Experimental investigation and optimization of welding for A TIG welding with SS310 using taguchi method

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Abstract

One of the most used methods for connecting ferrous and non-ferrous metal is tungsten inert gas welding. Wherein the molten metal is shielded from the atmosphere by the inert gas argon, and an arc is created between the work piece and a non-consumable tungsten electrode. TIG welding was used in this job to join SS310 sheet material with a 2 mm thickness. The selected input parameters include welding voltage, current, and gas flow rate. The output parameters are hardness and front width. The Taguchi technique recommended allocating the factors selected for the experiment using an orthogonal array design. Using the Taguchi method's L9 orthogonal array, nine experiments have been constructed. The signal-to-noise (S/N) ratio and analysis of variance (ANOVA) have been used to examine and adjust the welding settings. Following analysis, the front and rear widths' most important control factors were identified.

Keywords: Tig Welding, Anova, Taguchi Method, Minitab, Stainless Steel

1. Introduction

The process of uniting identical metals by adding filler material and applying heat, pressure, or both is called welding. As a result, there is a continuous flow of uniform material with the properties and makeup of two parts being linked. It wouldn't be an exaggeration to state that welding is used in every technical discipline and in every sector of the metals industry without exception due to its wide range of applications. Actually, the degree to which a new metal lends itself to welding manufacturing may determine its future. According to one definition, "weldability" is the ability to be welded into inseparable joints with specific characteristics like particular weld strength, correct structure, etc. Naturally, this means that a metal must weld easily in order for it to function well in the constructed structure if it is to be considered food weldable.

2. Literature Review

In 2021, Sibabrata Mohanty, Gopal Krushna Mohanta, Ajit Kumar Senapati, Kali Charan Rath [1] Welding speed contributes more to tensile strength than welding current and welding voltage, according to the ANOVA table. The welding current has a greater effect to the hardness value. For tensile strength and hardness, the model summary R-SQ (Predicted) was determined to be 97.4% and 96.04%, respectively. Grey Taguchi analysis revealed that the welding speed varied at level-1, welding current varied at level-3, and the parametric setting for reaching the ideal setting voltage changed at level-3. According to the model summary, the grey relational grade's R-SQ (Predicted) in the grey Taguchi analysis was 92.7%.

In 2020, Wichan Chuaiphan, Loeshpahn Srijaroenpramong [2] the investigation of the various TIG welding procedures for low nickel austenitic stainless-steel grades AISI 205 and AISI 216. The weld bead was demonstrated to be flawless and complete when welding at the 1–3.5 mm/sec speed indicated in the parameters. Nevertheless, as the welding speed was increased, the weld bead's width shrank.

It was discovered that the weld metal zone hardness was lower than that of the base metals. When the welding speed was increased, the tensile strength tended to be higher. Following testing, every fracture happened in the weld zone next to base metal 216. It is advised that the TIG welding procedure be used for the dissimilar joining of AISI 205 and AISI 216, with a minimum welding speed of 1 mm/sec and a maximum of 3.5 mm/sec. The welding speed can be increased to 5.2 mm/sec by adding hydrogen at a level of 6 vol.% to the argon shielding gas. This is contingent upon the appropriateness of the characteristics and additional factors affecting the welded metals.

In 2021, Mr. S. Kannan, Research Scholar, Dr. S. Senthil Kumaran, Professor and Head, Dr. L.A. Kumaraswamidhas [3] The Taguchi L25 orthogonal array is utilized to determine the process parameter that has the greatest influence on joint strength. Compression strength and hardness are assessed using the ANOVA approach in order to determine the percentage contribution for each process parameter. The obtained experimental value and GA value have a comparative strength of approximately 174.846 MPa and 174.6054 MPa, respectively. The obtained experimental value's examination of hardness yielded a value of 130.6824 HV, while the GA value was 131.364 HV. Both the compression strength and the hardness of the samples are nearly comparable, demonstrating that the experimental TIG welding procedure is measured and validated.

In 2021, Vela phi Msomi, Sipokazi Mabuwa, Ali Merdji, Oritonda Muribwathoho, Sharon S. Motshwanedi [4] The AA6082/AA8011 TIG-welded joint was successfully processed using the submerged MFSP. Throughout the MFSP process, the AA6082 was maintained on the advancing side. The findings of this investigation have led to the following deductions: The refined grains at the stir zone were the outcome of more FSP passes. The percentage elongation of the joint was significantly impacted by the grain refinement, although the joint's tensile strength was only slightly affected. The majority of the time, an increase in FSP passes has negative effects, but in this study, the regulated heat from the submerged settings prevented this from happening.

In 2021, Kamlesh Kumar, Ch. Sateesh Kumar, Manoj Masanta, Swastik Pradhan [5] The literature review leads to the conclusion that TIG welding techniques can successfully weld thick section materials in a single pass. Several TIG welding variations, including pulse TIG, A-TIG, K-TIG, and MT-TIG, greatly increase the weld penetration depth with comparatively lower heat input, which ultimately raises the weld joint's quality and production efficiency. In addition, the advancement of TIG welding technology has expanded its use in the fabrication sector and drawn significant interest from researchers looking to enhance the quality of weld joints, particularly for sophisticated materials.

In 2019, Nabendu Ghosh, Pradip Kumar Pal, Goutam Nandi [6] Sample number nine yields the greatest results, with a current of 124A, a flow rate of 20 l/min, and a nozzle to plate distance of 12 mm. Sample number 5, which corresponds to current 112 A, gas flow rate of 15 l/min, and nozzle to plate distance of 15 mm, yielded the worst result in the tensile tests. Plots showing the mean main effect and the S/N ratio have been used to identify the ideal parametric combination. With a welding current of 124A, a gas flow rate of 10 l/min, and a nozzle to plate distance of 9 mm, the ideal factor setting is C3F1S1.

3. Literature review summery

I've discovered a gap in the literature from numerous literature reviews: numerous research papers focus on welding and various parameters. Thus, by carrying out work for tig welding optimization, we attempted to extract the target. While researching for a research paper, I discovered that, when comparing the ANOVA result from Taguchi, the welding current is the parameter that has the biggest impact on performance attributes, followed by welding voltage and speed. In addition, I have chosen SS310 material with a plate thickness of 2 mm, chosen process variables such gas flow rate (LPM) and welding current (A), and examined the impact on bead height and width. Through my study, I have attempted to optimize the process parameters. The Taguchi approach is what I used for this project.

4. Design Experiment

In an experiment containing numerous parameters, DOE is a strategy for defining, examining, and determining the optimal combination. This identifies various elements along with their respective levels. Combining variables at the right amounts, each within their own acceptable range, to yield the greatest findings and yet show the least amount of variance around the optimal results is another valuable application of experimental design. The arrangement of the many situations to be investigated is developed using the experiment design. Two requirements must be met by the experiment design: first, the number of trails and second, the circumstances for each trail must be established. Understanding the product or process being studied is crucial before designing an experiment in order to determine the variables that will most likely affect the result. A technique for determining the critical elements of a process, locating and resolving process issues, and spotting potential estimation interactions is the Design of Experiments (DOE).

1. Taguchi Design

In order to arrange the process parameters and the levels at which they should be varied, Taguchi proposed an experiment design that uses an orthogonal array. This design saves time and resources by allowing for the collection of the necessary data to identify the factors that most affect product quality with the least amount of experimentation.

2. Process Parameters

Input Parameter

1) Factor A: Welding Current
2) Factor B: Welding Voltage Factor
3) C: Gas Flow Rate

Constant parameter

1) Work Piece Thickness

Output Parameter

1) Front Width Hardness
2) Hardness

Table 1: Process Parameter Level

Thickness	Parameters	Level 1	Level 2	Level 3
2mm	Welding Current	80	90	100
	Welding Voltage	18	22	24
	Gas Flow Rate	1.5	2.5	3.5

Table 2: Taguchi Design Factor

Ex. No.	Welding Current	Welding Voltage	Gas Flow Rate	Plate Thick Ness
1.	80	18	1.5	2
2.	80	22	2.5	2
3.	80	24	3.5	2
4.	90	18	2.5	2
5.	90	22	3.5	2
6.	90	24	1.5	2
7.	100	18	3.5	2
8.	100	22	1.5	2
9.	100	24	2.5	2

5 Experimental works

A. Working procedure

- Material selection
- Material testing
- Specimen preparation
- Experiment work
- Testing result

B. TIG welding machines specifications are as

- Make-HALLMARK
- Code- TIG 200A
- Volatge-230 V AC
- Curent-25-200 A
- Electrode-Tungsten

Fig. 1: TIG Welding Machine set-up

C. Welding Torch

Specifications of the welding torch which is used for these experiments are Forced Air cooled cooling system Collets for 0.8-1.6. Φ electrode.

Fig 2: Welding Torch

D. Material selection

SS310 is the material chosen for the trials and tests with welding. Compared to Type 302, austenitic Cr-Ni stainless steel is more resistant to corrosion. Superior drawing, shaping, and spinning qualities, along with high ductility. When cold worked, this mostly non-magnetic material becomes mildly magnetic. Less susceptibility to intergranular corrosion and less carbide precipitation in the heat-affected zone during welding are two benefits of low carbon content.

Table 3: Chemical Composition

Chemical	3mm
%C	0.055
%Mn	1.65
%Si	0.50
%Cr	24.00-26.00
%S	0.001
%P	0.023
%Ni	19.10
%Mo	0.062

Table 4: Physical properties of SS310)

Density	7.84 gm/cc
Melting Point	1150°C
Thermal Expansion	8.8×10^{-6}/K

E. Work piece detail

SS310 is chosen for the study because the process industry uses it extensively. The chosen material thickness was 2 mm. The chosen specimen size, in accordance with ASTM standards, is 60 x 40 mm.

Fig 3: Thicknesses of work piece material of SS310

E. Welding performance of tig welding machine

Visual observations are used to verify penetration following the welding of the work components. Rejected specimens have inappropriate penetration. The impact of welding parameters on bead geometry is investigated by utilizing a traveling microscope to measure the front and rear widths.

Fig 4: Welded job

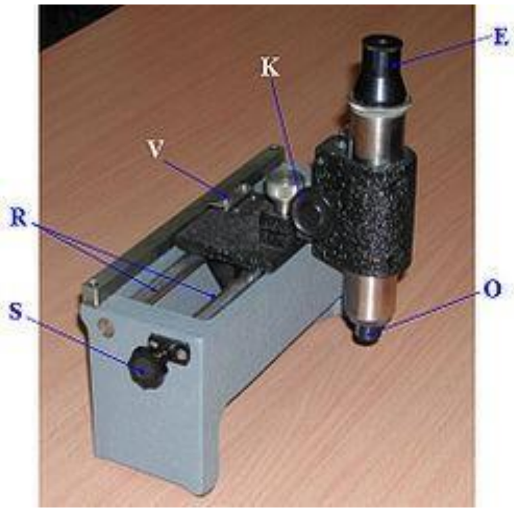

Fig 5: Travelling Microscope

E- Eyepiece
V- Vernier
O- Objective
R- Rail
K- Knob of focusing
S- Screw

Table 5: Experiment

Ex. No	Welding Current	Welding Voltage	Gas Flow Rate	Plate Thick Ness	Front Width	Hardness
1	80	18	1.5	2	5.15	65.33
2	80	22	2.5	2	5.04	90.33
3	80	24	3.5	2	4.35	83.66
4	90	18	2.5	2	4.90	77.33
5	90	22	3.5	2	5.41	88.33
6	90	24	1.5	2	5.75	93.00
7	100	18	3.5	2	5.95	94.33
8	100	22	1.5	2	6.10	105.33
9	100	24	2.5	2	5.80	115.00

6. Objective

- For the experiment, I have chosen SS310 sheet material with a 2 mm thickness.
- The Taguchi Method of Choice Using the L9 Orthogonal Array.
- The experimental data is analysed using Minitab software.
- Set up the Tig welding job and measure the job's front breadth and hardness.
- Use this study to optimize the process parameter by analysing the impact of the welding process parameter on the weld bead geometry.

7. Conclusions

- The current study used parametric analysis to determine the hardness and front width of SS316 material. SS316 material with a thickness of 2 mm is used in experiments utilizing the Taguchi Method, which involves adjusting the welding voltage, current, and gas flow rate. The software Minitab 16 was utilized to examine the experimental data.
- I've come to the conclusion that the maximum F.W. (6.10 mm) may be measured at welding current (100A), welding voltage (22V), and gas flow rate (1.5LPM). Similarly, the minimum F.W. (4.35) can be measured at welding current (80A), welding voltage (24V), and gas flow rate (3.5 LPM).and measure the maximum hardness (115 HRB) at the welding current (100A), welding voltage (24V), and gas flow rate (2.5 LPM). Likewise, measure the minimum hardness (65.33 HRB) at the welding current (80A), welding voltage (18V), and gas flow rate (1.5 LPM).
- Welding current increases as front width increases, as does gas flow rate, and voltage increases as front width increases up to a certain point before declining.
- Up to a certain point, increasing hardness causes a rise in welding current and voltage, and ultimately a fall in hardness.
- The most important control factor for front breadth and hardness is welding current.

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