

X. CONCLUSIONS

The following conclusions can be drawn from the case study.

A. Weld Strength

For similar materials: Optimum setting of various process parameters for maximum breaking strength are:- Diameter = 6mm, pressure = 2 bar, current = 12 KA, weld time cycle = 8 cycles/sec. Based on the ANOVA method, the highly effective parameters on weld strength were found as welding current and electrode diameter, whereas electrode force and welding time were less effective factors.

For dissimilar materials: Optimum setting of various process parameters for maximum breaking strength are:- Diameter = 6mm, pressure = 2.5 bar, current = 12 KA, weld time cycle = 8 cycles/sec. Based on the ANOVA method, the highly effective parameters on weld strength were found as welding current and electrode force, whereas electrode diameter and welding time were less effective factors.

B. Nugget Diameter

For similar materials: Optimum setting of various process parameters for maximum breaking strength are:- Diameter = 8mm, pressure = 5 bar, current = 12 KA, weld time cycle = 16 cycles/sec.

Based on the ANOVA method, the highly effective parameters on nugget diameter were found as welding current and welding time, whereas electrode diameter and electrode force were less effective factors.

For dissimilar materials: optimum setting of various process parameters for maximum breaking strength are:- Diameter = 6mm, pressure = 2 bar, current = 12 KA, weld time cycle = 16 cycles/sec.

Based on the ANOVA method, the highly effective parameters on nugget diameter were found as welding current and welding time, whereas electrode diameter and electrode diameter were less effective factors.

C. Heat Affected Zone:

For similar materials: Optimum setting of various process parameters for maximum breaking strength are:- Diameter = 6mm, pressure = 5 bar, current = 8 KA, weld time cycle = 8 cycles/sec.
Based on the ANOVA method, the highly effective parameters on heat affected zone were found as welding current and electrode diameter, whereas electrode force and welding time were less effective factors.

For dissimilar materials: Optimum setting of various process parameters for maximum breaking strength are:- Diameter = 6mm, pressure = 5 bar, current = 8 KA, weld time cycle = 8 cycles/sec.
Based on the ANOVA method, the highly effective parameters on heat affected zone were found as welding current and welding time, whereas electrode diameter and electrode force were less effective factors.

So, finally we can say that the Taguchi Method for design and analysis of experiments and its tools like ANNOVA, Regression etc. are the effective methods for the design and analysis of experiments and can be used for any process.

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