Comparative Study of Gas Metal Arc Welding (GMAW) and Gas Tungsten Arc Welding (GTAW) for Aluminium Alloy 3003-H2 Using Taguchi Method

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Abstract: **A manufacturer's often face the problem to achieve a good welded joint with the required quality due to the control of the input process parameters. The Taguchi method with L_{27} orthogonal array were used to find out the best settings of welding current, welding voltage, welding speed, gas flow rate and root gap. It is also the investigation of welding process parameter's effect on the tensile strength of weld specimen were carried out by statistical technique i.e. analysis of variance (ANOVA) and Signal- to- Noise (S/N) ratio. The optimum parametric conditions were found out by Taguchi method. This investigation the presents an effective approach for the comparative study for the optimization of the process parameters using MINITAB-18. The GMAW process and the GTAW process are one of the widely used methods for the joining ferrous and non-ferrous metals. In this design of experiment method (DOE) the aluminium alloy 3003 used as base material and ER4043 used as filler wire for both welding process, also find out the percentage contribution of each input parameters.**

Key words: **GMAW, GTAW setup, aluminium alloy, Taguchi, L_{27} array, ANOVA & S/N ratio.**

I. INTRODUCTION

The American Welding Society (AWS) defines the welding as a localized coalescence of metals or non-metals produced either by heating the materials to suitable temperatures, with or without the application of pressure, or by pressure alone, and with or without the use of filler material. **Indian Standard IS: 812-1957** defines the welding as a union between two pieces of a metal at faces rendered plastic or liquid by heat or by pressure, or both. The filler metal may be used to affect the union . **International Organization for Standards (ISO)** defines the welding as an operation by which two or more parts are united, by means of the heat or pressure, or both, in such a way that there is continuity of the nature of the material between these parts. A filler material, the melting temperature of which is of the same order as that of the parent material, may or may not be used.

The gas metal arc welding (GMAW), sometimes referred by its subtype the metal inert gas (MIG) welding or the metal active gas (MAG) welding is a welding process in which an electric arc forms between a consumable wire electrode and the work piece metals, which heats the work piece metals, causing them to melt and join. Along with the wire electrode, a shielding gas feed through the welding gun, which shields the process from contamination in the air. The process can be semi-automatic or automatic.

The gas tungsten arc welding (GTAW), also known as the tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it.

The comparative study of the gas metal arc welding (GMAW) and the gas tungsten arc welding (GTAW) are a welding process that is now widely used for welding a variety of materials like as ferrous and non-ferrous. In manual welding operations, the welder has to have control over the input welding parameters which affect the weld penetration, bead geometry and overall weld quality. Proper chances of input welding parameters like as welding current, welding voltage, welding speed, gas flow rate and root gap will increase the chances of producing welds of a satisfactory quality. An aluminium alloy plates are joined by the GMAW and the GTAW. There are the five input parameters for the both welding process are taken for the analysis. Taguchi designs of experiment method are used to find out the optimization of welding parameters. The analysis of signal to noise ratio was done using MINITAB- 18 software for higher the better quality characteristics.

II. LITERATURE SURVEY

Choi *et al*. (2008) investigated the effect of welding condition according to the mechanical properties of the pure titanium and presents the optimum welding condition through the evaluation about the weld ability of the pure titanium by the welding conditions such as the welding pass, the amount of shielded gas and the welding time interval. In order to find out the optimum welding condition by the mechanical properties of pure titanium, the annealed pure titanium of the ASTM B265 grade 2 is selected as a specimen and is classified by several welding conditions. The experiments performed the test of tension, impact and hardness under the welding condition, respectively.

Jun *et al*. (2009) investigated the microstructure and the mechanical properties of SS304 joints by the tungsten inert gas (TIG) welding, the laser welding and the laser TIG hybrid welding. The X-ray diffraction has been used to analyze the phase composition, while the microscopy has been conducted to study the microstructure characters of joints. The tensile tests have been performed and the fracture surfaces have been analyzed. The results showed that the joint by the laser welding had the highest tensile strength and the smallest dendrite size in all the joints, while the joint by the TIG welding had the lowest tensile strength, the biggest dendrite size.

Ahmed *et al*. (2010) discussed the tungsten inert gas welding is one of the widely used techniques for the joining ferrous and non ferrous metals. The TIG welding process offers several advantages like joining of the unlike metals, the low heat effected zone, absence of slag etc the compared to the MIG welding. This paper deals with the investigation of the effect of welding speed on the tensile strength of the welded joint. The experiments are conducted on the specimens of single v butt joint having the different bevel angle and bevel heights. The material selected for the preparing the test specimen is AA6351. The mechanical properties of the welded joint are tested by a universal tensile testing machine and the results are evaluated.

Suresh *et al*. (2011) describes the mechanical properties of stainless steel (austenitic) for the process of MIG and TIG welding. Other welding processes such as the gas metal arc welding, shielding gases are necessary in GMAW or MIG welding is used to protect the welding region from the atmospheric gases such as oxygen and nitrogen which can the cause of fusion defects, porosity and the weld metal embitterment if they come in contact with the arc of welding metal and electrode. We used the MIG and the TIG process to the find out the characteristics of the metal after welded. The voltage is taken constant and various mechanical characteristics like as strength, hardness, ductility, grain structure, modulus of elasticity, tensile strength breaking point, HAZ etc are observed in two processes and analyzed and concluded.

Abbasi *et al*. (2012) carried out the effect of the MIG welding parameters on the weld bead and shape factor characteristic of bright drawn mild steel specimen of the dimensions 144 x 31 x 10 mm has been the investigated. The welding current, welding speed, arc voltage, heat input rate are chosen as the welding parameters. The depth of weld penetration and weld width have been measured for every specimen after the welding operation and the effect of heat input and welding speed rate parameters on depth of weld penetration and weld width have been investigated. The aims of this paper at the evaluation of weld width and depth of weld penetration by employing different GMAW parameters.

Pasupathy *et al*. (2013) carried out the tungsten inert gas welding (TIG) process is an important component in many industrial operations. The TIG welding parameters are the most important factors affecting the productivity, the quality and the cost of welding. In this investigation the influence of welding parameters like welding current, welding speed on strength of low carbon steel on AA1050 material during welding process. A plan of experiments based on the taguchi technique has been used to acquire the data. An orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to investigate the characteristics of welding for dissimilar joint and optimize the welding parameters.

Anoop *et al*. (2013) discussed the aluminium alloy 7039 is an Al-Mg-Zn alloy employed in aircraft, automobiles, infantry combat vehicles and high speed trains due to their low density, high specific strength and the excellent corrosion resistance. The settings of the process parameters have been too determined by using the taguchi experimental design approach. An orthogonal array, the signal-to-noise (S/N) ratio, the regression analyses and the analysis of variance ANOVA), are employed to find out the optimal process parameter levels and to analyze the effect of these parameters on the weld.

Pawan *et al.* (2013) the author discusses an investigation into the use of taguchi's parameter design approach for the parametric study of the gas metal arc welding of low carbon steel and stainless steel. The design of an experiments using orthogonal array is employed to develop the weldments. A total number of 9 experimental runs have been conducted using an L9 orthogonal array. After calculating the data signal-to-noise (S/N) ratios have been evaluated and used in order to obtain optimum levels for every input parameter. The subsequently, using the analysis of variance (ANOVA) the significant coefficients for each input parameter on hardness (PM, WZ & HAZ) and tensile strength have been determined and validated.

Deepak *et al*. (2014) discussed the GMAW is a fusion welding process having wide applications in the industry. The process parameters play a very significant role in the determining the quality of a welded joint in GMAW process. In the research work the experiments have been carried out on 1018 mild steel plates using the gas metal arc welding (GMAW) process. L9 orthogonal array of the taguchi`s experimental design has been used for the optimization of current, voltage and gas flow rate on welded joints.

Vineeta *et al*. (2015) carried out the parametric optimization of the MIG welding for hardness has been performed by using the taguchi technique. The materials used for this purpose have been AA6061 and AA5083 having the dimensions of 75x60x6 mm. the argon have been used as a shielding gas. The filler wire 4043 of diameter 1.2 mm has been used. An orthogonal array, L9 has been used to conduct the experiments. Signal to noise (S/N) ratio and analysis of variance (ANOVA) have been employed to study the welding characteristics of the material. The optimization of parameters has been done by the taguchi method using the statistical software of MINITAB17.

Chandrasheker *et al*. (2017) describe the experimental study and the presents an effective approach for the optimization of turning parameter using MINITAB 17 and the taguchi technique in varying condition. In this investigation the machining parameters namely the depth of cut, cutting speed, feed rate and the cutting fluids are optimized with the multiple performance characteristics, such as the maximum material removal rate and the maximum surface finish. The response table and response graph for the each level of the machining parameters are obtained from the taguchi approach and the optimum levels of the machining parameters are being selected.

Sindiri Mahesh *et al*. (2017) the problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required weld quality. In this investigation the influence of welding parameters such as current, voltage, welding speed on ultimate tensile strength (UTS) of AISI 1050 mild steel material during the welding. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal to noise (S/N) ratio and the analysis of variance (ANOVA) are employed to study the welding characteristics of material and optimize the welding parameters. The result calculated is in form of the contribution from each parameter, through which the optimal parameters are identified for maximum tensile strength. According to this study, it is observed that welding current and welding speed are major parameters which the influence on the tensile strength of the welded joint.

III. TAGUCHI METHOD

Taguchi design of experiment is one of these techniques which are used widely. The Taguchi method involves reducing the variation in a process through robust design experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by **Dr. Genichi Taguchi** of Japan who maintained that variation. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting and the levels at which they should be varies. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and **Dr. Taguchi's** Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

There are 3 Signal-to-Noise ratios of common interest for optimization.

$$\frac{S}{N}HB = -10\log_{10}\left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{1}{\sqrt{yi}}\right)\ldots..1$$

$$\frac{S}{N}LB = -10\log_{10}\left(\frac{1}{n}\right)\sum_{i=1}^{n}\sqrt{yi}\ldots\ldots2$$

$$\frac{S}{N}NB = -10log_{10}\frac{1}{n}\sqrt{(yi-M)^4}\ldots..3$$

IV. EXPERIMENTATION

The parent material used for the present research work is an aluminium alloy 3003- H2 (IS - 737) with the dimensions of the work piece as 100 mm x 40 mm x 5 mm. ER4043 used as the filler wire of 1.6 mm diameter and the consumable electrode with the helium and the argon as inert gas was used for the gas metal arc welding (GMAW) and the non-consumable electrode with the helium and argon as inert gas was used for the gas tungsten arc welding (GTAW). The welding of specimens has been carried out by the GMAW and the GTAW setup available at Durga dhalai udhyog, B-20, industrial area, Rudrapur (U.S Nagar), India. The element composition of parent material and the filler wire is given in Table 4.1 and Table 4.2 respectively.

4.1 Parent Material AA3003

It is one of the most extensively used alloys in the 3xxx series. Manganese is the major alloying element of alloys in this group, which are generally non-heat-treatable. Because only a limited percentage of the component like as manganese, between 1.0-1.5 percent can be effectively added to the aluminium it is the used as a major element in only a few instances. One of these however is the popular AA3003 which is widely used as a general purpose alloy for the moderate strength applications requiring the good workability. An aluminium alloy has become during the last century one of the most important construction materials in the engineering section.

Table 4.1: Element compositions of the base material (AA3003)

Material Grade	Size (mm)	Element	Cu	Mg	Si	Fe	Mn	Zn	Ti	Cr	Al
3003 (IS-737)	Thickness 5	Wt %	0.05-0.20	-	0.6	0.70	1.0-1.5	0.1	-	-	Balance
(Condition) H2 = Strain hardened and partially annealed.											

4.2 Filler Wire ER4043

In the present research work aluminium alloy ER4043 has been used as filler wire. It is one of the oldest and most widely used welding and brazing alloy. The addition of Si reduces the melting point and increases the fluidity in molten state of the material. This alloy is less sensitive to the weld cracking and produces brighter; almost smut free welds, because it does not contain magnesium. The chemical composition are shown in table 4.2 extracted from Hindalco extrusions.

Table 4.2: Element compositions of filler wire (ER4043)

Element	Size (mm)	Cu	Si	Fe	Mn	Mg	Cr	Zn	Ti	Al
% age	Φ 1.6	0.30	4.5-6.0	0.8	0.05	0.05	-	0.10	0.20	Balance

4.3 Input Process Parameter Values for GMAW and GTAW

The input welding process parameters selected for this research work were current, voltage, welding speed, gas flow rate and root gap. The tensile strength test was taken as the output quality characteristic. The each of these response parameters was varied at 3 levels. The range and levels of these response parameters were decided on the basis of preliminary experiments conducted by using one variable at a time approach. The feasible range for the GMAW and the GTAW machining parameters was defined for the both process as shown in table 4.4 & 4.5 for the welding of selected parent material and the filler wire.

4.4 Process Parameters and their Levels

According to the number of input factors and their levels L_{27} orthogonal array is selected from the Taguchi's special set of standard arrays used MINITAB-18.

Table 4.4: Process parameters and their values at different levels and DOE for GMAW

Si. No.	Parameters	Levels		
		1	2	3
1.	Current (Amp)	170	185	200
2.	Voltage (Volt)	20	24	28
3.	Speed (cm/min)	50	65	80
4.	Gas flow rate (Ltr/min)	15	19	23
5.	Root gap (mm)	1.5	2.0	2.5

Table 4.5: Process parameters and their values at different levels and DOE for GTAW

Si. No.	Parameters	Levels		
		1	2	3
1.	Current (Amp)	210	225	240
2.	Voltage (Volt)	22	26	30
3.	Speed (cm/min)	60	75	90
4.	Gas flow rate (Ltr/min)	12	16	20
5.	Root gap (mm)	1.0	1.5	2.0

4.5 Selection of Orthogonal Array

To select an appropriate orthogonal array for experiments, the total degrees of freedom need to be computed. In this study each three level parameter has 2 degree of freedom (DOF = Number of level–1), the total DOF required for five parameters each at three levels is 2. Once the degrees of freedom required are known, the next step is to select an appropriate orthogonal array to fit the specific task. Basically, the degrees of freedom for the orthogonal array should be greater than or at least equal to those for the process parameters. In this study, an L_{27} Orthogonal array (a standard 3-level OA) having total 10 degree of freedom was selected from the Taguchi's special set of predefined arrays.

4.6 Output Response

The tensile strength of the welded samples is measured on Universal Testing Machine (UTM). The specimens are machined according to ASME standards as shown in Fig. 4.1.

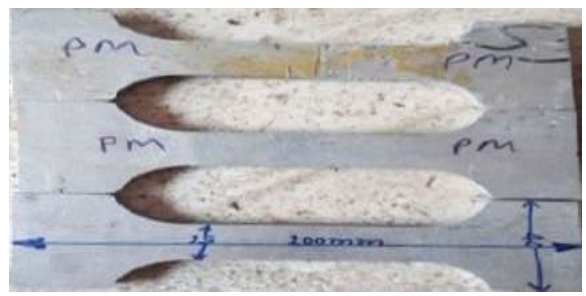

Fig. 4.1: Standard Tensile Test Specimen

V. RESULT AND DISCUSSION

Table 5.1: Result of tensile strength and S/N ratio for GMAW

Run	Current (Amp)	Voltage (Volt)	Speed (cm/min)	GFR (Ltr/min)	Root gap (mm)	UTS (Mpa)	S/N ratio
1	170	20	50	15	1.5	135.685	42.65064
2	170	20	50	15	2	153.7013	43.73355
3	170	20	50	15	2.5	174.46	44.83392
4	170	24	65	19	1.5	162.6467	44.2249
5	170	24	65	19	2	182.0327	45.20299
6	170	24	65	19	2.5	185.7773	45.37985
7	170	28	80	23	1.5	177.978	45.00733

8	170	28	80	23	2	191.8823	45.6607
9	170	28	80	23	2.5	205.0367	46.23663
10	185	20	65	23	1.5	175.2317	44.87225
11	185	20	65	23	2	170.352	44.62694
12	185	20	65	23	2.5	167.5857	44.48474
13	185	24	80	15	1.5	177.9087	45.00394
14	185	24	80	15	2	192.8497	45.70438
15	185	24	80	15	2.5	181.1593	45.16121
16	185	28	50	19	1.5	197.1767	45.89711
17	185	28	50	19	2	186.0477	45.39248
18.	185	28	50	19	2.5	214.5613	46.63103
19	200	20	80	19	1.5	197.1833	45.8974
20	200	20	80	19	2	188.646	45.51295
21	200	20	80	19	2.5	184.103	45.30122
22	200	24	50	23	1.5	194.9237	45.79729
23	200	24	50	23	2	218.9493	46.80687
24	200	24	50	23	2.5	205.0333	46.23649
25	200	28	65	15	1.5	211.482	46.50547
26	200	28	65	15	2	204.979	46.23419
27	200	28	65	15	2.5	215.6003	46.67299

Table 5.2: Result of tensile strength and S/N ratio for GTAW

Run	Current (Amp)	Voltage (Volt)	Speed (cm/min)	GFR (Ltr/min)	Root gap (mm)	UTS (Mpa)	S/N ratio
1	210	22	60	12	1	129.356	42.23573
2	210	22	60	12	1.5	152.688	43.6761
3	210	22	60	12	2	172.691	44.74539
4	210	26	75	16	1	160.161	44.09114
5	210	26	75	16	1.5	181.161	45.16129
6	210	26	75	16	2	174.828	44.85222
7	210	30	90	20	1	190.779	45.61061
8	210	30	90	20	1.5	207.446	46.3381
9	210	30	90	20	2	174.779	44.84979
10	225	22	75	20	1	174.893	44.85545
11	225	22	75	20	1.5	166.226	44.41398
12	225	22	75	20	2	181.893	45.19632
13	225	26	90	12	1	177.736	44.99551
14	225	26	90	12	1.5	191.402	45.63893
15	225	26	90	12	2	180.402	45.12483
16	225	30	60	16	1	199.962	46.01895
17	225	30	60	16	1.5	185.628	45.37287
18	225	30	60	16	2	215.628	46.6741
19	240	22	90	16	1	193.033	45.71263
20	240	22	90	16	1.5	187.366	45.45382
21	240	22	90	16	2	183.703	45.28232
22	240	26	60	20	1	193.022	45.71214
23	240	26	60	20	1.5	225.689	47.07021
24	240	26	60	20	2	191.355	45.6368
25	240	30	75	12	1	216.96	46.72759
26	240	30	75	12	1.5	201.293	46.07657
27	240	30	75	12	2	211.627	46.51142

In taguchi method signal-to-noise ratios is used to determine the optimum level of each factor. This is done by collecting levels with high signal-to-noise ratio. The response table shows the average of each response characteristic (S/N ratios, means) for each level of each factor. Table 6.1 & 6.2 include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values; rank 1 to the highest Delta value, rank 2 to the second highest, and so on. Finally the optimum level of each factor is given in Table 6.3. These levels are the peak values of each factor as shown in fig. 2 & 3.

Table 5.3: Response table of Signal to Noise ratio for GMAW

Level	Current	Voltage	Speed	GFR	Root gap
1	44.77	44.66	45.33	45.17	45.1
2	45.31	45.5	45.36	45.49	45.43
3	46.11	46.03	45.5	45.53	45.66
Delta	1.34	1.37	0.17	0.36	0.56
Rank	2	1	5	4	3

Table 5.4: Optimum values of each factor for GMAW

Input parameters	Levels	Input values	Responses values
Current (Amp)	3	200	46.11
Voltage (Volt)	3	28	46.03
Welding speed (cm/min)	3	80	45.5
Gas flow rate (Ltr/min)	3	23	45.53
Root gap (mm)	3	2.5	45.66

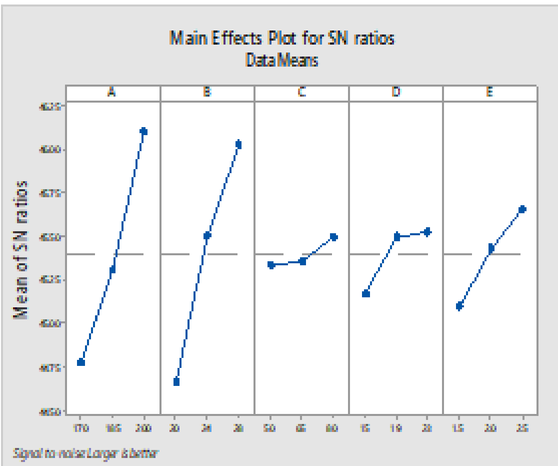

Fig. 5.1: Graph for S/N Ratio of Different Parameters for GMAW

Table 5.5: Response Table of Signal to Noise Ratio for GTAW

Level	Current	Voltage	Speed	GFR	Root gap
1	44.62	44.62	45.24	45.08	45.11
2	45.37	45.36	45.32	45.4	45.47
3	46.02	46.02	45.45	45.52	45.43
Delta	1.4	1.4	0.21	0.44	0.36
Rank	1	2	5	3	4

Table 5.6: Optimum values of each factor for GMAW

Input parameters	Levels	Input values	Responses values
Current (Amp)	1	210	44.62
Voltage (Volt)	1	22	44.62
Welding speed (cm/min)	3	90	45.45
Gas flow rate (Ltr/min)	3	20	45.52
Root gap (mm)	2	1.5	45.47

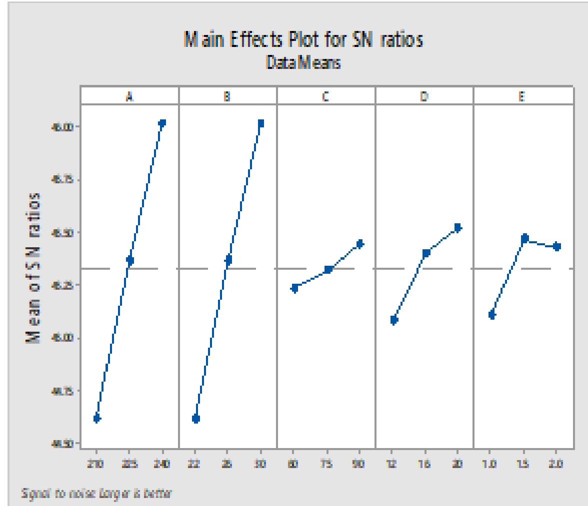

Fig. 5.2: Graph for S/N Ratio of Different Parameters for GTAW

Table 5.7: Result of ANOVA test summery of S/N data (tensile strength) for GMAW process

Source	DF	Seq SS	Adj SS	Adj MS	F	P	PC (%)
A	2	8.1479	8.1479	4.07395	14.89	0	34.79↑
B	**2**	**8.5923**	**8.5923**	**4.29616**	**15.7**	0	**36.68**↑↑
C	2	0.1467	0.1467	0.07337	0.27	0.768	0.64
D	2	0.7093	0.7093	0.35466	1.3	0.301	3.04
E	2	1.4516	1.4516	0.72579	2.65	0.101	6.20
Residual Error	16	4.3784	4.3784	0.27365			
Total	26	23.4262					
S = 0.5231, R-Sq = 81.31 %, R-Sq(adj) = 69.63 % Order of significance 1: Current; 2: Voltage							

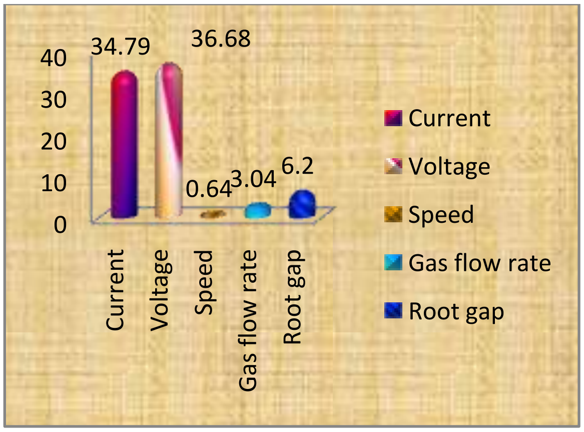

Fig. 5.3: Graph representing percentage contribution for S/N ratios (tensile strength) for GMAW process

Since the degree of freedom calculated from the S/N data for the numerator is 2 and that for the denominator is 2. The limiting value at 95% confidence level of the Fisher's constant from .It is clear from the table 6.7 that F value for the parameters of current, voltage and root gap are more than the limiting value but for welding speed and gas flow rate the F value is less than to the limiting value. Therefore current, voltage and root gap are more significant than the welding speed and gas flow rate at 95% confidence level. The bar graph as shows in fig. 4 the percentage contribution of process parameters affecting the average values of S/N data. Indicate that the maximum percentage contribution is of welding voltage i.e. **36.68 %.**

Table 5.8: Result of ANOVA test summery of S/N data (tensile strength) for GTAW process

Source	DF	Seq SS	Adj SS	Adj MS	F	P	P C (%)
Current	**2**	**8.8654**	**8.8654**	**4.43271**	**9.88**	**0.002**	**33.1845↑**
Voltage	2	8.8439	8.8439	4.42193	9.85	0.002	33.0837↑
Speed	2	0.1957	0.1957	0.09785	0.22	0.806	0.7389
GFR	2	0.9289	0.9289	0.46447	1.04	0.378	3.4931
Root gap	2	0.7077	0.7077	0.35384	0.79	0.471	2.6534
Residual Error	16	7.1802	7.1802	0.44876			
Total	26	26.7218					
S = 0.6699, R-Sq = 73.13 %, R-Sq(adj) = 56.34 % Order of significance 1: Current; 2: Voltage							

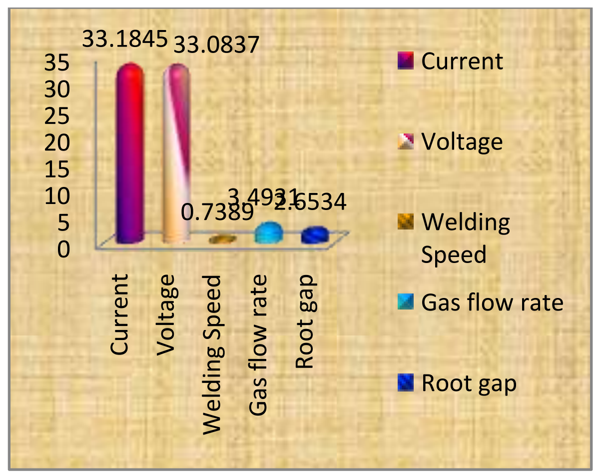

Fig. 5.4: Graph representing percentage contribution for S/N ratios (tensile strength) for GTAW process

Since the degree of freedom calculated from the S/N data for the numerator is 2 and that for the denominator is 2. The limiting value at 95% confidence level of the Fisher's constant. It is clear from the table 6.8 that F value for the parameters of current, voltage and root gap are more than the limiting value but for welding speed and gas flow rate the F value is less than to the limiting value. Therefore current, voltage and root gap are more significant than the welding speed and gas flow rate at 95% confidence level. The bar graph as shows in fig. 5 the percentage contribution of process parameters affecting the average values of S/N data. Indicate that the maximum percentage contribution is of welding current i.e. **33.1845 %.**

The purpose of ANOVA is to investigate which welding process parameters significantly affect the tensile strength. This is accomplished by separating the total variability of the S/N Ratios, which is measured by the sum of squared deviations from the total mean of the S/N ratio, into contributions by each welding process parameter and the error. In the experimentation work, for S/N ratios, current and voltage (p = 0.0) has the significant effect on tensile strength at a α-level of 0.05for GMAW and current and voltage (p = 0.002) has significant for GTAW and the other parameters for GMAW and GTAW the welding speed, gas flow rate and root gap are non significant because their p-values are greater than 0.05.

The percentage contribution by each of the welding process parameters in the total sum of the squared deviations can be used to evaluate the importance of each parameter change on the tensile strength. From the fig. 4 & 5 we can see that voltage (GMAW) & current (GTAW) has the greatest percentage contribution of 36.68 %, current has 33.185 %. It can be concluded that voltage & current has greatest effect followed by remaining parameters for both process respectively.

Table5.9: The S/N ratio and tensile strength of the responses between GMAW process and GTAW process

No. of Run	GMAW		GTAW	
	At weld zone			
	UTS	S/N Ratio	UTS	S/N Ratio
1.	135.685	42.6506	129.356	42.2357
2.	153.7013	43.7335	152.688	43.6761
3.	174.46	44.8339	172.691	44.7453
4.	162.6467	44.2249	160.161	44.09114
5.	182.0327	45.2029	181.161	45.1612
6.	185.7773	45.3798	174.828	44.8522
7.	177.978	45.0073	190.779	45.6106
8.	191.8823	45.6607	207.446	46.3381
9.	205.0367	46.2366	174.779	44.8497
10.	175.2317	44.8722	174.893	44.8554
11.	170.352	44.6269	166.226	44.4139
12.	167.5857	44.4847	181.893	45.1963
13.	177.9087	45.0039	177.736	44.9955
14.	192.8497	45.7043	191.402	45.6389
15.	181.1593	45.1612	180.402	45.1248
16.	197.1767	45.8971	199.962	46.0189
17.	186.0477	45.3924	185.628	45.3728
18.	214.5613	46.6310	215.628	46.6741
19.	197.1833	45.8974	193.033	45.7126
20.	188.646	45.5129	187.366	45.4538
21.	184.103	45.3012	183.703	45.2823
22.	194.9237	45.7972	193.022	45.7121
23.	218.9493	46.8068	225.689	47.0702
24.	205.0333	46.2364	191.355	45.6368
25.	211.482	46.5054	216.96	46.7275
26.	204.979	46.2341	201.293	46.0765
27.	215.6003	46.6729	211.627	46.5114
Average	187.1471	45.3951	185.9891	45.3346
Max	218.9493	46.8068	225.689	47.0702
Min	135.685	42.6506	129.356	42.2357

Table 5.10: The experimental values of mechanical properties for parent material

No. of Run	Tensile strength (Mpa)
1.	189.5014
2.	195.0738
3.	191.9027
Average	**192.1593**

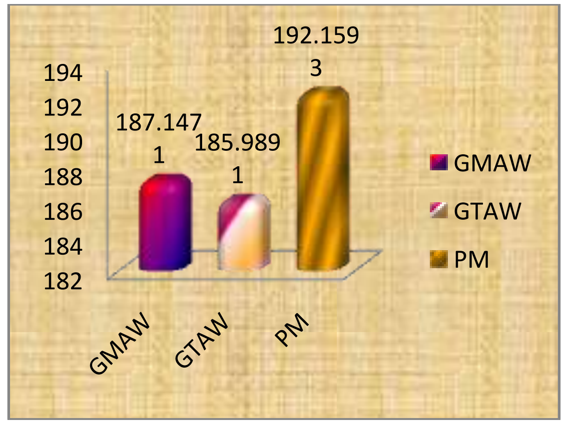

Fig. 5.5: Comparison of tensile strength for GMAW, GTAW and PM

VI. CONCLUSION

Optimization of the process parameters in the comparative study of GMAW & GTAW by Taguchi's experimental design method has been performed. An L_{27} orthogonal array was selected to study the relationships between the tensile strength and the five controllable input welding parameters such as current, voltage, welding speed, gas flow rate and root gap for the GMAW & GTAW process.

The following conclusions can be drawn based on the experimental results of this research work:

1. Taguchi's experimental design method provides a simple, systematic and efficient methodology for the optimization of the GMAW & GTAW parameters.
2. The optimum values for each parameter during GMAW & GTAW process are shown in table 6.6 as above.
3. The tensile strength of parent material is higher than GMAW & GTAW process. The GMAW having higher the tensile strength as comparison of GTAW as shown in fig. 5
4. Voltage has the greatest percentage contribution followed by current, welding speed gas flow rate and root gap during GMAW process.
5. Current has the greatest percentage contribution followed by voltage, welding speed gas flow rate and root gap during GTAW process.
6. Current and voltage are the significant factor for tensile strength but welding speed, gas flow rate and

root gap are the non-significant parameters in GMAW and GTAW.

7. From the tension test conducted on the specimen we can conclude that

7.1 Ultimate load of GMAW the welded specimen is 57600 N where as for the GTAW the welded specimen is 56160N and the parent material having the load is 59140N. Therefore we can say that GMAW the welded specimen can bear higher loads than GTAW the welded specimen, but the parent material having the higher load as compared to the both processes.

7.2 The tensile strength of GMAW the welded specimen is 187.1471 MPa where as for the GTAW the welded specimen is 185.9891MPa, but the strength of parent material is 192.1593. Therefore we can say that the parent specimen has higher tensile strength.

7.3 Tensile strength decreases with increase in current and tensile strength increase with increase remaining all parameters during GMAW process. Tensile strength increases with increase in current, voltage, welding speed, gas flow rate and root gap in fluctuating order during GTAW process, but in case of both GMAW & GTAW process, it increases up to the optimum level and decreases on further increasing these values.

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