IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Optimization of TIG welding parameters for Dissimilar Metals Aluminium 6061 and SS304 using Taguchi Method

Vidit H. Mehta[1], Dr. Jignesh J. Patel [2]

[1] *M.Tech scholars Department of Mechanical Engineering, School of Engineering & Technology, Dr. Subhash University*
[2] *Professor of Mechanical Engineering, School of Engineering & Technology, Dr. Subhash University*

***Abstract*-This study focuses on optimizing Tungsten Inert Gas (TIG) welding parameters, namely Welding Speed, Feed, and Distance of Welding Flux, for dissimilar metals Aluminium 6061 and Stainless Steel 304, using the Taguchi Method. The primary objective is to improve weld quality by systematically adjusting these parameters to enhance Tensile Strength, Yield Strength, and Ultimate Tensile Strength of the welded joints. Through a series of controlled experiments designed using Taguchi's orthogonal array approach, the influence of each welding parameter on the mechanical properties of the welds is investigated. Signal-to-noise ratios and analysis of variance (ANOVA) are utilized to quantify the impact of individual parameters and their interactions on the desired mechanical properties. The optimal combination of welding parameters is determined based on the Taguchi Method, providing valuable insights for achieving superior weld quality and mechanical performance in dissimilar metal TIG welding applications. This research contributes to the advancement of welding process optimization techniques, offering practical guidelines for industrial applications where weld strength and integrity are crucial factors.**

***Keywords:* TIG Welding, Dissimilar Metals, Aluminium 6061, Stainless Steel 304, Taguchi Method, Optimization, Welding Parameters**

I. INTRODUCTION

Tungsten Inert Gas (TIG) welding is a widely utilized technique in various industries for joining metal components due to its versatility, precision, and ability to produce high-quality welds. However, welding of dissimilar metals presents unique challenges, as the distinct metallurgical properties of different materials can affect the welding process and the quality of the resulting joint. Optimization of welding parameters is crucial in achieving optimal weld quality and performance, particularly when joining dissimilar metals. The optimization of TIG welding parameters for dissimilar metals involves identifying the most effective combination of welding parameters such as welding current, welding speed, shielding gas flow rate, and electrode composition. These parameters significantly influence the heat input, arc stability, penetration depth, and metallurgical characteristics of the weld, ultimately affecting the mechanical properties and integrity of the joint.

The objective of this study is to explore the optimization of TIG welding parameters for dissimilar metals, focusing on Aluminium 6061 and Stainless Steel 304, through the application of the Taguchi Method. By systematically varying welding parameters and analysing their effects on weld quality, this research aims to identify the optimal parameter settings that result in improved mechanical properties, such as tensile strength, yield strength, and fracture toughness. The findings of this study will provide valuable insights into the TIG welding process for dissimilar metals, offering practical guidelines for enhancing weld quality, reducing defects, and optimizing process efficiency. This research is relevant to a wide range of industries, including automotive, aerospace, construction, and manufacturing, where the joining of dissimilar metals is common and weld quality is paramount for structural integrity and performance.

II. LITERATURE REVIEW

Tungsten Inert Gas (TIG) welding has long been recognized as a versatile and widely adopted welding technique across various industries, owing to its capability to produce high-quality welds with precision and control. In recent years, there has been a growing interest in optimizing TIG welding parameters, particularly for dissimilar metal joints, to address the increasing demand for joining diverse materials in modern manufacturing processes. The optimization of TIG welding parameters for dissimilar metals has been extensively explored in the literature, with researchers investigating various aspects of the welding process to enhance weld quality and performance.

Sreekumar, K. M., & Sivakumar, M. (2021). focuses on optimizing TIG welding parameters for dissimilar welding of AA7075-T6 and AA6061-T6 aluminum alloys using response surface methodology. It likely explores the effects of welding parameters on weld quality and mechanical properties to determine optimal settings [1].Mishra, D., Jha, P. K., & Pal, S. K. (2020). employs response surface methodology (RSM) to optimize TIG welding parameters for dissimilar metal joints. It investigates the relationship between welding parameters and mechanical properties to identify optimal parameter settings [2].Zhang, Y., & Zhang, L. (2020). analyzes the microstructure and mechanical properties of TIG welded dissimilar joints between stainless steel and aluminum alloy. It likely provides insights into the weld microstructure and its correlation with mechanical properties [3].Cao, Y., & Cong, B. (2020). studied an orthogonal experimental method to optimize TIG welding parameters for dissimilar metals. It focuses on enhancing weld quality and mechanical properties through systematic variation and analysis of welding parameters [4].Zhu, L., & Zeng, X. (2019). focuses on dissimilar TIG welding between titanium alloy Ti6Al4V and stainless steel 304. It likely explores the challenges and solutions in welding these dissimilar materials and evaluates the mechanical properties of the resulting joints [5].Yang, K., & Li, J. (2019). examines the laser-TIG hybrid welding of dissimilar metals, specifically aluminum alloy to stainless steel. It likely investigates the feasibility and effectiveness of this hybrid welding process in achieving high-quality dissimilar metal joints [6]. Keshavarz, A., & Mousavizadeh, M. (2019). focuses on studying the mechanical properties of dissimilar joints between AA7075-T6 and AA5083-H111 aluminum alloys welded using TIG. It likely evaluates the influence of welding parameters on the strength and integrity of these dissimilar welds [7]. Hou, J., & Wang, S. (2019). explores the TIG welding process and properties of dissimilar joints between stainless steel and aluminum alloy. It likely delves into the challenges and solutions specific to welding these two dissimilar materials [8]. Xu, L., & Du, Y. (2018). investigates the dissimilar joining of aluminum alloy to stainless steel using hybrid TIG-MIG welding. It likely explores the advantages and challenges of this hybrid welding process and evaluates the mechanical properties of the resulting joints [9]. Jafarian, F., & Kermanpur, A. (2018). examines the effects of welding parameters on the mechanical properties and microstructure of dissimilar joints between stainless steel and AISI 4130 steel, fabricated using TIG welding. It likely provides insights into optimizing parameters for desired weld quality [10].

III. WORK MATERIALS

Material used in this study are 10 mm thick Aluminum 6061 and 15 mm thick SS 304. Chemical Composition and Mechanical Properties are mentioned in Table 1 & Table 2. Welding parameters are mentioned in Table 3.

Table 1: Chemical Composition & Mechanical Properties of Aluminum 6061

A) Chemical Composition

Element	Composition (%)
Aluminum (Al)	95.8 - 98.6
Magnesium (Mg)	0.8 - 1.2
Silicon (Si)	0.4 - 0.8
Iron (Fe)	0.7 max
Copper (Cu)	0.15 - 0.4
Manganese (Mn)	0.15 max
Chromium (Cr)	0.04 - 0.35
Zinc (Zn)	0.25 max
Titanium (Ti)	0.15 max

B) Mechanical Properties

Property	Value
Tensile Strength (MPa)	310 - 415
Yield Strength (MPa)	276 - 310
Elongation (%)	12 - 25
Hardness (Brinell, HB)	95
Modulus of Elasticity (GPa)	68.9
Poisson's Ratio	0.33
Thermal Conductivity (W/m·K)	167

Table 2: Chemical Composition & Mechanical Properties of SS 304

A) Chemical Composition

Element	Composition (%)
Carbon (C)	0.08 max
Chromium (Cr)	18 - 20
Nickel (Ni)	8 - 10.5
Manganese (Mn)	2 max
Silicon (Si)	0.75 max
Phosphorus (P)	0.045 max
Sulfur (S)	0.03 max
Nitrogen (N)	0.1 max
Iron (Fe)	Balance

B) Mechanical Properties

Property	Value
Tensile Strength (MPa)	515 - 860
Yield Strength (MPa)	205 - 240
Elongation (%)	40 - 60
Hardness (Brinell, HB)	170 - 200
Modulus of Elasticity (GPa)	193
Poisson's Ratio	0.29
Thermal Conductivity (W/m·K)	16.2 - 24.9

Table 3: Welding Parameter and level

Parameter	Low Level	Medium Level	High Level
Welding Current (Amps)	100	150	200
Welding Voltage (Volts)	10	15	20
Gas Flow Rate (L/min)	5	10	15

IV. OPTIMIZATION TECHNIQUES

Taguchi method

The Taguchi method was named after Japanese quality manager who is also an engineer and statistician [11]. Since its development, various fields of study have applied it in the optimization of countless processes. This method involves maximizing the ratio of the process parameters that can be controlled known as the signal to those that cannot be controlled known as the noise (signal-to-noise ratio). There are three standard signal-to-ratios (S/N ratios) generally adopted depending on the desired output response. In this Larger is best is chosen. By this approach, the optimal setting of the input process parameters is achieved with a minimum number of experiments known as the Taguchi standard orthogonal array. As a minimum number of the experiment is conducted to achieve the optimal setting that would give the best-desired outcome instead of trying out all the possible combinations of the input process parameters as is the case in the classical design of experiment both time and cost is saved[12] The steps taken for Taguchi optimization include determination of the process performance/characteristics to be maximized or minimized or maintained, determining the factors that control the performance, choosing of the appropriate orthogonal array, carrying out the experimental trials to obtain the output responses, analysing the output response values to determine the optimal setting and then finally confirmation of the optimal setting [11]. In the current study, three levels for the welding current, voltage and gas flow rate are to be optimized against tensile strength, yield strength and hardness. The Taguchi analysis was performed with Minitab software for the L9 orthogonal array. The orthogonal array is presented in Table 4.

Table 4: Welding parameters and the experimental values

Run	Current (Amps)	Voltage (Volts)	Gas Flow Rate (L/min)
1	100	10	5
2	100	15	10
3	100	20	15
4	150	10	10
5	150	15	15
6	150	20	5
7	200	10	15
8	200	15	5
9	200	20	10

Table 5: Welding parameters and the experimental values

Run	Current (Amps)	Voltage (Volts)	Gas Flow Rate (L/min)	Tensile Strength (MPa)	Yield Strength (MPa)	Hardness
1	100	10	5	397.15	314.80	178.89
2	100	15	10	415.71	322.76	177.35
3	100	20	15	523.21	361.15	162.21
4	150	10	10	360.13	263.57	170.85
5	150	15	15	435.32	323.35	173.45
6	150	20	5	480.45	341.89	173.21
7	200	10	15	430.56	316.12	207.25
8	200	15	5	489.97	353.12	173.75
9	200	20	10	514.41	359.89	243.56

Table 6: Welding parameters and the signal-to-ratios of the experimental values

Run	Current (Amps)	Voltage (Volts)	Gas Flow Rate (L/min)	Tensile Strength (MPa)	Yield Strength (MPa)	Hardness
1	100	10	5	51.9791	49.9607	45.0517
2	100	15	10	52.3758	50.1776	44.9766
3	100	20	15	54.3735	51.1538	44.2016
4	150	10	10	51.1292	48.4179	44.6523
5	150	15	15	52.7762	50.1935	44.7835
6	150	20	5	53.6330	50.6777	44.7715
7	200	10	15	52.6807	49.9970	46.3299
8	200	15	5	53.8034	50.9584	44.7985
9	200	20	10	54.2262	51.1234	47.7321

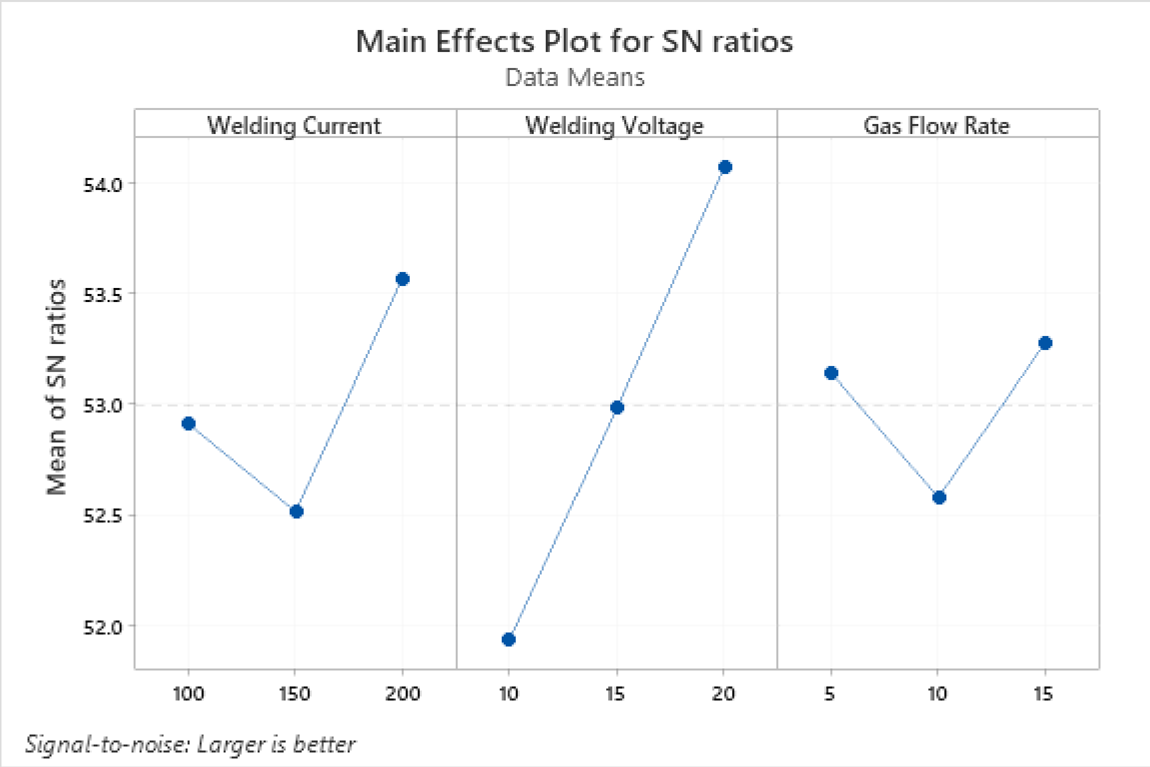

Fig. 1(a) .Main effect plots of the Tensile Strength

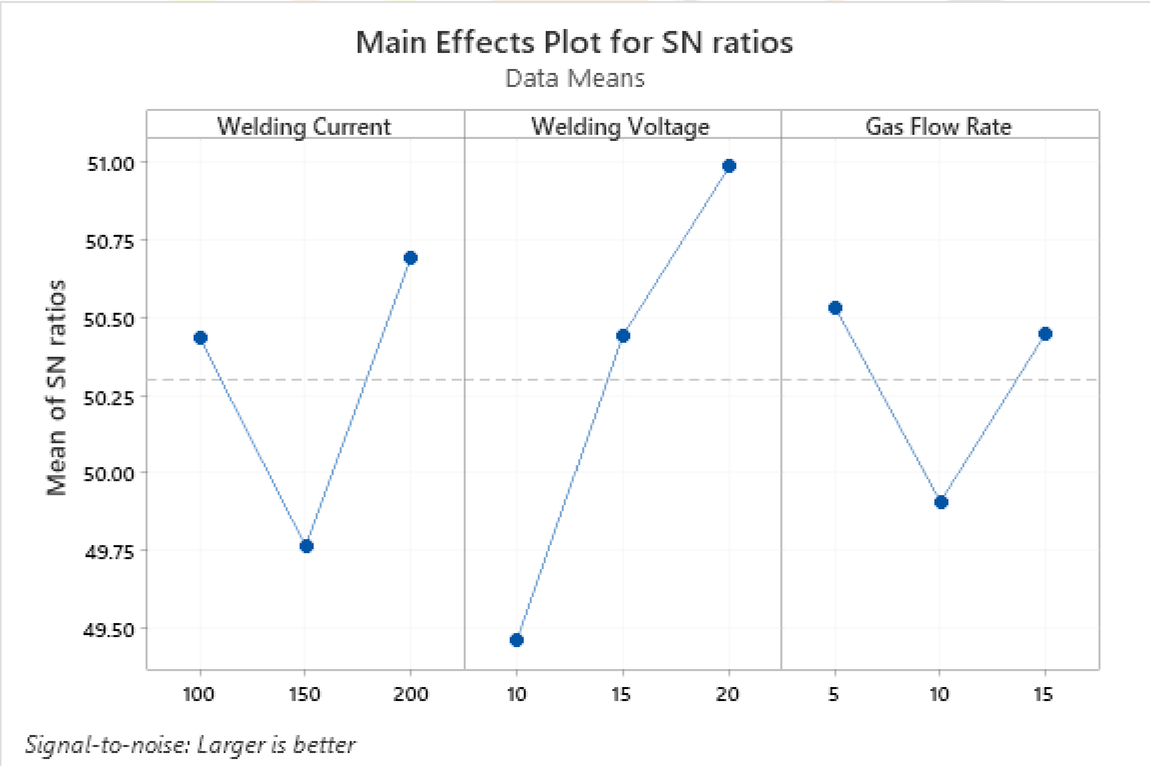

Fig. 1(b) .Main effect plots of the Yield Strength

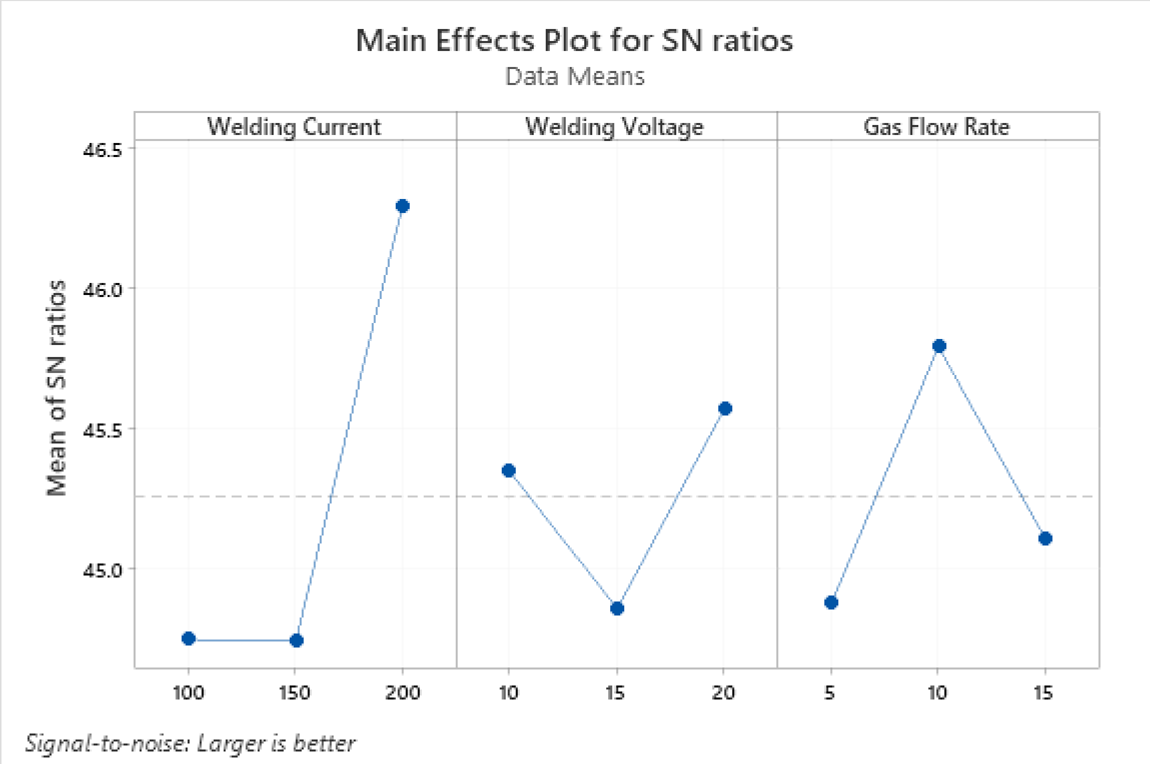

Fig. 1(c) .Main effect plots of the Hardness

To determine the most significant parameter for the multi-performance characteristics, analysis of variance (ANOVA) at 95% confidence level was performed as shown in Table 7. The ANOVA results show that all the process parameters were significant as can be seen from their p-values which are all lower than 0.05%. Judging by p-value test, voltage with a p-value of 0.02 was the most significant process parameter followed by the welding current and gas flow rate.

Table 7: Anova Result

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Welding Current	2	4298.8	2149.4	11.81	0.030
Welding Voltage	2	18207.1	9103.5	50.03	0.020
Gas Flow Rate	2	1801.2	900.6	4.95	0.032
Error	2	364.0	182.0		
Total	8	24671.1			

V. Results and Conclusion

Table 5 shows the tensile strength , yield strength and hardness results of the experimental design which shows maximum tensile strength and hardness of 523.21 MPa and 361.15 MPa respectively at the welding current of 100 A, voltage of 20 V and gas flow rate of 15 l/min, and maximum hardness of 243.56 HV at the welding current of 200 A, voltage of 20 V and gas flow rate at 10 l/min. Table 6 presents the signal-to-noise ratios of the experimental results using larger the better criterion. The main effect plots for each of the output responses are shown in Fig. 1. In can be observed that for the tensile strength, the optimum setting is current, voltage and gas flow rate all at level 3 (C3V3G3).. The optimal setting for the yield strength and hardness is similar to the optimal setting for the tensile strength except for the gas flow rate. The optimal setting for yield strength (C3V3G1) while for the hardness, the optimum is (C3V3G2). Furthermore, the input process parameters show both increasing and decreasing effect on the output responses except for the tensile strength and the yield strength which increased as the voltage increased and percentage elongation which increases with an increase in the welding current. The impact of process parameters on the mechanical properties such as Tensile Strength and Yield strength are depicted in main effects plots as seen in Fig. 1.

REFERENCE

[1] K. M. Sreekumar and M. Sivakumar, "Optimization of TIG welding parameters for dissimilar welding of AA7075-T6 and AA6061-T6 using response surface methodology," in Materials Today: Proceedings, vol. 43, pp. 1252-1257, 2021.

[2] D. Mishra, P. K. Jha, and S. K. Pal, "Optimization of TIG welding parameters for dissimilar metal joints using response surface methodology," in Materials Today: Proceedings, vol. 26, pp. 3357-3363, 2020.

[3] Y. Zhang and L. Zhang, "Microstructure and mechanical properties of TIG welded dissimilar joints of stainless steel and aluminum alloy," in Journal of Materials Processing Technology, vol. 279, p. 116494, 2020.

[4] Y. Cao and B. Cong, "Optimization of TIG welding process parameters for dissimilar metals based on orthogonal experimental method," in Materials Research Express, vol. 7, no. 3, p. 036531, 2020.

[5] L. Zhu and X. Zeng, "Investigation on dissimilar TIG welding of titanium alloy Ti6Al4V to stainless steel 304," in Materials Science and Engineering: A, vol. 743, pp. 369-377, 2019.

[6] K. Yang and J. Li, "Study on laser-TIG hybrid welding of dissimilar metals of aluminum alloy to stainless steel," in Optics and Laser Technology, vol. 110, pp. 286-293, 2019.

[7] A. Keshavarz and M. Mousavizadeh, "Investigation on the mechanical properties of TIG welded AA7075-T6/AA5083-H111 dissimilar joints," in Welding in the World, vol. 63, no. 3, pp. 589-601, 2019.

[8] J. Hou and S. Wang, "Investigation on the TIG welding process and properties of dissimilar stainless steel/aluminum alloy joints," in Welding in the World, vol. 63, no. 1, pp. 147-155, 2019.

[9] L. Xu and Y. Du, "Study on dissimilar joining of aluminum alloy to stainless steel by hybrid TIG-MIG welding," in Journal of Manufacturing Processes, vol. 32, pp. 477-486, 2018.

[10] F. Jafarian and A. Kermanpur, "Influence of welding parameters on mechanical properties and microstructure of dissimilar stainless steel/AISI 4130 steel joints fabricated by TIG welding," in Journal of Manufacturing Processes, vol. 31, pp. 336-343, 2018.

[11] P. B. Kanakavalli, B. N. Babu, C. P. N. V. Sai, "A hybrid methodology for optimizing MIG welding process parameters in joining of dissimilar metals," in Mater. Today: Proceedings, vol. 23, Elsevier Ltd, pp. 507–512, 2020.

[12] H. R. Kim, Y. W. Park, K. Y. Lee, "Application of grey relational analysis to determine welding parameters for Nd:YAG laser GMA hybrid welding of aluminium alloy," Sci. Technol. Weld. Join., vol. 13, pp. 312–317, 2008.

[13] Jignesh J. Patel, Dr. Mohammad Israr, "Experimental Investigation of Friction Stir Welding of Aluminium Alloy AA7075 for Various Process Parameters" International Journal of Mechanics and Solids. ISSN 0973-1881 Volume 12, Number 2 (2017), pp. 169-177

[14] Jignesh J. Patel, Mitesh S. Patel, Dr. Mohammad Israr, "Simulation of Top Surface Temperature & Flow Stress during FSW of Aluminium Alloy AA7075 for Various Process Parameters", International Journal of Darshan Institute on Engineering Research and Emerging Technologies Vol. 6, No. 1, 2017, pp. 36-39

[15] Dr. Jignesh J Patel, Mr. Mitesh S Patel, Mr. Utsav M Dholakiya, “Analyze Process Parameter of Friction Stir Welding of Alluminium Alloy by FEM and Experiment,” International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 11 (2019) pp. 2536-2542

[16] Jignesh J. Patel, Dr. Mohammad Israr, "Optimization of process parameters for friction stir welded aluminium alloyAA7075 using full factorial method", International Journal of Advance Engineering and Research Development (IJAERD)Volume 4, Issue 2, February -2017, e-ISSN: 2348 -4470, print-ISSN: 2348-6406