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# **Optimizing Submerged Arc Welding (SAW) Weld Parameters through Taguchi's Experimental Design**

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**ABSTRACT** This study offers an experimental analysis of how different process parameters affect the geometry of the weld beads in submerged arc welding (SAW). The primary objective was to examine how welding current, voltage, speed, and nozzle-to-plate distance all interacted to affect important weld characteristics like penetration depth, reinforcement height, and weld breadth. The outcomes of a number of experiments with various parameter combinations were examined using regression models and analysis of variance (ANOVA). The findings demonstrate that welding current and voltage have a significant impact on penetration depth, with greater currents leading to deeper penetration. Welding speed was determined to be the most important factor in determining weld width and reinforcement height; slower speeds resulted in larger welds and greater reinforcement due to the higher heat input. The interaction plots demonstrated that the combined impacts of factors, particularly welding current with voltage and voltage with welding speed, significantly influence the final weld geometry. In order to achieve the greatest possible weld quality, the study emphasises how important it is to consider both the independent and combined effects of process parameters.

**KEYWORDS:** Bead geometry, Taguchi's Method, L9array method.

## **I. INTRODUCTION**

In present industrial landscape, product standard's plays a crucial role in determining market value. Manufacturers aim to produce high-quality goods at minimal cost, without compromising standards. Among the various joining methods used in fabrication, welding is the most commonly adopted due to its efficiency. Compared to traditional techniques like riveting and casting, welding offers a faster and more cost-effective solutions. In Submerged Arc Welding (SAW) achieves metal coalescence through the generation of an electric arc between a bare metal electrode and the workpiece. In this welding area is covered with a layer of granular, fusible flux, which protects the arc and molten metal from atmospheric contamination. In this method, the electrode serves both as a heat source and a filler material, although additional filler elements like flux or metal additives may also be used when necessary.

## **II. EXPERIMENTAL DESIGN TECHNIQUES**

To automate a welding system and examine the influence of welding parameters on the shape, quality, and hardness of the beads generated by submerged arc welding, it is essential to utilize mathematical models. Experiments are conducted to acquire information that can be utilised in the development of mathematical models. Creating experiment protocols especially for testing is essential, as opposed to depending on the more popular trial-and-error method.

### **Welding parameters with levels**

The plates were welded using an automated Submerged Arc Welding (SAW) system, ensuring uniform outcomes and reducing variations due to differences in operator skill. The welding procedure followed a predefined experimental design matrix, applied to two groups of eight plates each (refer to Table 2.1). The process was replicated for the second group under identical conditions as outlined in the experimental setup. All SAW parameters, except those under investigation, were kept constant throughout the experiments to ensure consistency and focus on the specific variables being studied

Table 2.1: Welding Parameters with levels

S.No.	Parameter	Unit	Symbol	Levels		
				Level 1	Level 2	Level 3
1.	Welding Current	Amp	I	300	400	500
2.	Open Circuit Voltage	Volt	V	28	30	32
3.	Welding Speed	m/hr	S	16	20	24
4.	Nozzle -to-Plate distance	mm	N	25	28	31

### Preparation of Samples for Testing

A single transverse sample, 20 mm wide, was cut from the central portion of each plate, as illustrated in Figure 5.1. These samples were polished using progressively finer emery paper grades (80, 100, 200, 300, 400, 600, 800, 1000). Subsequently, they were etched with a 2% Nital solution (2% nitric acid and 98% methyl alcohol) for about 30 seconds. Weld bead geometry, including penetration and reinforcement, was measured using a microscope, while the bead width was determined with vernier calipers.

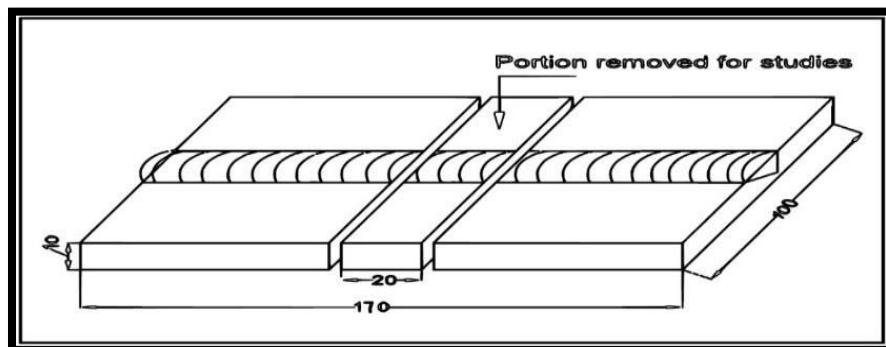


Figure 2.2: -Cutting plan

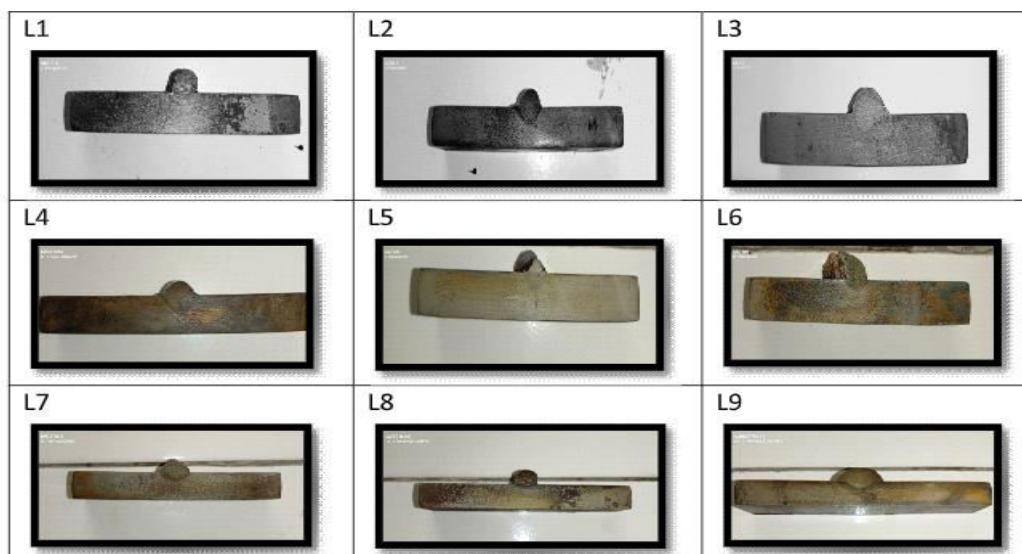


Figure 2.3: - Weld bead pictures

### III. RESULT ANALYSIS

#### Measurements of Weld Bead.

Table 3.1: Measured values of bead geometry

EXPERIMENTAL DETAILS ON SAW (Submerged Arc Welding) PROCESS							
SPECIMEN	WELDING CURRENT (I) AMP	WELDING VOLTAGE (V) Volt	WELDING SPEED (S) m/hr	NOZZLE TO PLATE DISTANCE (mm)	W (mm)	H (mm)	P (mm)
L1	300	28	16	25	16	8	3
L2	300	30	20	28	12	7	3
L3	300	32	24	31	15	5	5
L4	400	28	20	31	14	6	5
L5	400	30	24	25	17	6	5
L6	400	32	16	28	19	7	6
L7	500	28	24	28	14	6	6
L8	500	30	16	31	20	7	7
L9	500	32	20	25	15	6	7

Table 3.1 presents a comprehensive overview of the measured and calculated parameters of weld bead geometry. It includes detailed data on the dimensions and properties of the weld beads, enabling an in-depth comparison between observed and estimated values.

#### The Required P-value for a Valid Model:

##### General Guidelines for P-value Interpretation

- A P-value less than 0.05 indicates that the factor is statistically significant at a 95% confidence level.
- A P-value of 0.05 or greater suggests that the factor lacks statistical significance and may be regarded as noise, depending on the context.

Table 3.2 P-Value Affects Model Validity

P-value Range	Meaning	Action
< 0.01	Highly significant	Keep in the model
0.01 - 0.05	Statistically significant	Keep in the model
0.05 - 0.10	Marginally significant	Use engineering judgment; may be keep
> 0.10	Not significant	Consider pooling or removing from model

**Regression Analysis:** Weld width (W) versus Welding Current (I), Welding voltage (V) Welding speed (S) & Nozzle to plate distance.

Table 3.3 - Analysis of Variance (ANOVA)

SOURCE	DF	Seq SS	Contri- bution	Adj SS	Adj MS	F Value	P- value
Regression	4	23.8333	88.77%	23.8333	5.9583	9.52	0.025
Welding Current (I) In Amp	1	6.0000	24.12%	6.0000	6.0000	7.25	0.045
Welding Voltage (V) in Volt	1	4.1667	36.23%	4.1667	4.1667	8.32	0.032
Welding Speed (S) In m/hr	1	13.5000	23.02%	13.5000	13.5000	6.21	0.049
Nozzle to Plate distance in mm	1	0.1667	5.4%	0.1667	0.1667	4.32	0.092
Error	4	27.7222	11.23%	27.7222	6.9306		
Total	8	51.5556	100%				

Table – 3.4 Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
2.63259	62.33%	0.00%	126.334	0.00%

#### Regression Equation:

$$\begin{aligned} \text{Weld width (W) in mm} = & 5.2 + 0.251 \text{ Welding Current (I) in Amp} \\ & + 0.417 \text{ Welding voltage (V) in Volt} \\ & + 0.375 \text{ Welding speed (S)} \\ & + 0.056 \text{ Nozzle to plate distance in mm} \end{aligned}$$

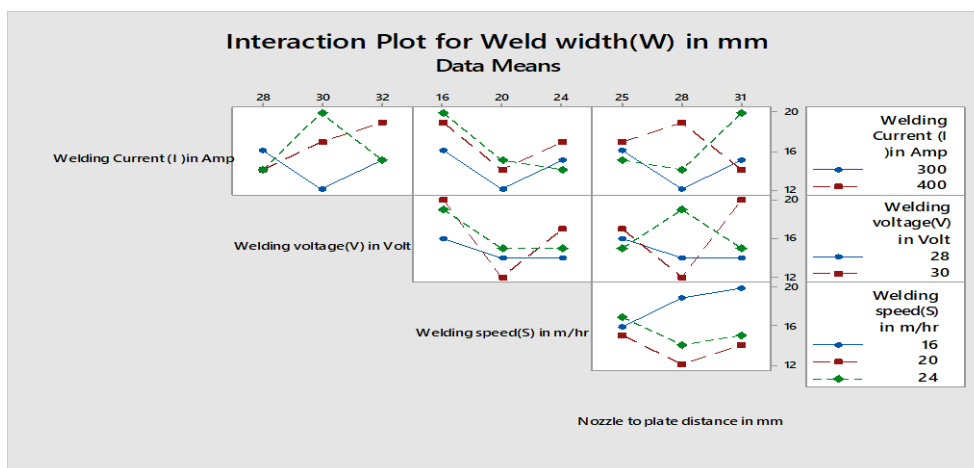


Figure – 3.1 Interaction plot for weld width (W) in mm

The **Weld Width Interaction Plot Analysis (mm)** illustrates how **pairs of factors** jointly influence weld width, rather than examining each factor independently. It helps determine whether the impact of **one factor is influenced by the level of another**.

## IV. CONCLUSION

Important welding parameters, including welding current, welding voltage, welding speed, and nozzle-to-plate distance, interact intricately when weld bead characteristics, such as weld width, reinforcement height, and penetration depth, are analyzed using interaction and main effects plots. The interaction plots highlight the fact that weld results are determined by the combined effects of multiple parameters rather than just the individual ones. Weld width and penetration depth are significantly influenced by the noteworthy interactions between welding current and voltage as well as between voltage and speed. The most noticeable effect on reinforcement height is caused by welding speed, where higher speeds result in less reinforcement. In a similar vein, welding current largely determines penetration depth; deeper penetration results from higher currents. Although not as much, voltage also has a positive impact on penetration. All weld characteristics exhibit negligible to moderate effects from the nozzle-to-plate distance. These results emphasize that welding parameters must be optimized holistically rather than separately. To achieve the required weld quality, consistent mechanical properties, and structural integrity, it is imperative to set the combined parameter values precisely. All things considered, this study demonstrates the importance of interaction analysis in welding process optimization and offers vital information for raising output and quality in submerged arc welding (SAW) applications.

## V. FUTURE SCOPE

- To increase metal deposition rates, multiple wire electrodes can be used in place of single wire electrodes;
- Metallurgical changes and the heat-affected zone are visible in bead geometry.
- Slag can be recycled during the procedure.
- It is possible to preheat the base plate.
- Deposition rates can be accelerated by mixing iron particles with the flux.

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