Parametric Optimization for Tensile Strength and Hardness of MIG Welding Joint of Dissimilar Steel Alloys Using Taguchi Technique

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***Abstract*: This paper explores the Welding process of joining metals which are similar and different in composition, using a filler rod and with or without the use of pressure. During the welding process, metals and thermoplastics are joined together. The most basic level of welding needs the application of four components, including metals, a heat source, filler metal, and some kind of air barrier, to be successful. Heat is applied to the metals to bring them to their melting temperatures while keeping them shielded from the air. A filler metal is then introduced into the heated area to form a single piece of metal. In both domestic and industrial applications, the welding method is extensively employed, for example, in the connecting of railroads and ships, as well as the construction of roads and bridges, and in the assembly of mechanical components. The brazing and soldering processes are similar to the welding process in their results. When it comes to MIG welding stainless steel 202 and stainless steel, a selection of three factors was used in this study, including soldering current, soldering voltage, and gas flow rate. The need for selecting these three parameters is only due to the fact that these three variables have the greatest influence on the geometry of the solder bed. The investigation is carried out with the help of nine components. The orthogonal array L9 (3*3) is used in this design, which is based on the Taguchi design. For tensile strength, it was discovered that the highest soldering voltage has the greatest effect, followed by the lowest soldering current and the slowest gas flow rate. Hardness is influenced by many factors, the most significant of which is the gas flow rate, which is followed by soldering current and soldering voltage. It is very beneficial in the creation of high-quality products to use the Taguchi method. We are unable to handle the many design elements without the assistance of human judgments, and doing so would be very time consuming and expensive.**

***Keywords*: Parametric Optimization, Tensile Strength, MIG Welding, Steel Alloys, Taguchi Technique**

I. INTRODUCTION

Welding is a process of connecting comparable and dissimilar metals using a filler rod and with or without the use of pressure. Metals or thermoplastics are welded during the welding process. At the simplest level, welding requires the application of four components, such as metals, a heat source, filler metal and a kind of air barrier. The metals are heated while protected from the air to their melting points, and a filler metal is then added to the heated region in order to create a single piece of metal. The welding technique is widely used for household and industrial applications such as joining of railways, ships, roads, bridges and mechanical components, etc. The brazing and soldering methods are comparable to the welding process.

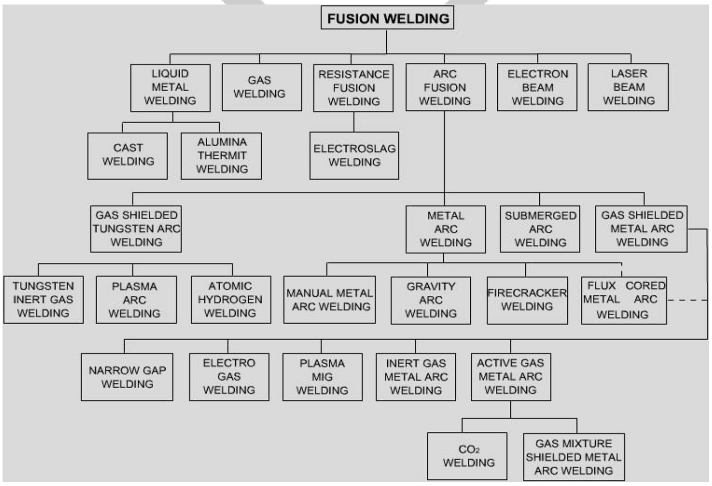

Fig. 1: Classification of Fusion welding [1].

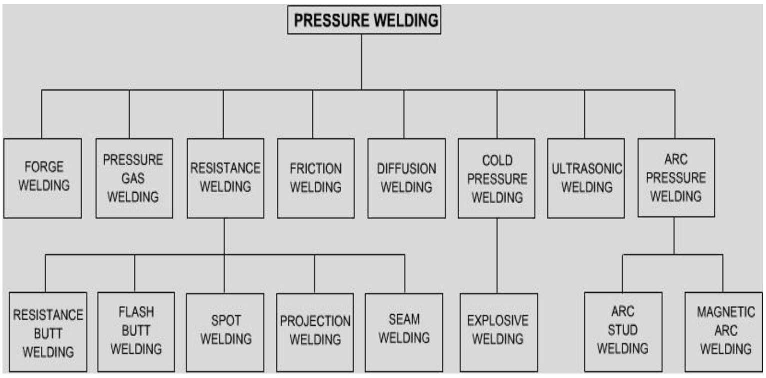

Fig. 2: Classification of Pressure welding [1].

Arc welding is the most renowned method of welding above. This kind of welding initially appeared in the late 19th century. During the Second World War, Arc welding became the most important manufacturing technique. It is a kind of welding that utilizes a power source for soldering the metals at the welding point in an electric arch between an electrical arc and the base material. The electricity may be either direct (DC) or alternating (AC) and consumable or non-consumable. The welding area is typically covered by gas, vapor or slag shielding [1].

Welding techniques are extensively utilized in industrial applications such as oxy-acetylene, arc welding (SMAW), gas metal arc (GMAW), gas arc (GTAW), resistance welding and soldering of heat. Upstream welding has an own field, such as strength welding in the automotive industry. The soldering of thermite is used to connect railway lines. Gas Tungsten Arc welding is used in aerospace and nuclear sectors. GMAW is utilized in the welding of low carbon steel, inox, aluminum and carbon steel, etc.

Gas metal arc welding (GMAW) can be done in three ways:

1. Automatic welding: This process appliance uses welding equipment without changing the operator's settings. This kind of soldering regulates the gun's alignment in a solder junction.
2. Machine welding: utilizes the manipulator gun. 2. A sand-set operator changes the controls that move the manipulator.
3. Semi-automatic softening: This process equipment regulates the wire feed of the electrode. The movement of the welding gun is controlled by hand. It is sometimes referred to as hand welding.

Working principle and operation of Metal Inert Gas (MIG) welding

The arc develops between the workpiece and the filler metal. Work-piece must be sold with the assistance of a wire-shaped consumable electrode linked to a DC power source. The arc is generated when the consumable electrode is close to the workpiece. After this melted electrode covers the area of the workpiece, this arc melts the electrode. The electrode is supplied with inert gas. This implies protecting gas surrounding the arc to protect the welding region from the atmosphere[4].

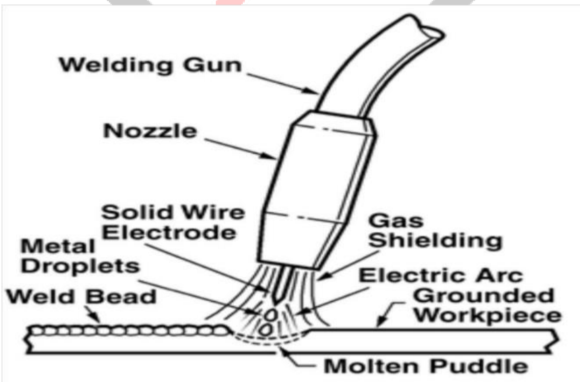

Fig. 3: Metal Inert Gas Welding [4].

During the welding process, protective gas and electrode depending on the material to be sold are utilized. Consumable electrode acting as a filler metal is utilized for MIG welding. So no additional filler wire or filler rod is needed. This technique connects the negative pole to the workpiece and the positive polarity to the torch or weapon. The primary aim is to improve penetration and smoothness.

welding. MIG welding is suited for materials of greater than 3 mm thickness. The concept of MIG and TIG is almost the same but the difference is that the MIG process uses a consumable wire electrode and the thickness of the material should be 3 mm. The main concept of MIG welding is 'electric arc heat production.' The heat melts the electrode wire and the base metal plates throughout the process. After making a sturdy junction, solidify together. If this process uses non-ferrous metal, argon gas is frequently utilized. In this process various shielding gasses such as CO2, oxygen, helium, carbon dioxide and nitrogen, etc. are utilized, but CO2 mostly is used for ferrous material. The CO2 gas is heavy and the welding area may easily be covered. In the Gas Metal arc soldering process, a constant voltage and direct current (DC) source is frequently utilized. Alternative and continuous current may be utilized, though. This welding may be carried out automatically and semi-automatically. Sulks, such as mild steel, copper, stainless steel and aluminum may mostly be used in all kinds of metals[4].

II. TAGUCHI OPTIMIZATION APPROACH

Introduction of Taguchi technique

Taguchi approach is the quality engineering system and one of the major engineering techniques created by a Japanese engineer, Genichi Taguchi, in the 20th century. Taguchi techniques use factorial designs of two, three and mixed levels. This approach focuses on the use of engineering rather than the sophisticated statistical methodology. Taguchi's primary aim is to improve quality at a minimal cost. Taguchi approach develops experimental design techniques to examine how the various factors influence the variance and mean process parameters. In Taguchi, experimental design is presented where 'OA' organizes the input parameters and levels that vary. The Taguchi method is best used when there is an intermediate no. of variances such as 4 to 55 between certain variables and few variables which refer to designs as "off-line quality control," as they guarantee the high quality of the design stage [25].

Philosophy of Taguchi technique

Fig. 4: Philosophy of Taguchi technique

Taguchi method is utilized in both quality engineering on the factory floor and the upstream. The shop floor is based on costs, maintenance quality and real-time for monitoring and the upstream approach is utilized to minimize costs, variability and placing of the market. Moreover, a technology of improvement that saves time and cost etc.[26].
Three basic concepts such as: Taguchi's philosophy

i. Product quality should be developed and not examined.

ii. The quality that is best achieved by reducing the departure from the objective.

iii. Quality costs must be assessed from standard standards as function deviations and system wide losses must be quantified. Under Taguchi technology, bad quality cannot be improved by screening, inspecting etc., three parameters such parameters, system design and tolerance design etc [38] are included in this process.

Design of experiments strategy

It is a method that R.A. Fisher developed in 1920 to investigate the effects of numerous factors. The experimental design utilizes Taguchi method to solve process and product design issues and optimization problems. DOE method of investment and the definition of potential combinations and the identification of the best combinations also identified the various variables and levels. The primary goals of the DOE are to find the optimal levels and achieve the acceptable outputs for the different variables.
The DOE goals are as follows:

1. To study optimal process or product conditions, etc.
2. To evaluate the reaction under different best or optimal circumstances.
3. Examine the contribution of different interactions and parameters [37].

In the first goal showing the impact of different settings. The primary impact that displays the influence trend of several factors. In the second goal, the individual parameters using the ANOVA method, which may be used to estimate the percentage of different parameters versus experimental levels.

III. METHODOLOGY

Selection of process parameters

In this study, eight parameters are primarily utilized. But three factors are utilized during MIG Welding process. This may improve soldering strength and hardness. For this experimental activity, the following process parameters were chosen.

• Current welding - A

• Voltage for soldering - B

• Rate of gas flow – C

IV. RESULTS AND DISCUSSIONS

Table 1: Tensile strength test results

RUN	CURRENT (Amp)	VOLTAGE (Volt)	GAS FLOW RATE (L/min)	TENSILE STRENGTH (MPa)
1.	50	15	15	455.96
2.	50	20	10	653.06
3.	50	18	20	379.82
4.	75	15	10	326.44
5.	75	20	20	537.36
6.	75	18	15	235.57
7.	100	15	20	149.89
8.	100	20	15	436.70
9.	100	18	10	484.59

Taguchi analysis for S/N Ratio and tensile strength

Taguchi method studies the variance in S/N response and minimizes the change in quality attributes owing to uncheckable factors. Here, using the idea "Larger the better," tensile strength is taken into account.The formula utilized for the bigger response is better for the S/N ratio.

$$S/N = -10 \log 1/n\ (\Sigma 1/Y^2)$$

Where n is the row / trial number of measurements, in this instance n=1 and y = row / row value measurements.
Table 2: Response table of Tensile strength versus current, voltage and gasflow rate.

LEVEL	WELDING CURRENT	WELDING VOLTAGE	GAS FLOW RATE
1.	53.69	48.99	53.43
2.	50.77	50.91	51.14
3.	50.01	54.57	49.90
DELTA	3.68	5.58	3.52
RANK	2	1	3

Results and discussions of S/N Ratio of the Tensile strength

Each linear model analysis gives the coefficient at the low level of each component, p values and variance table analysis no. Use these results to establish the factor in the response data and each relative factor in the mode is essential.

Absolute value indicating the proportional significance of each component to the sequential and adjusted sum of ANOVA squares Table shows the proportional significance of each element which has the largest effect on the square. These findings are shown in the answer tables. The response tables 5.3. displays the average of the S/N ratio and mean of each answer. For each degree of the individual variables. The table contains the rank based on the delta statistics and compares the relative size of the impacts, the Minitab ranking, and the usage of the levels in the response table to decide which level of each component gives the best outcome.

These rankings are shown in my experimental work and demonstrate that the soldering voltage has the largest impact on the S/N ratio and then the welding current, followed by a gas flow rate, has the biggest impact thereafter. Our objective is therefore to increase the MIG solder joint strength of different materials and also to increase the factor levels, the average of which is the highest by dayuchi technique, we want to maximize the S/N ratio and we want also the maximum possible means at 18 Volt soldering voltage, 50 Amps soldering current and 15 L/min gas flow rate.

The following table displays the findings of the optimal tensile strength parameters:

Table 3: Results of optimum parameter for tensile strength

RANK 1	Welding Voltage	Level 3	18 Volts
RANK 2	Welding Current	Level 1	50 Amps
RANK 3	Gas Flow Rate	Level 1	15 L/min

Those findings indicate that Stainless Steel 202 and Stainless Steel 304 have greater tensile strength. When we used a soldering voltage of 18 volts, we used 50 amps and a gas flow rate of 15 l/min. These are thus optimal welding conditions for the greater tensile strength of Stainless Steel 202 and Stainless Steel 304.

Table 4: ANOVA results for Tensile strength versus the welding parameters.

SOURCE	DF	SEQ. SS	ADJ. SS	ADJ. MS	F-VALUE	P-VALUE
Welding Current(Amp)	2	36325	36325	18162	1.03	0.492
Welding Voltage(Volt)	2	87643	87643	43821	2.49	0.286
Gas Flow Rate(L/min)	2	30463	30463	15232	0.87	0.536
Residual Error	2	35129	35129	17565		
Total	8	189560				

V. CONCLUSIONS AND FUTURE SCOPE

In this present research, a choice of three parameters, i.e., soldering current, soldering voltage and gas flow rate, were chosen for MIG welding of Stainless Steel 202 and Stainless Steel. The need to choose these three parameters is only due to these three factors having the most impact on the geometry of the solder bed. The research is carried out using 9 components. On the basis of Taguchi design, the orthogonal array L9 (3*3) is utilized. The research showed that soldering voltage has the most impact, followed by soldering current and gas flow rate, in the case of tensile strength. In the event of hardness, the most important impact is the gas flow rate followed by the soldering current and the soldering voltage. Taguchi technique is extremely helpful in the development of goods of high quality. With the aid of human judgements, we cannot manage the different design aspects and it is very time consuming and costly if we do so. The research conclusion may be reached:

1. The Taguchi technique is extremely helpful for optimizing the welding settings.
2. Optimum tensile strength parameter values.

RANK 1	Welding Voltage	Level 3	18 Volts
RANK 2	Welding Current	Level 1	50 Amps
RANK 3	Gas Flow Rate	Level 1	15 L/min

Future scope

• We may improve additional factors by utilizing Taguchi method.
• By adopting an optimization method, operating costs may be minimized.

This technique may also improve other welding parameters such as welding speed, electrode size, polarity, etc. for future work and can be applied to other grades of Stainless Steel as well.

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