OPTIMIZATION OF PROCESS PARAMETERS IN TIG WELDING USING TAGUCHI OF 5086-ALUMINIUM ALLOY

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***Abstract*: Today's manufacturing world is concerned with customer's satisfaction. Quality of welded product is of utmost important which manufacturers are trying to improve in order to sustain in today's competitive world. Taguchi method is popularly used to optimize the process parameters. It gives us the best combination of parameter values so that the process is more robust. TIG welding is a widely used welding technique in industries because of its welding quality. This paper investigates the process parameters affecting the tensile strength of welded specimen AA 5086. It emphasizes the influence of process parameters such as welding current, filler rod diameter and gas flow rate on tensile strength of material. Analysis of Variance (ANOVA) method was used to identify which parameters significantly affect the tensile strength. Confirmation test was conducted to validate the result. The result obtained will help the researchers while carrying out experimentation on same material or using it for one of its application.**

Index Terms: TIG welding, Taguchi Method, AA-5086, Tensile strength, ANOVA.

INTRODUCTION

Quality has gained vital importance in today's manufacturing world. TIG welding can be used for a large variety of metals due to which this process can be used in several industries. This process is commonly used in aerospace industries for construction of aircraft and spacecraft, in automotive industries for welding of car fenders, repairing of wagon to aluminium tools as well as in field of art for metal sculptures or industrial fixtures. TIG welding is an arc-welding process where coalescence is produced by heating metals with an arc between a non-consumable electrode and the base metal. In TIG welding, weld quality mainly depends on factors such as bead geometry, mechanical and metallurgical characteristics of the weld and the weld chemistry which in turn depend on process parameters like welding current, welding voltage, filler rod diameter, gas-flow rate, weld speed, etc. Various literatures were studied from where the input process parameters, viz; welding current, filler rod diameter and gas-flow rate were selected and were optimized using Taguchi method.

Al-5086 alloy is primarily alloyed with magnesium. It is light in weight, has relatively low cost and can be treated to fairly high strength levels. It is not strengthened by heat treatment; instead it becomes stronger due to strain hardening or cold mechanical working of the material. Since heat treatment does not strongly affect the strength, AA-5086 can be readily welded and can retain most of the mechanical properties. The good result with welding and good corrosion properties in sea water make AA-5086 extremely popular for vessel gangways, building boats, etc.

Taguchi method is popularly used to optimize the process parameters. It is a statistical method developed by Taguchi and Konishi. It gives us the best combination of the parameters so that the process is more robust. It is a powerful tool for producing product with good quality and comparatively less cost. An orthogonal array is used to conduct sets of experiments which give much reduced variance for experiments, Dr. Taguchi's Signal-to-Noise ratio serve as objective function for optimization, helps in data analysis and prediction of optimum results. Analysis of variance (ANOVA) is used to evaluate the response magnitude in (%) of each parameter in the orthogonal experiments. It is used to determine whether or not the contribution of various parameters on the objective is significant or not.

I. LITERATURE REVIEW

Welding quality of the material largely depend upon the TIG welding parameters. For this, it is important to get a brief knowledge about the effect of various process parameters on welding quality and to study various method to optimize them. It is important to review the publish literature for understanding current status of work in this area.

Sanjeev Kumar et. al [1] attempted to explore the possibility for welding of higher thickness plates by TIG welding. Aluminium Plates (3-5mm thickness) were welded by Pulsed Tungsten Inert Gas Welding process with welding current in the range 48-112 A and gas flow rate 7 -15 l/min. Shear strength of weld metal (73MPa) was found less than parent metal (85 MPa). Indira Rani et. al [2] investigated the mechanical properties of the weldments of AA6351 during the GTAW /TIG welding with non-pulsed and pulsed current at different frequencies. Ahmed Khalid Hussain et. al [3] investigated the effect of welding speed on tensile strength of the welded joint by TIG welding process of AA6351 Aluminium alloy of 4 mm thickness. From the experimental results it was revealed that strength of the weld zone is less than base metal and tensile strength increases with reduction of welding speed. Sushil Kumar Kamat et. al [4] perform the FSW and TIG welding on Al 6061 alloy and found that tensile strength and hardness of FSW is more than that of TIG welding. Raveendra et. al [5] done experiment to see the effect of pulsed current on the characteristics of weldments by GTAW. To weld 3 mm thick 304 stainless steel welding current 80-83 A and arc travel speed 700-1230 mm/min. More hardness found in the HAZ zone of all the weldments may be due to grain refinement. Higher tensile strength found in the non-pulsed current weldments. It was observed that UTS and YS value of non-pulsed current were more than the parent metal and pulsed current weldments. Karunakaran et. al [6] performed TIG welding of AISI 304L stainless steel and compare the weld bead profiles for constant current and pulsed current setting. Effect of welding current on tensile strength, hardness profiles, microstructure and residual stress distribution of welding zone of steel samples were reported. For the experimentation welding current of 100-180 A, welding speed 118.44 mm/min, pulse frequency 6 Hz have been considered. Kumar and Sundarrajan [7] performed pulsed TIG welding of 2.14 mm AA5456 using welding current (40-90) A, welding speed (210-230) mm/min. Taguchi method was employed to optimize the pulsed TIG welding process parameters for increasing the mechanical properties and a Regression models were developed. Microstructures of all the welds were studied and correlated with the mechanical properties. 10-15% improvement in mechanical properties was observed after planishing due to or redistribution of internal stresses in the weld. Ahmet Durgutlu et.al [8] investigated the effect of hydrogen in argon as shielding gas for TIG welding of 316L austenitic stainless steel. They used current 115 A, welding speed 100 mm/min and gas flow rate 10 l/min for welding of 4 mm thick plate. Ajit Khatter et.al [9] performed TIG welding using Taguchi on Stainless Steel-304 and optimize the parameter for maximize the tensile strength of welded specimen.

From the above literatures, the parameters that have direct effect on quality of weld were identified. Based on the literature review and the availability of welding apparatus, the process parameters were selected and the flow of project was determined. The Taguchi approach has been built on traditional design of experimental methods to improve the design of products and processes. The steps and importance of Taguchi method and ANNOVA were studied.

II. TIG WELDING PROCESS

Tungsten Inert Gas Welding (TIG Welding), also known as Gas Tungsten Arc Welding (GTAW), is an arc welding method that uses a non-consumable tungsten electrode to weld two or more work pieces. Arc welding is a fusion welding technique that uses an electric arc to weld two or more work-pieces. It is one of the most commonly used welding method today. It may be done manually, automatically or semi-automatically. The electrode used in arc welding may be consumable or non-consumable. TIG is an arc welding technique that makes use of a non-consumable tungsten electrode. TIG welding process is shown in below figure. [4]

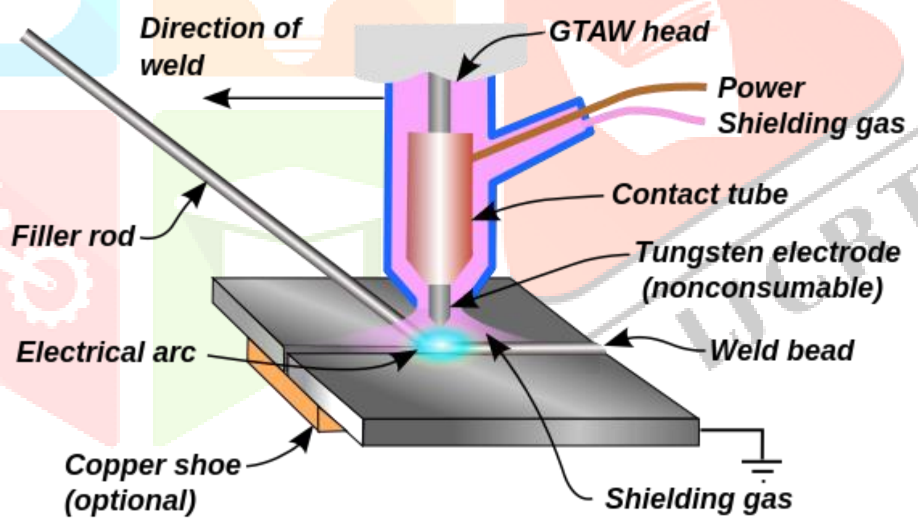

Fig 3.1: TIG welding Process

The electrode is brought near the work piece with a small air gap (say 3mm). Electrons from the negatively charged cathode discharge into the positively charged anode at high velocity. This produces tremendous amount of heat in the anode. Meanwhile, positive ions from the anode discharge into cathode. This produces some heat in the cathode. Heat produced in the anode is always greater than the heat produced in the cathode. Hence, in consumable electrode processes, to produce deep weld, electrode is made anode and work piece is made cathode. In non-consumable electrode processes, the exact opposite is done. To produce deep weld, electrode is made cathode and work piece is made anode.

III. Experimental work:

4.1 Selection of material:

The material used for investigation is AA-5086. It is widely used for small aluminium boats or larger yacht, in vehicle armour in M113 Armoured Personnel Carrier and M2 Bradley Infantry fighting vehicle, fired pressured vessel, aircraft etc. No experimentation were carried out on the selected material according to the authentic research papers, hence AA 5086 was selected.

Table 4.1: Chemical composition of 5086 Aluminium Alloy

Cr	Co	Fe	Mg	Mn	Si	Zn	Other	Aluminium
0.05-0.25%	0.1% max	0.5% Max	3.5-4.5%	0.2-0.7% max	0.6%	0.25% max	0.5% Max	Balance

Table 4.2: Properties of 5086 Aluminium Alloy

Density	Young's modulus	Ultimate tensile strength	Yield strength	Thermal expansion
2.66 g/cm^3	70 GPa	290MPa	207 MPa	22.1 µm/m-K

5 mm thick AA 5086 were used. The dimensions of the work piece are: Length 150mm and Breadth 50mm.The experiments were designed by Taguchi method using L-9 orthogonal array. The selected welding parameters for the study are welding current, gas flow rate and filler rod diameter. The S/N ratio for each level of process parameter is computed based on S/N analysis. Further analysis of variance was performed to identify the significance of process parameter.

4.2 Filler rod:

AA-4043 typical provides higher rating for weldability and provides slightly lower crack sensitivity. It generally tends to produce weld with improve cosmetic appearance smoother surface less spatter and less smut.

Table 4.3: Chemical composition of 4043 Aluminium Alloy

Si	Fe	Cu	Mn	Mg	Zn	Ti	Be	Al
4.5-6.0	0.80	0.30	0.05	0.05	0.10	0.20	0.0003	Balance

4.3 Input process parameter:

The input process parameters used for welding were welding current, gas flow rate and filler rod diameter. A couple of trails were carried out to select the upper and lower levels of the process parameters. The process parameters and levels are given in the below. The objective of the experimentation is to maximize the tensile strength. The tensile test was carried out UTM 400.

Table 4.4: Input parameters and their levels

Process Parameters	Levels		
	1	2	3
Current(A)	90	120	150
Gas flow rate (lit/min)	5	10	15
Filler rod(mm)	1.6	2.4	3.1

4.4 Taguchi Methodology

The Full Factorial Design requires a large number of experiments to be carried out. It becomes laborious and complex, if the number of factors increases. To overcome this problem Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. Taguchi thus, recommends the use of the loss function to measure the performance characteristics that are deviating from the desired target value. Usually, there are three categories of the performance characteristics to analyse the S/N ratio. They are: nominal-the-best, larger-the-better, and smaller-the-better.

In Taguchi design methods, following steps are involved:

1. Identify the main function, side effects and failure modes.
2. Identify the noise factors, testing conditions and quality characteristics.
3. Identify the objective function to be optimized.
4. Identify the control factors and their levels.
5. Select the Orthogonal Array Matrix Experiment.
6. Conduct the matrix experiment.

7. Analyse the data, predict the optimum levels and performance.
8. Perform the verification experiment and plan the future action.

4.1.1 Taguchi Orthogonal Array:

The standardised Taguchi based experimental design used in this study was an L9 orthogonal array, as described shown in Table 5. [8]

Table 4.5: L9 orthogonal array

Exp. No.	Process Parameters		
	Welding current	Gas flow rate	Filler rod diameter
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

IV. RESULT AND DISSCUSION

Table 6 represents the value of tensile strength obtained for the above parameters combination from the UTM 400. S/N ratio is calculated using larger the best characteristics for tensile strength. In order to maximize the response parameter, larger the better S/N ratio formula is used to calculate S/N ratio for respective parametric combination.

$$\frac{S}{N} = -10\log\left[\frac{1}{n}\sum_{i=0}^{n}\frac{1}{y_i^2}\right]$$

Where,

n = Number of trials or measurement
y_i = measured value
$\bar{y}$ = mean of measured value
s = standard deviation

Table 5.1: Experimental result for strength and S/N ratio

Exp. No.	Welding current (A)	Gas flow rate (lit/min)	Filler rod diameter(mm)	Tensile strength (MPa)	S/N ratio
1	90	5	1.6	71.84	37.1273
2	90	10	2.4	84.47	38.5340
3	90	15	3.125	68.03	36.6540
4	120	5	2.4	79.33	37.9887
5	120	10	3.125	63.40	36.0418
6	120	15	1.6	74.20	37.4018
7	150	5	3.125	139.51	42.8921
8	150	10	1.6	173.03	44.7624
9	150	15	2.4	143.30	43.1249

Table 5.2: S/N response table for strength

Level	A	B	C
1	37.44	39.34	39.77
2	37.15	39.78	39.88
3	43.59	39.78	38.53
Delta	6.45	0.72	1.35
Rank	1	3	2

From above delta values it can be seen that welding current is the most significant factor followed by filler rod diameter and gas flow rate. Using the above values the main effect plot was obtained using MINITAB 18 software.

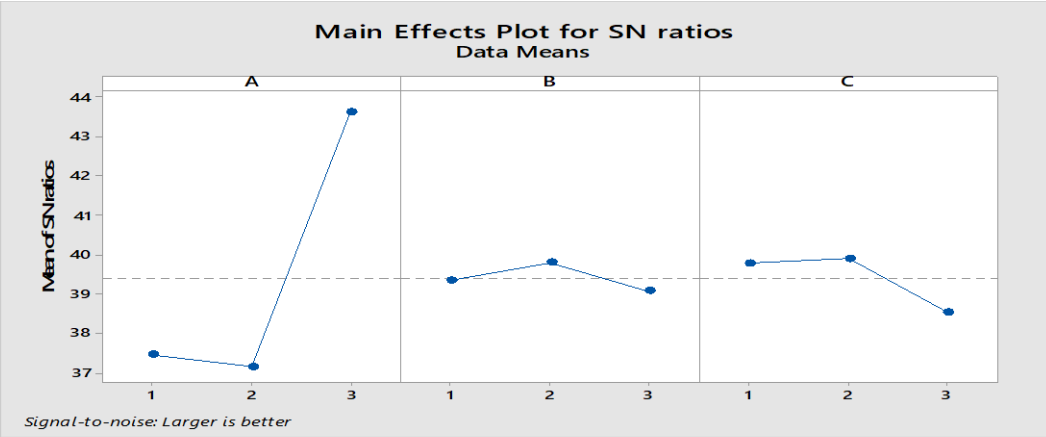

Fig 5.1: Effect of welding speed, gas flow rate, filler rod diameter on tensile strength based on S/N ratio

In main effect plot, if inclination of line is more, then the corresponding variable is more significant and vice versa. It is observed that for maximum tensile strength, the optimum condition is A3, B2 and C2; i.e current = 150A, gas flow rate =10lit/min, filler rod diameter=2.4mm.

Table 5.3: Analysis of variance

Source	DF	Adj. SS	Adj. MS	F-Value	P-Value
A	2	12302.8	6151.4	42.09	0.023
B	2	243.3	121.7	0.83	0.546
C	2	418.6	209.3	1.43	0.411
Error	2	292.3	146.1		
Total	8	13257.1			

Result obtained from ANOVA is shown in above table. It was earlier assumed that ANOVA is carried out with 95% confidence level which implies that if P value in table is less than 0.05, then the corresponding variable is statistically significant. From the table, it is clear that P value for current is less than 0.05 which is the only significant parameter.

Confirmatory test:

Confirmatory test was carried out at optimal parameter combination obtained from S/N ratio analysis. From the result obtained, it is found that optimal welding parametric condition produce maximum tensile strength. Optimum parameter setting and result for tensile strength is:

Table 5.4: Confirmation results for tensile strength

Sr. No.	**Process parameters**			**Tensile Strength(MPa)**	**S/N ratio**
1	Welding Current(amp)	Gas flow rate(lit/min)	Filler rod diameter(mm)		
	150	10	2.4	191.89	45.66

Fig 5.2: Confirmation test specimen

V. CONCLUSION

Table 6.1: Levels obtained from ANOVA and % contribution

Parameters	Levels	Values	% Contribution
Current(A)	Level 3	150	92.801%
Gas flow rate(lit/min)	Level 2	10	1.836%
Filler rod diameter(mm)	Level 2	2.4	3.158%

This paper has described the use of Taguchi method and statistical technique like ANOVA and S/N ratio for optimizing the tensile strength in TIG welding for AA 5086. From the experimentation following conclusions were made,

1.The optimum welding condition obtained by Taguchi method is: Current=150A, gas flow rate =10 lit/min, and filler rod =2.4mm.
2. It can be identify from main effect plot that current has considerable influence on tensile strength followed by filler rod diameter and gas flow rate.
3. From ANOVA result it is found that current is the only significant parameter whereas filler rod diameter and the gas
4. flow rate does not affect considerably on tensile strength. Confirmation test confirms the improvement of tensile strength that validates the proposed optimization methodology.

REFERENCE

1. Influence of Welding Current on Bead Shape, Mechanical and Structural Property of Tungsten Inert Gas Welded Stainless Steel Plate by Rajeev Kumara*, Somnath Chattopadhyayab, Sanjeev Kumar.

2. Indira Rani, M., & Marpu, R. N.(2012). Effect of Pulsed Current Tig Welding Parameters on Mechanical Properties of J-Joint Strength of Aa6351. The International Journal of Engineering And Science (IJES),1(1), 1-5.

3. Hussain, A. K., Lateef, A., Javed, M., & Pramesh, T. (2010). Influence of Welding speed on Tensile Strength of Welded Joint in TIG Welding Process. International Journal of Applied Engineering Research, Dindigul, 1(3), 518-527.

4. Sushil Kumar Kamat & Ajay Kumar (2013). An experimental investigation of mechanical properties of Al 6106 t6 alloy joined by Friction Stir Welding and TIG welding. Vol. 3, 2319-1058.

5. Raveendra, A., & Kumar, B. R.(2013). Experimental study on Pulsed and Non-Pulsed Current TIG Welding of Stainless Steel sheet (SS304). International Journal of Innovative Research in Science, Engineering and Technology, 2(6)

6. Karunakaran, N. (2012). Effect of Pulsed Current on Temperature Distribution, Weld Bead Profiles and Characteristics of GTA Welded Stainless Steel Joints. International Journal of Engineering and Technology, 2(12).

7. Kumar, A., & Sundarrajan, S. (2009). Optimization of pulsed TIG welding process parameters on mechanical properties of AA 5456 Aluminum alloy weldments. *Materials & Design*, *30*(4), 1288-1297.

8. Durgutlu, A. (2004). Experimental investigation of the effect of hydrogen in argon as a shielding gas on TIG welding of austenitic SS. Materials & design, 25(1), 19-23.

9. Ajit Khatter, Pawan Kumar and Manish Kumar (2014). Optimization of process parameters in TIG welding using Taguchi of Stainless Steel-304.4(1) 2249-5762.