

Parametric Optimization of Seam Welded AISI 1015 Mild Steel for Nugget Width

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ABSTRACT: Resistance welding is one of most widely used welding technique in sheet metal manufacturing industries. It is method of joining two faying surfaces of metal sheets. The three variants of Resistance welding are spot, seam and projection welding. Response variables like nugget width and tensile strength are major quality factors that plays vital role in seam welding process. The objective of this paper was to investigate effect of process parameters on nugget width for seam welded AISI 1015 low carbon steel. The study parameters considered in the experiments are welding current, electrode pressure, welding time. Taguchi's experimental design has been used for optimization to determine optimum process parameters. An orthogonal array of L9 was used for the experimental design and Nugget width was investigated for each experimental run. ANOVA and signal to noise ratio (S/N) were used to find the significant effect of process parameters on nugget width and optimized condition for process parameters. The result showed that welding current found to be most significant factor contributes 78.36 % and welding time was the least significant factor contributing 6.60 %.

KEYWORDS: Nugget width, Resistance welding, Seam welding, Taguchi method, welding current.

I. INTRODUCTION

Resistance welding is pressure welding process widely used in industries for joining of ferrous and non-ferrous materials. Resistance welding process in which the metallurgical bond is created between the faying surfaces either by using heat or pressure. Resistance seam welding is a modified spot welding process which produces continuous weld. Resistance seam welding is a process in which series of overlapping nuggets made progressively along a joint of overlapped faying surfaces of metal sheets by resistance to flow of electric current combined with the pressure of circular electrodes. The principle of Resistance seam welding is similar with the spot welding but produces pressure tight continuous joints by pair of wheels as electrode. The major advantages of seam welding are producing gas tight or liquid tight joints, low cost, high production rates and suitability for automation.

There are three variants of resistance seam welding: standard seam, mash seam and roll spot welding. In standard seam, series of overlapping weld nuggets produced by firing series of continuous current pulses. In mash seam, small overlap of sheet approximately one to two times thickness mash welded by applying current to form solid state joint. The analysis of signal to noise ratio was done using MINITAB 17 software for higher the better quality characteristics. The seam may be butt or overlap joint. As given in Figure.1. Current pulses are timed to flow through the pair of wheels to form row of spot welds along the interface. Heat is generated at the interface of the sheets where joint is to be made. Copper alloy electrodes are commonly used to keep the electrode surface contact minimum. Overlap is depends upon the current on and off time.

Resistance welding works on the joules heating principle. Heat generated at the interface governed by the formula,

$$Q = I^2 Rt \dots \dots \dots (1.1)$$

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Where, Q is heat generated (J), I is current (A), R is resistance of the interface (Ω) and t is time of application of current (Sec or cycle). Principle of resistance seam resistance seam welding Shows in figure 1.

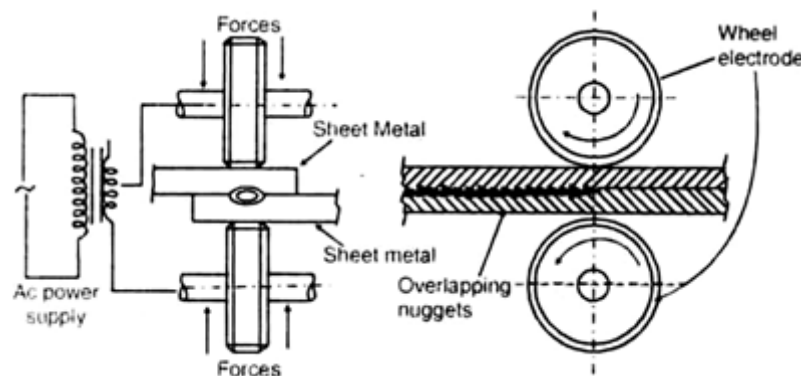


Fig 1. Principle of Seam Welding

II. LITERATURE REVIEW

Resistance seam welding having significant importance in manufacturing gasoline tanks, radiators, heat exchangers, basin sinks due to automated, economical and fast process. Automobile joints require higher load conditions. Hence to avoid the failure weld strength should be higher. Following are the literature survey has been done for work:

Williams et al. [2] studied the factors which influence on the weld formation at high welding speeds for both uncoated and coated steels. They stated that increase in welding speed, increases current requirement for weld formation gradually. Low electrode force levels, interrupted current programs and steels with high resistivity are the Factors which can control the welding speed. The results showed that with use of a wide range of welding speeds and currents minimum indentation welds can be produced.

Tumuluru et al. [3] determined procedure development and practice considerations for seam welding process. Peel test and tensile test was carried out to determine mechanical strength of weld. This paper gives information about seam welding of ferrous materials like low carbon steel, stainless steel. It also described about seam welding of nonferrous materials like Aluminium, Copper, and Bronze etc. They concluded that if the indentation is carefully controlled then tensile strength of 80 to 100% of the parent metal can be achieved of welded joint.

Robert Matteson [4] stated the concept of fundamentals of resistance seam welding. This Paper experimentally showed that if weld force increases under given electrode conditions, there is an improvement in the welding range in speed can be possible. It also leads to control cracking.

Khosravi et al. [5] experimented that when the current for low welding speeds increases it will leads in the decrease nugget size. When more current is used, it also increases joining zone thickness in each galvanized and electro galvanized sheet. Keeping welding current constant when welding speed increases, results in increase in joining zone thickness and nugget size decreases.

Habel-Aleem et al. [6] emphasized that when exhausting pressure increases, there was increase nugget penetration at an identical welding current. The experimental results of tensile shear testing of joints determined that fracture on the 1050 material always takes place near to the fusion boundary. The hardness at the fusion boundary of 1050 Aluminium material increases.

Inoue Tomohiro et al. [7] studied the JFE Steel developed an electric resistance welding (ERW) line pipe technique with a high performance weld seam. The Finite element analysis technique was implemented to construct an analytical

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model of the ERW weld seam. It can be possible to improve seam mechanical properties by Development of homogeneous heating technology.

Esme [8] presents experimental investigation to determine the effect and optimization of process parameters for resistance spot welded SAE 1010 low carbon steel sheets. This paper presents the experimental work conducted under the varying conditions welding current, electrode diameter, electrode force and welding time. Different thickness SAE 1010 the steel sheets taken for the experimental work. Effect of input parameters like on the tensile shear strength is studied during the work. Level of contribution of the each welding process parameter to the overall improvement of the strength and quality is determined by using ANOVA. This paper concludes that welding current and electrode force were found as most dominating process parameters and electrode diameter and welding time were least. The results showed that tensile shear strength was increased by 2.03 and 1.20 mm for 1 mm and 2 mm respectively.

Sahota et al. [9] investigated significant effect of process parameters on spot welded Austenitic SS 316 material on percentage improvement in material hardness. The experimental studies carried out for the process parameters welding current, electrode force and weld cycles. The result showed that an increase in values of weld current, electrode force and weld time, slight increase in weld nugget diameter and width. Increase in electrode indentation due to an increase in current, weld time and electrode force.

III. EXPERIMENTAL PROCEDURE

3.1 Material

AISI 1015 is a general purpose low carbon steel with carbon content lower than 0.18%. Low carbon steel is offers superior workability and machinability. AISI 1015 is used normalized, hot rolled, cold worked or annealed. AISI 1015 material used in industrial applications i.e. Machinery parts, Tool and die applications, Cold extruded and case hardened parts. AISI 1015 steel of thickness 0.8 mm. Chemical composition (percent by weight) and properties of AISI 1015 low carbon steel are given in table 1 and 2.

Table. 1 Material Composition

Percent Composition (%)	Iron Fe	Carbon C	Manganese Mn	Phosphorous P	Sulphur S
	99.296	0.138	0.393	0.005	0.003

Table. 2 Material Properties

Mechanical Properties	Tensile strength MPa	Yield strength MPa	Modulus of elasticity GPa	% Elongation at break	% Reduction in area at break	Hardness (HB)
	385	325	190-210	20%	40%	115

3.2 Experimental Details

Thesize of the specimen used for the experimentation 110 mm × 25 mm suitable dimension for the nugget width measurement. The material selected for this study is AISI 1015 low carbon steel sheet of thickness 0.8mm. The contact overlap of 15 mm selected for the study as shown in fig. 1.

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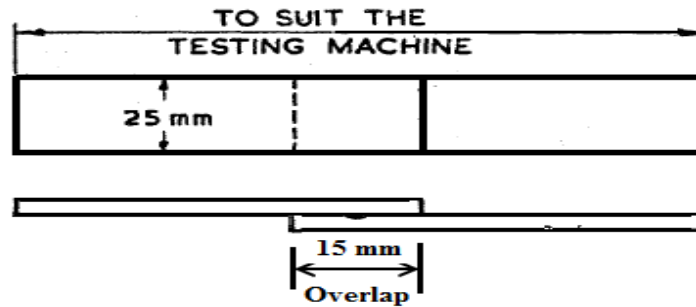


Fig. 2 Dimensions of specimen

Following are the input and output parameters selected for this study: Input parameters are welding current, electrode pressure and welding time. Output parameter is the nugget width. The values for process parameters and their levels is given in the Table 3.

Table. 3 Process parameters and their levels

Process Parameter	Unit	Level 1	Level 2	Level 3
Welding current	KA	4.0	4.5	5.0
Electrode pressure	Kg/ cm ²	3	4	5
Welding Time	Millisecond	10	20	30

For this work, Taguchi experimental design is used for the optimization of the process parameters. With the help of Taguchi method, it is possible to achieve good quality without increasing cost. Taguchi method focused on the mean performance characteristics which close to target value than a value within the specific limit. As the input parameters increases, number of experiments carried out also increases. So in order to solve this, Taguchi method uses orthogonal array to study all process parameters space with only few number of experiments. In this study, L_9 orthogonal array which has 8 degrees of freedom was used. Three levels of each parameter was selected for experimentation. The experimental design layout for process parameters and their levels using orthogonal array L_9 is shown in Table 4.

Table. 4 Experimental layout using L_9 orthogonal array

Experiment No.	Welding Conditions		
	Welding Current(kA)	Electrode force (kg/cm ²)	Welding time (ms)
1	4.0	3.0	10
2	4.0	4.0	20
3	4.0	5.0	30
4	4.5	3.0	20
5	4.5	4.0	30
6	4.5	5.0	10
7	5.0	3.0	30
8	5.0	4.0	10
9	5.0	5.0	20

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IV. RESULT AND DISCUSSIONS

The effect of these process parameters was investigated in form of response variables as nugget width (mm). Nugget width was measured using micro-zoom stereoscope. Results of nugget width are shown in Table 5. The analysis of responses were done by ANOVA and main effects plot.

Quality of the seam welded specimen are determined by the shape and size of the weld nugget formed. Nugget width is the width of weld produced by circular electrode wheel on metal sheets. Measurement of nugget size was used to correlate welding process parameters and mechanical properties of weld produced. Nugget width is measured with the use of stereo-zoom microscope. Table 5. Gives measured nugget width with nugget penetration.

Table 6. also shows that weld penetration are increases, when selected process parameters values increased from their lower to higher levels, Nugget width increases significantly when welding current value increases from low to high level. For the same current, nugget width increased as welding time was also increased. The S/N ratio plots for nugget width is shown in Fig. 4. Result shows that current and electrode force are dominating factors which controls nugget width. It was found that Lower cooling time gives more nugget width.

Table. 5Nugget width analysis

Experiment No.	Nugget width (mm)	Weld Penetration
1	3.12	Lowest
2	3.58	Low
3	3.62	Low
4	3.88	Medium
5	3.82	Medium
6	3.95	Medium
7	4.03	High
8	4.05	High
9	4.25	Highest

V. ANALYSIS OF VARIANCE (ANOVA)

The main aim of ANOVA is statistically based decision making tool to determining the design parameters and indicate the most significant parameters which are affecting the seam welding performance. The results of ANOVA are analyzed using MINITAB 17 software are shown in the Table 6. In ANOVA analysis, sum of squares and variance are determined. F-Test value at 95% confidence level is used to decide the most effective parameters and percentage contribution of them are calculated. Larger F-value shows that variation in the process parameter may large effects on performance [10].

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Table. 6 ANOVA for nugget width

Source	DF	SeqSS	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Welding Current	2	0.69682	0.69682	0.34841	23.52	0.041	78.36
Electrode Pressure	2	0.10416	0.10416	0.05208	3.52	0.221	11.71
Welding Time	2	0.05869	0.05869	0.02934	1.98	0.335	6.60
Error	2	0.02962	0.02962	0.01481			3.33
Total	8	0.88929					100

R- sq = 96.67%

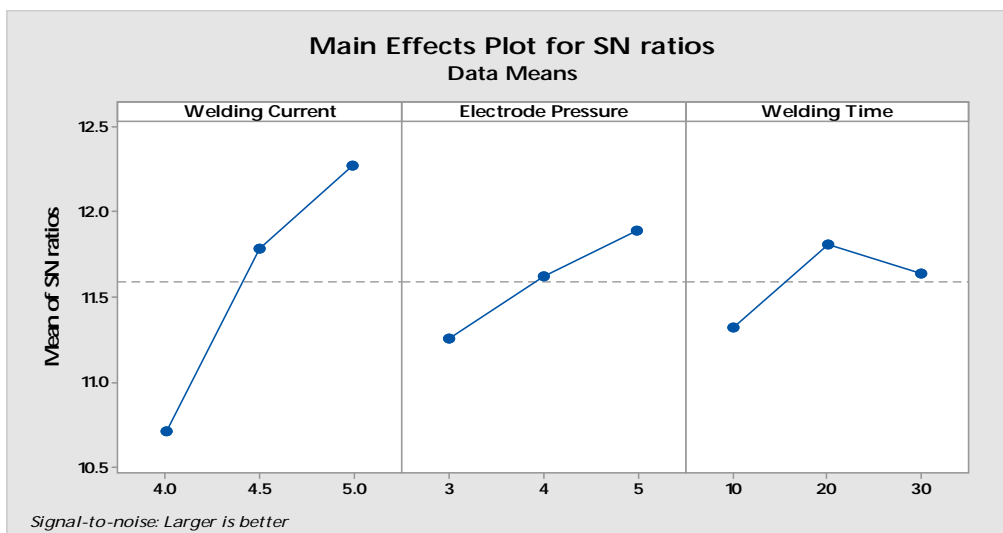


Fig. 4 S/N ratio plot for nugget width

V. CONCLUSIONS

This paper based on the optimization of seam welding process using Taguchi's experimental design method. Experiments have been carried out using L_9 orthogonal array. The following conclusions were drawn:

1. S/N ratio response with respect to nugget width shows that the welding current found as a most significant parameter that controls the nugget width whereas electrode pressure and welding time are comparatively less significant in this regard.

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2. The contribution of welding current towards nugget width is 78.36 % which is highest in all three process parameters affecting weld performance. Nugget width less affected by electrode pressure and welding time contributing 11.71 % and 6.60 % respectively.
3. The optimum parameters were obtained by Taguchi method for nugget width which were as welding current of 5 kA, Electrode pressure of 5 Kg/cm², Welding time of 20ms.

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