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Process Parameter Optimization in Dissimilar Joining with MIG Welding between SAPH 440 steel and Aluminium Alloy 6063

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Abstract: In any manufacturing firm, welding is amongst the most important and effective industrial operations. In today's production environment, welding process optimization is critical in order for a production unit to react successfully to fierce competition & rising excellence demands that must be met at a low cost.

Welding input parameters determine the a weld's fineness. The objective of this research was to investigate the best welding conditions for joining SAPH 440 steel and aluminium alloy 6063. The purpose of this research is to evaluate the effects of the fusion & its welding speed and other variables, welding current, rate of wire feed, & torch distance and its angles were among the welding variables evaluated in this case study. An productive strategy is founded on Taguchi's method approach, and the S/N ratio was used to optimise responsiveness on shear strength. Welding variables had a considerable impact on shear strength behaviour, according to the findings. Experiments were carried out by altering welding speed, welding current, wire feed rate, and torch distance and its angles using the Taguchi method's L27 orthogonal array.

Keywords: Taguchi method, Process parameters, MIG Welding, optimization SAPH 440 steel, aluminium alloy 6063, shear strength, dissimilar joining

I. INTRODUCTION

Among the different industrial processes, Metal Inert Gas Welding is amongst the most basic and widely employed fabrication methods. Tensile strength, yield strength, and elongation are all desirable physical qualities in welded components. Because of their great strength, formability, and low density, aluminium alloy and steel sheet are generally utilized for complex parts. These disparate materials, on the other hand, are difficult to weld together. This occurs as a result of the materials' dissimilar and disparate physical properties.

In contrast to steel properties, aluminium alloys have a low melting temperature, high heat conductivity and solubility, oxide formation, and significant solidification shrinkage. Aluminum alloy is very well-known for oxidizing easily when exposed to greater temperatures or increased during the welding process, heat is used as a source of energy. In general, increasing transmission of heats during the weld methodology reduces joint strength because it increases the development and growth of intermetallic compounds (IMCs). The IMC surface's depth has increased an impact on joint endurance and dependability. The IMC's expansion can compromise the joint's mechanical strength.

Due to its easily regulated joining technique for sheets metal, MIG/MAG welding machines are commonly used in the automotive production industries. As a result, MIG is a good choice for connecting aluminium and steel alloys since it has a variable heat input. Furthermore, the spreadability metals used for the filler's liquid on the surface of the welded joint helps to improve the mechanical qualities of dissimilar sheet joins. In such cases, welding and joining processes must be used, with optimization parameters specified to ensure safety and joint ability in working conditions. In general, mathematical, and statistical methodologies can be utilised to determine the best parameter. The Taguchi technique is well known for determining the elements that have the most impact on the outcome with the least number of experimentations, therefore saving time and money for industry. As a result, the ideal welding condition for dissimilar joining of SAPH 440 steel & aluminium alloy 6063 by MIG welding was identified in this work. Welding speed, current, wire feed rate, torch distance, and angle were among the variables investigated. This study looked into the effect of response optimization on shear strength. The Taguchi method was utilised to determine the best welding conditions using the S/N ratio.

A. MIG Welding Process

The wires is supplied in such a perpetual cycle an appropriate torches or firearms that serves as an electrodes as well as a fillers. A circumferential gaseous nozzle is found on the cannon or flame that routes a protective gas that surrounds and envelopes the freshly produced weld to avoid any contamination from the atmosphere. The weld is generated when +ve charged electrode (its unbroken cable) comes into close contact with the work piece's negative electrode, allowing a large current to flow through the wire and heating the tip above its melting point.

The type of gas or gas combination used in welding varies depending on the metal to be welded. To some extent, the gas is chosen to save money because inert gases are expensive, but it is more typically chosen for its effect on arc properties, such as burn off rate, metal transfer type, and penetration. When it comes to choosing a gas, these crucial factors play a big role. Argon plus carbon dioxide is a gas mixture that combines the benefits of both gases. The fundamental benefit of the MIG welding technology is its fast-welding speed and high deposition rates. Because no slag is left behind in this technique, there is no need to clean the weld once the welding operation is completed; this saves the welder a lot of time, increasing production rates.

The main benefit is that, assuming all welding process parameters are optimised, only low-skill labour is required to operate the welding setup. There is also the benefit of no stub end losses or lost man hours due to electrode changes. A whole spool is used as an electrode since it lasts longer and can be simply interchanged. With the use of welding fixtures and robots, the MIG welding process can be simply automated. MIG welding is a type of easy metal welding that does not necessitate a high level of competence to get satisfactory results.

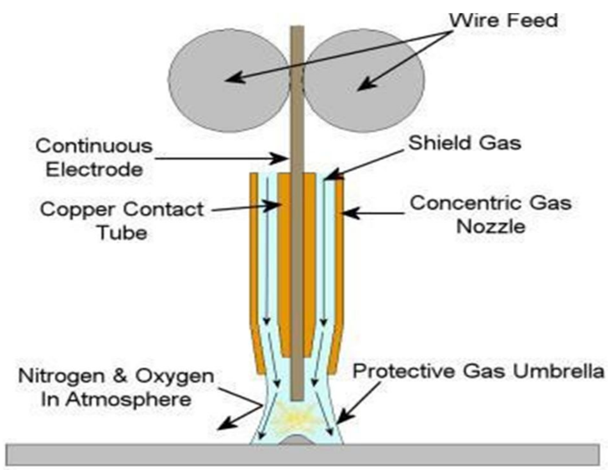

Figure 1: MIG Welding Process

When the operator pulls down the trigger, an electrode wire and gas are automatically fed through the gun at a user-defined speed or pressure. The electronic arc can also be user-defined and carried out automatically during operation. MIG welding is a fast and simple kind of welding that is frequently employed by robotics in automated manufacturing lines. The capacity of a welding operation to achieve the necessary depth of penetration is determined by a number of factors. The penetration of a weld is determined by the current, voltage, gas flow, welding speed, and wire diameter. Small modifications in any of the elements stated can have a big impact on penetration depth.

The purpose of this research is to show and debate several optimization methodologies and tactics for improving penetration depth based on experimental research.

Before beginning the primary experimentation, I conducted some interviews with firm employees and used a research article to choose three input parameters: current, voltage, and gas flow rate. According to the results of the OVAT (One Variable at a Time) analysis, current, voltage, and gas flow rate are affecting parameters on Penetration. Three values for each parameter were chosen based on the results. According to OVAT analysis, the following input parameters, namely current, voltage, and gas flow rate, are chosen while other process parameters that have a lesser impact on penetration are kept unchanged.

II. EXPERIMENTAL DETAILS

A. *Design of Experiments*

To plan the tests, the Taguchi Technique is employed. The Taguchi technique has become a popular approach for enhancing research and development output so that higher-quality goods may be produced rapidly and at a low cost. Dr. Taguchi of the Nippon Telephone and Telegraph Company in Japan has developed a method based on "ORTHOGONAL ARRAY" tests that results in a considerably lower "variance" for the experiment when the control variables are "optimised".

The Taguchi Method does this by combining Design of Experiments with control parameter optimization to find the optimal results. It presents a simple and economical integrated approach for determining the best range of designs in terms of quality, performance & computational cost. Dr. Taguchi's Signal-to-Noise Ratios (S/N) and "Orthogonal Arrays" (OA) provide a set of well-balanced (minimum) trials, which are log functions of the intended output and serve as objective functions in optimization, assisting in data analysis and estimating the best results.

In this study, we looked at three elements that have a significant impact on quality characteristics: (A) welding speed, (B) welding current, (C) wire feed rate, (D) torch distance, (E) torch angle. Taguchi approach was used to design the experiment, which was done with Minitab 14 software. The major goal of this technique is to optimize Penetration, which is influenced by 5 different input processes that were chosen for this study.

B. *Experimental Setup*

The following items are required for any MIG welding process: welding power source, welding torch, wire feed mechanism, shielding gas cylinder, pressure regulator, flow meter, gas preheater, electrode wire, control panel, operator safety equipment, and finally a suitable welding fixture. A series of experiments were carried out to determine the impact of MIG welding process parameters and tensile strength.

C. *Selection of Orthogonal Array*

L9 (3*5) Orthogonal Array was chosen for this study since there were five controllable parameters and three levels of each factor to evaluate.

1) *Power Source:* On a Fronius, Vario Star 2500, the test was performed. The type of welding machine to use is determined by the material to be welded, overall size, material thickness, and other factors. The minimal penetration desired is 25 percent of thickness, according to the thumb rule. To attain maximum durability, it is self-evident that bigger is always better. MIG welding is performed with a positive polarity DC electrode (welding wire) (DCEP). With certain self-shielding and gas-shielded cored wires, however, DCEN is employed (for a faster burn off rate). A transformer-rectifier architecture with a flat characteristic is used for DC output power sources (constant voltage power source). Switched primary transformer rectifiers with constant voltage characteristics from both 3-phase 415V and 1-phase 240V input sources are the most frequent type of power source used for this procedure. The overall components are taken into account, and a welding machine is chosen based on the minimum and maximum dimensions of each component. Table 1 shows the machine's specifications and description.

Table 1: Specification and Description ofmachine

Specification	Description
Mains voltage	3 x 230 V / 400 V, +/- 10 %
Mains frequency	50/60 Hz
Mains fuse protection	16 Amp
Efficiency	75% (130 Amp)
Welding current range	25 – 250 Amp
Open circuit voltage	38 V
Operating voltage	15.3 – 26.5 V
Cooling	Air
Dimensions	800 x 380 x 680 mm
Weight	74 kg / 162.8 lb

2) *Wire feed Mechanism:* The main purpose of the wire feed mechanism is to send electrode to the torch at a constant or variable pace according on the component's requirements. The wire spool is located near the feeding mechanism, and the electrode is fed through the feeder at a predetermined speed using the welding flame. The controlled supply of welding wire to the point to be welded is provided by the wire-feed unit, or sub-assembly, which is mounted in the power source cabinet (known as a composite MIG). A constant rate of wire speed is necessary depending on the welding wire size and the Arc voltage provided by the power source; in MIG welding, the power source provides the Arc voltage.

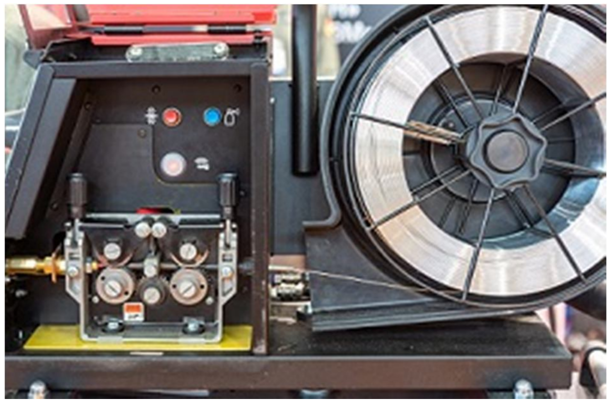

Figure 2: Wire Feed Mechanism

The source controls the arc voltage, whereas the wire feed unit controls the welding wire speed (which in MIG translates to welding current).

3) *Gas Preheater and Pressure Regulator:* The main goal of the shielding gas pressure regulator and the preheater is to keep the shielding gas temperature at an optimal level for maximum welding efficiency. The importance of the parameter setting is that it is directly proportional to the gas consumption.

Figure 3: Gas Preheater and PressureRegulator

III. EXPERIMENTAL CONDITIONS

Various steel plates of SAPH 440 steel & aluminium alloy 6063 of 1.0 mm thickness have been brazed by MIG/MAG welding machine in this experiment (*Fronius, Vario Star 2500*). All equipment must be configured with the correct parameters, such as wire feed speed, shielding gas cylinder pressure, flow meter adjustment, gas preheater temperature, electrode wire spool positioning, operator safety equipment, and finally, the appropriate welding fixture.

Tables 1 and 2 reveal the chemical compositions of the steel and aluminium alloys used in this investigation. Before welding, the substrates sheet was trimmed to 10x10cm dimensions and chemically cleaned with acetone. The Al-12Si wt% filler metal with a diameter of 1.0 mm was employed in the welding process, along with high-purity argon gas for weld protection. The aluminium alloy & steel plates will be at the top and bottom of the brazed joint, which had a 20 mm overlap length. Figure 1 depicts a brazed sheet design and geometric representations for a lap joint. The brazed specimens were then cut into 20x60 mm pieces after welding. A universal testing equipment was used to perform the lap shear testing (Zwick, Z020).

Table 2: SAPH 440 steel chemical composition.

C	Si	Mn	P	S	Al	Fe
0.21	0.3	1.5	0.03	0.025	0.01	Bal.

Table 3: Aluminum alloy 6063 chemical composition

Si	Cu	Mg	Cr	Al
0.60	0.10	0.90	0.10	Bal

The controlled variables and levels chosen in this experiment are listed in Table 3. The control variables were determined based on previous research and the MIG/MAG welding machine's user manual guide. The experimental design was based on the Taguchi method and used an L27 orthogonal array. Main effects and signal-to-noise ratio (S/N ratio) analysis were used to examine the findings. The optimal levels with the highest S/N ratio were chosen, and Minitab software was used to calculate the projected shear strength from the best welding condition. Finally, the experimental and estimated results were compared in a confirmation test.

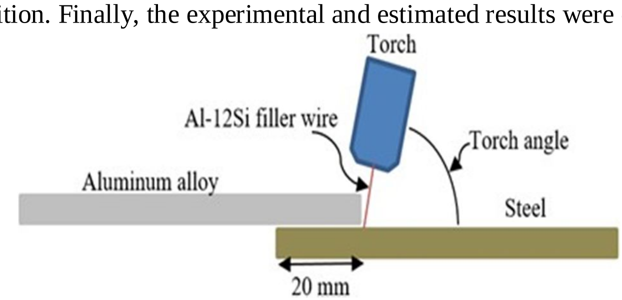

Figure 4: Brazed joint geometry and diagram.

Table 4: Process parameters and levels

Control Variables	Symbols	Units	Levels		
			Low	Medium	High
Welding speed	A	mm/min	550	860	1510
Welding current	B	Amp	26	52	78
Wire feed rate	C	m/min	4	6	8
Torch distance	D	mm	3	4	5
Torch angle	E	degree	70	80	90

All equipment must be configured with the correct parameters, such as wire feed speed, shielding gas cylinder pressure, flow meter adjustment, gas preheater temperature, electrode wire spool positioning, operator safety equipment, and finally, the appropriate welding fixture. The experimental design matrix created using the Taguchi approach and Minitab 14 software. The parameters are determined by analyzing the current configuration and component quality requirements. The penetration depth is a critical quality characteristic that influences the weld's strength and, as a result, the product's long-term durability.

IV. RESULTS AND DISCUSSION

A. S/N Ratio Analysis

The terms 'signal' and 'noise' in the Taguchi technique refer to the desired (mean) value for the output characteristic and the undesirable (noise) value for the output characteristic, respectively. The S/N ratio is used by Taguchi to determine whether a quality feature is straying from the desired value. Depending on the type of feature, there are numerous S/N ratios to choose from: smaller is better (SB), nominal is best (NB), or larger is better (LB). This study implemented and introduced a higher-the-better quality feature.

The higher the value, the better the characteristic.

$$S/N = -10 \log 10 \,(MSD)$$

Where MSD= Mean Squared Division

$MSD = (1/Y_1^2 + 1/Y_2^2 + 1/Y_3^2 + \ldots\ldots\ldots)/n$

Where Y1, Y2, and Y3 are the responses, n is the number of tests in a trial, and m represents the result's goal value. For various design matrix combinations, penetration and S/N ratios were calculated. The optimal condition, where Penetration is maximal, is a combination of elements with the highest S/N ratio.

Table 5: Shear strength results of each condition.

No.	A	B	C	D	E	Shear Strength (N)	S/N Ratios
1	550	26	4	3	70	3073.75	69.7534
2	550	26	4	3	80	3284.31	70.3289
3	550	26	4	3	90	3438.25	70.7267
4	550	52	6	4	70	2447.54	67.7746
5	550	52	6	4	80	2327.25	67.3369
6	550	52	6	4	90	1801.77	65.1140
7	550	78	8	5	70	1726.18	64.7417
8	550	78	8	5	80	2342.98	67.3954
9	550	78	8	5	90	819.27	58.2685
10	860	26	6	5	70	2677.63	68.5550
11	860	26	6	5	80	2384.42	67.5477
12	860	26	6	5	90	1968.11	65.8810
13	860	52	8	3	70	2275.85	67.1429
14	860	52	8	3	80	2358.12	67.4513
15	860	52	8	3	90	2034.34	66.1685
16	860	78	4	4	70	816.24	58.2364
17	860	78	4	4	80	2072.80	66.3311
18	860	78	4	4	90	1152.83	61.2353
19	1510	26	8	4	70	2534.39	68.0775
20	1510	26	8	4	80	2483.14	67.9000
21	1510	26	8	4	90	2051.32	66.2407
22	1510	52	4	5	70	956.14	59.6104
23	1510	52	4	5	80	573.29	55.1675
24	1510	52	4	5	90	456.29	53.1848
25	1510	78	6	3	70	648.99	56.2448
26	1510	78	6	3	80	1303.24	62.3005
27	1510	78	6	3	90	1137.86	61.1218

Summarises the shear strength findings for each condition. Main effects and signal-to-noise ratio (S/N) analysis were used to examine the findings. Table 5 showed the S/N response, and Figure 2 showed the plots of each response variable against the predicted factors. As a result, the workpiece's shear strength was increased by setting the welding speed (A), welding current (B), and torch distance (D) to low levels. On the other side, for good shear strength, a higher wire feed rate (C) and a medium degree of torch angle (E) are desirable.

The best welding parameters were determined to be 550mm/min welding speed, 26Amp welding current, 8 m/min wire feed rate, 3 mm welding distance, and an 80-degree welding angle based on the calculation. The ideal welding condition projected a shear strength of 3808.50N for the welding joint.

Figure 5: The samples of optimal welding condition.

The samples were put through a confirmation test, which yielded a shear strength of 3438.25N. Figure 4 shows a welding workpiece under ideal conditions. On the surface of the weld, there are no imperfections like as pores or spatters. Figure 5 depicts the shear strength of appropriate welding conditions.

Response Table for Signal to Noise Ratios

Table 6: Control variable signal to noise ratios.

Levels	A	B	C	D	E
1	66.83	68.33	62.73	65.69	64.46
2	65.39	63.22	64.65	65.36	65.75
3	61.09	61.76	65.93	62.26	63.10
Delta	5.73	6.57	3.20	3.43	2.65
Rank	2	1	4	3	5

Table 7: Response Table for Means

Level	A	B	C	D	E
1	2362	2655	1758	2173	1906
2	1971	1692	1855	1965	2126
3	1349	1336	2070	1545	1651
Delta	1013	1319	311	628	474
Rank	2	1	5	3	4

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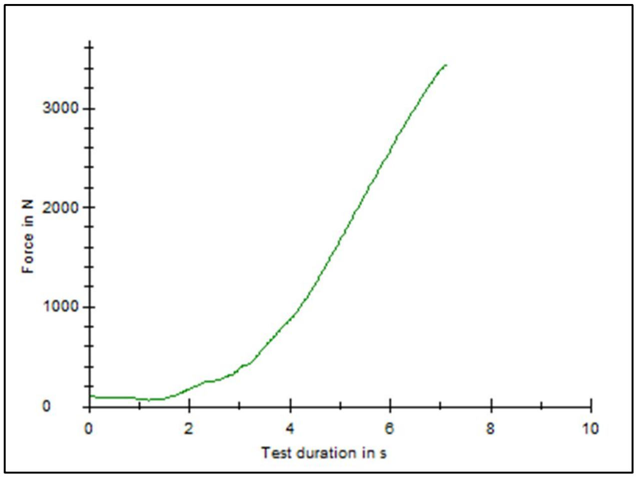

Figure 7: The optimum welding condition's shear strength

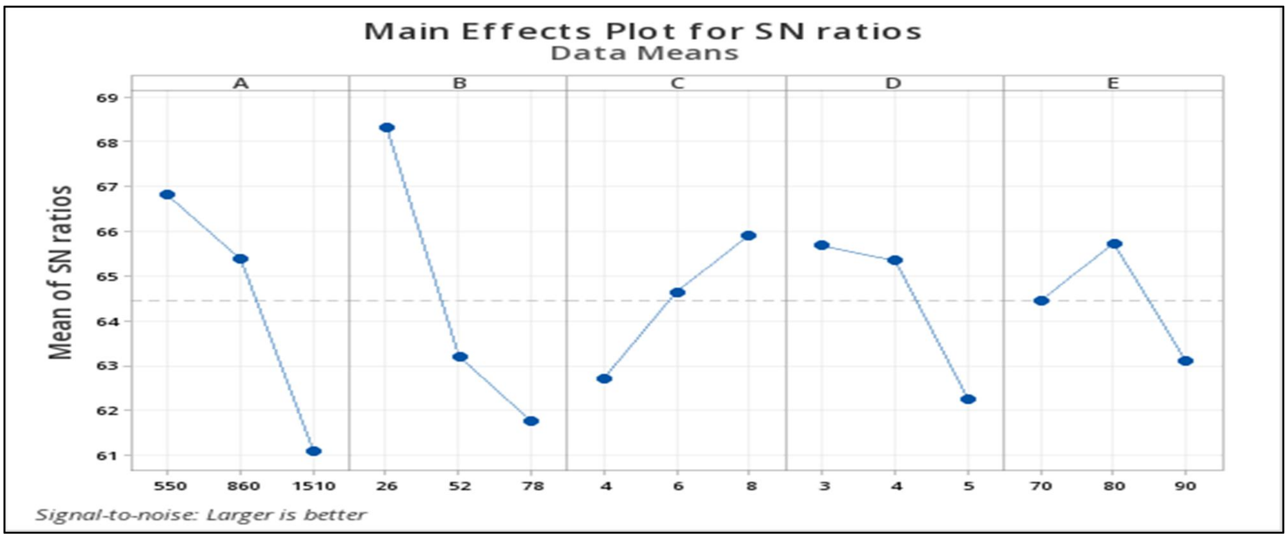

Figure 5: Main effect plot for SN ratios.

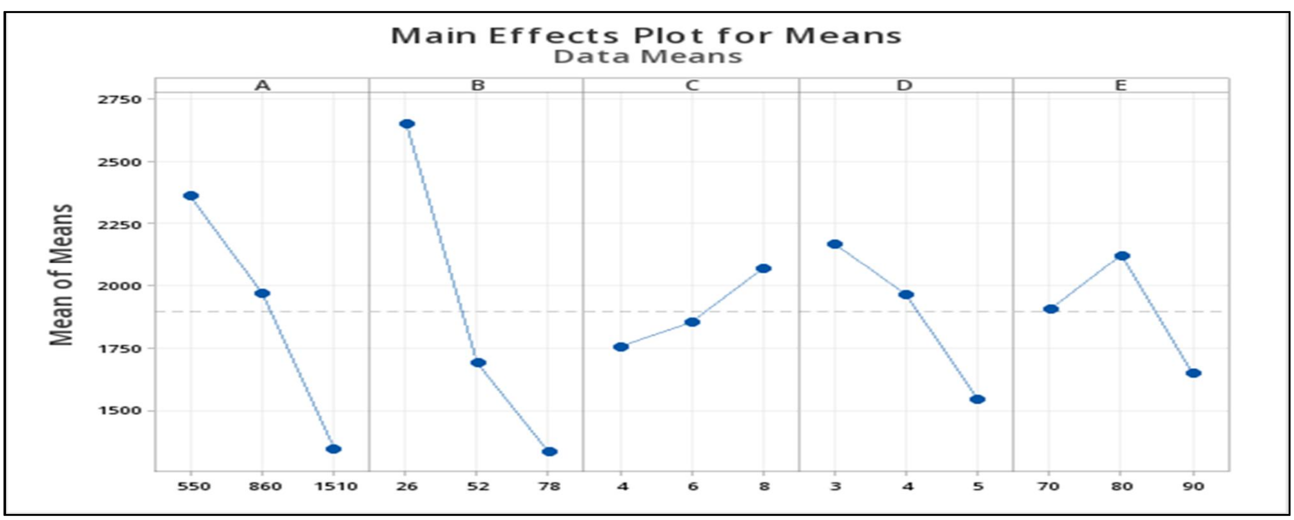

Figure 6: Main effect plot for response variable.

V. CONCLUSION

This research focused on optimising process parameters for dissimilar joints made of SAPH 440 steel and aluminium alloy 6063. Welding speed, welding current, wire feed rate, torch distance, and torch angle were the process variables evaluated in this experiment, whereas shear strength of the workpiece was the response. Welding speed of 550mm/min, welding current of 26 A, wire feed rate of 8m/min, welding distance of 3mm, and welding angle of 80 degrees were found to be the best conditions for maximal shear strength. For the forecast and confirmation, the shear strength of the workpiece brazed with ideal welding circumstances was 3808.50 and 3438.25N, respectively.

VI. ACKNOWLEDGEMENT

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VII. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

[1] S.S. Sravanthi, Swati Ghosh Acharyya, K.V. Phani Prabhakar, G. Padmanabham, "Integrity of 5052 Al-mild steel dissimilar welds fabricated using MIG-welding and cold metal transfer in nitric acid medium," Journal of Materials Processing Tech. 268 (2019), ScienceDirect, 97–106.

[2] Vijander Kumar, Navneet Goyal, "Parametric Optimization of Metal Inert Gas Welding for Hot Die Steel by using Taguchi Approach" Material Science Research India, ISSN: 0973-3469, Vol.15, No. (1) 2018, Pg. 100-106.

[3] Sachindra J Doshi, A V Gohil, N D Mehta, S R Vaghasiya (2018) Challenges in Fusion Welding of Al alloy for Body in White. Materials Today: Proceedings 5: 6370-6375.

[4] Vijaya Sankar, Daniel Lawrence, Jayabal, "Experimental Study and Analysis of Weld Parameters by GRA on MIG Welding" Materials Today: Proceedings 5 (2018), Science Direct, 14309–14316.

[5] Pavan G. Chaudhari, Priyank B. Patel, Jaksan D. Patel, "Evaluation of MIG welding process parameterusing Activated Flux on SS316L by AHP-MOORA method" Materials Today: Proceedings 5 (2018), ScienceDirect, 5208–5220.

[6] H.J. Park, D.C. Kim, M.J. Kang, S. Rhee [1] VOLUME 27 ISSUE 1 March 2008. Received 15.01.2008; published in revised form 01.03.2008.

[7] Yufeng Zhang, Jihua Huang, Zheng Ye, Zhi Cheng, Jian Yang. Et al., (2018) Influence of welding parameters on the IMCs and the mechanical properties of Ti/Al butt joints welded by MIG/TIG double-sided arc welding-welding. Journal of Alloys and Compounds 747: 764-771.

[8] Chao Chen, Chenglei Fan, Sanbao Lin, Xiaoyu Cai, Lei Zhou, Sanfeng Ye, Chunli Yang, "Effect of ultrasonic pattern on weld appearance and droplet transfer in ultrasonic assisted MIG welding process" Journal of Manufacturing Processes 35 (2018), Science Direct, 368–372.

[9] Xiaohong Zhan, Qiyu Gao, Cheng Gu, Weihua Sun, Jicheng Chen, Yanhong Wei, "The porosity formation mechanism in the laser-MIG hybrid welded joint of Invar alloy" Optics and Laser Technology 95 (2017), Science Direct, 86–93.

[10] Guoliang Qin, Yang Ji, Hong Ma, Zhiyong Ao (2017) Effect of modified flux on MIG arc welding-fusion welding of aluminum alloy to steel butt joint. Journal of Materials Processing Technology 245: 115-121.

[11] Zheng Ye, Jihua Huang, Wei Gao, Yufeng Zhang, Zhi Cheng, et al., (2017) Microstructure and mechanical properties of 5052 aluminum alloy/mild steel butt joint achieved by MIG-TIG double-sided arc welding-welding. Materials and Design 123: 69-79.

[12] Nabendu Ghosh, Pradip Kumar Pal, Goutam Nandi, "Parametric Optimization of MIG Welding on 316L Austenitic Stainless Steel by Grey-Based Taguchi Method" 2212-0173, Procedia Technology 25 (2016) 1038 –1048.

[13] Xiaohong Zhan, Yubo Li, Wenmin Ou, Fengyi Yu, Jie Chen, Yanhong Wei, "Comparison between hybrid laser- MIG welding and MIG welding for the invar36 alloy" Optics & Laser Technology 85 (2016), Science Direct, 75–84.

[14] Vijay Verma, Ram Sajeevan (2015) Multi process parameter optimization of Diesinking EDM on Titanium alloy (Ti6Al4V) using Taguchi approach. Materials Today: Proceedings 2: 2581-2587.

[15] Amitesh Goswami, Jatinder Kumar (2014) Optimization in wire-cut EDM of Nimonic-80A using Taguchi's approach and utility concept. Engineering Science and Technology, an International Journal 17: 236- 246.

[16] S. R. Patil, C. A. Waghmare, "Optimization of Mig Welding Parameters for Improving Strength Of Welded Joints" International Journal of Advanced Engineering Research and Studies, ISSN: 2249–8974, July-Sept., 2013/14-16.

[17] H.T. Zhang, J.Q. Song, "Microstructural evolution of aluminum/magnesium lap joints welded using MIG process with zinc foil as an interlayer" Materials Letters 65 (2011), Science Direct, 3292–3294.