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Comparison and Prediction of TIG and MIG Welding Parameter to Improve Strength (Impact and Tensile)

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Abstract

Various welding process are present, among the various welding process, Tungsten inert gas (TIG) welding plays a major role in the welding of mild steel or thin sections of non-ferrous metals such as copper alloys, aluminium alloys, magnesium and stainless steel. MIG input welding parameters are the most important factors affecting the quality of the welding and weld quality is strongly characterized by weld bead geometry. The choice of the welding depends on several factors; primarily among them are the compositional range of the material to be welded, the thickness of the base materials and type of current. TIG welding has several advantage like joining of dissimilar metals, the absence of slag, low heat affected zone and etc. Since input parameters play a major role in determining the quality of a welded sample. A plan of experiments based on Taguchi technique has been used to design of experiment, acquire the data and to optimize the welding parameters as well as the process. An Orthogonal array and analysis of variance (ANOVA) are employed to investigate the welding characteristics of alloy Steel material and predict the welding parameters. Properties are Hardness, Tensile strength etc. are taken as responses of input parameter. Finally the comparison tests have been carried out to compare for given alloy steel with the ANOVA values for prediction of parameter its effectiveness in the analysis of penetration.

Keywords: *- Alloy steel; design of experiment; ANOVA, Tensile strength.*

INTRODUCTION

Arc welding is a technique to melt and join different materials that is widely used in the industry. The gas tungsten arc welding (GTAW) process is sometimes referred to as TIG or MIG. The term TIG is short for tungsten inert gas welding. Under the correct welding conditions, the tungsten electrode does not melt and is considered to be non-consumable. To make a weld, either the edges of the metal must melt and flow together by themselves or filler metal must be added directly into the molten pool. Filler metal is added by dipping the end of a filler rod into the leading edge of the molten weld pool. Most metals oxidize rapidly in their molten state. . MIG is an arc welding process where in coalescence is obtained by heating the job with an electric arc produced between work piece and metal electrode feed continuously. Metal Inert Gas welding is one of the most widely used processes in industry. The input parameters play a very significant role in determining the quality of a welded joint. In fact, weld geometry directly affects the complexity of weld schedules and thereby the construction and manufacturing costs of steel structures and mechanical devices. Therefore, these parameters affecting the arc and welding should be estimated and their changing conditions during process must be known before in order to obtain optimum results; in fact a perfect arc can be achieved when all the parameters are in conformity. These are combined in two groups as first order adjustable and second order adjustable parameters defined before welding process. Selection of proper process parameters is important to obtain the desired weld bead profile and quality. Welding carried out work on numerical and graphical optimization techniques of the CO2 laser beam welding of dual phase transformation induced plasticity steel sheets using response surface methodology (RSM) based on Box–Behnken design. They have established procedure to improve the weld quality, increase the productivity and minimize the total operation cost by considering the welding parameters range of laser power, welding speed and focus position.

TIG welding

TIG welding offers several advantages i.e. joining of dissimilar metals, low heat affected zone, absence of slag etc. In TIG welding operation, weld quality mainly depends on features of bead geometry, mechanical-metallurgical characteristics of the weld and various aspects of weld chemistry. These features are greatly influenced by the welding parameters such includes current, voltage, gas flow rate, electrode stick-out, edge preparation, position of welding, weld speed (Ghosh et al 2013) etc. Selection of filler rod material also has significant effect on weld quality. Selection of optimum parametric setting is essential for obtaining desired weld quality. Again Datta et al (2008) applied Taguchi philosophy for obtaining optimal parametric combinations to achieve desired weld geometry and dimensions related to the heat affected zone in submerged arc welding. Esme et al. (2009) had done investigation on TIG welding process for an optimal parametric combination to yield favorable bead geometry of welded joints. They used grey-Taguchi method application to optimize multi-responses bead width, bead height, and penetration, area of penetration, HAZ and tensile load simultaneously. Kumar and Sundarrajan (2009) used Taguchi method to optimize the pulsed TIG welding process parameters of heat-treatable (Al-Mg-Si) aluminum alloy weldments for maximizing the mechanical properties. Another work presented by Zhang et al (2012) optimization of an aluminum profile extrusion process based on signal-to-noise ratio of Taguchi methodology.

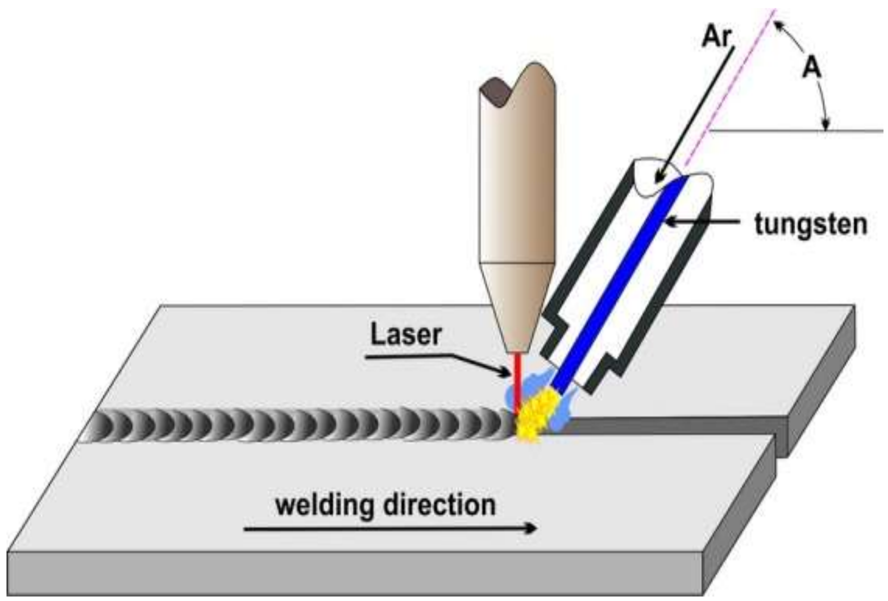

Fig.1. TIG welding

MIG WELDING

Now-a-days, determination of optimum values of process parameters in manufacturing are the areas of great interest for researchers and manufacturing engineers. The input parameters play a very significant role in determining the quality of a welded joint. The welding parameters are current, arc voltage and welding speed. These parameters will affect the weld characteristics to a great extent. Because these factors can be varied over a large range, they are considered the primary adjustments in any welding operation. MIG welding is a versatile technique suitable for both thin sheet and thick section components. An arc is struck between the end of a wire electrode and the work piece, melting both of them to form a weld pool. Metal Inert Gas welding as the name suggests, is a process in which the source of heat is an arc formed between a consumable metal electrode and the work piece, and the arc and the molten puddle are protected from contamination by the atmosphere (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of inert gas such as argon, helium or an argon-helium mixture.

Fig.2. MIG welding

LITERATURE REVIEW

TIG processes can weld practically all ferrous and nonferrous materials to themselves or to very similar alloy compositions. For welding dissimilar metals, TIG and MIG are the process of choice, permitting carbon steels to be joined to stainless or to copper alloys. Before opting for such designs, however, consideration should be given to consequent effects, such as galvanic corrosion and differences in expansion coefficients and conductivity. Many researches' have been done research work on different materials for obtaining maximum impact strength and tensile strength.

Bhargav & Jaivesh [1] studied the effect of MIG welding parameters like welding current, welding speed, flow of shielding gas arc voltage as input parameters and ANOVA methodology used. Tensile strength measured as output parameter. It is obvious that increasing welding current increased the UTS. In addition, arc voltage is another parameter in incrimination of UTS. However, its effect is not as much as current.

Deepak et. al. [2] investigate that the angular distortion is a major problem in butt weld plates. Restriction of this distortion by restraint may lead to higher residual stress. In initially angular distortion in (–ve) direction is provided to reduce the angular distortion if the magnitude of distortion is predictable. For optimizing the weld parameter control ANOVA is applied. In these paper the transverse direction of TIG, welding process was evaluated using following as main input parameter welding current, filler rod diameter, length of plate and time gap between passes. Experiment was carried out with SS 302 & MS samples of varying length, 50mm width and 6mm thick. The stainless steel and mild steel plates were prepared with V grove design and butt weld type. With single pass filler metal. The distortion is measured with dial gauge fitted to a height gauge. 70 to 100 Amps was used as a current variation. A carbon steel filler rod of 1.5 to 2.5 used as a filler metal in this case.

Dinesh et. al. [3] studied to investigate the optimization process parameters for Metal Inert Gas welding (MIG). This paper presents the influence of welding parameters like wire diameter, welding current, arc voltage welding speed, and gas flow rate optimization based on bead geometry of welding joint. The objective function have been chosen in relation to parameters of MIG welding bead geometry tensile strength, Bead height, Penetration and Heat affected zone (HAZ) for quality target. The most significant factor also found in this case welding current is having maximum percentage contribution. So it is most significant factor in this result.

Abbasi.K et. al. [4] investigated the effect of increased pressure on MIG welding arc using automatic robotic welding machine and a mixture of Argon and Carbon Dioxide as shielding gas. The variation of welding parameters like feed rate, arc voltage and arc current were observed on penetration. Variation of penetration with pressure at different wire feed speeds has also been studied. They observed that increased pressure has remarkable effect on the welding arc, weld penetration and bead geometry.

Pranesh B. Bamankaret. al. [5] studied the effect of process parameters on depth of penetration and bead width in saw (submerged arc welding) process. They conducted Experiments using submerged arc process parameters viz. welding current, arc voltage and welding speed (Trolley speed) on mild steel of 12 mm thickness, to study the effect of these parameters on penetration depth. The experiments are designed using Taguchi method (with Taguchi L9 orthogonal array) considering three factors and three levels.

H.J. Park et. al. [6] optimizing the wire feed speed against the welding speed during the pulse-MIG (Metal Inert Gas) lap joint fillet weld of 1.6 mm aluminium alloy typically used for the light-weight car body. Welding experiments were conducted with various wire feed speeds of 0.5 m/min, 1.0 m/min, and 1.5 m/min, and the bead characteristics were evaluated. As shape factors of the weld bead, the bead width, back bead width, and bead cross-section area were measured. According to the weld quality and defined objective functions, the wire feed speed was optimized for various welding speeds.

Experiment Work

Design of Experiment

Design of Experiments (DOE) is a powerful statistical technique introduced by R. A. Fisher in England in the 1920's to study the effect of multiple variables simultaneously. The DOE using Taguchi approach can economically satisfy the needs of problem solving and product/process design optimization projects. By learning and applying this technique, engineers, scientists, and researchers can significantly reduce the time required for experimental investigations. DOE is a technique of defining and investing all possible combinations in an experiment involving multiple factors and to identify the best combination.

Selection of process parameters

The cause-effect diagram was constructed to identify process parameters which may affect the desired quantity characteristics of the final job. These parameters can be listed in categories as follows:

1. Power source
2. Current
3. Speed of welding

The choice and the selection of the parameter were decided by considering the objective of present study. Before selecting a particular OA to be used as a matrix for conducting the experiments. Generally current and voltage are the major factor to join any material and the third one is taken as speed of welding because it can directly cause to productivity. The parameters are their best of three results are taken as level which is shown in table.1.

This basic design uses up to three control factors, each with three levels. A total of nine runs must be carried out, using the combination of levels for each control factor. In this case the DOE will generate the experiment design and then allow that design to both welding experiment to obtain responses. Taguchi orthogonal design uses a special set of predefined array called orthogonal arrays (OA) to design the plan of experiment. These standard arrays stipulate the way of full information of all the factors that affects the process performance as shown in table.2.

Table.1. Levels and Parameters

Factors	**Level 1**	**Level 2**	**Level 3**
Voltage in KV (V)	30	35	40
Current in Ampere (A)	240	245	250
Speed of welding in m/min (S)	2.5	2.8	3.1

Table.2. Design of Experiment

S No.	V (volts)	A (ampere)	S (m/min.)
1	30	240	2.5
2	30	245	2.8
3	30	250	3.1
4	35	240	2.8
5	35	245	3.1
6	35	250	2.5
7	40	240	3.1
8	40	245	2.5
9	40	250	2.8

MATERIAL

Alloy steels contain a wide range of steels whose compositions exceed the limitations of C, Mo, Cr, Va, Mn, Ni, Si, and B fixed for carbon steels. These steels are more responsive to mechanical and heat treatments than carbon steels. AISI 8620 alloy steel is a common, carburizing alloy steel. This alloy steel is flexible during hardening treatments, thus enabling improvement of case/core properties. The following table.3 shows the chemical composition of AISI 8620 alloy steel. The mechanical properties of annealed AISI 8620 alloy steel are outlined in the table.4 below.

Table.3Chemical Composition of AISI 8620

Element	Content (%)
Iron, Fe	96.895-98.02
Manganese, Mn	0.700-0.900
Nickel, Ni	0.400-0.700
Chromium, Cr	0.400-0.600
Carbon, C	0.180-0.230
Silicon, Si	0.150-0.350
Molybdenum, Mo	0.150-0.250
Sulfur, S	≤ 0.0400
Phosphorous, P	≤ 0.035

Table.4 Mechanical Properties

Properties	Metric	Imperial
Tensile strength	530 Mpa	76900 psi
Yield strength	385 Mpa	55800 psi
Elastic modulus	190-210 GPa	27557-30458 ksi
Bulk modulus (typical for steel)	140 Gpa	20300 ksi
Shear modulus (typical for steel)	80 Gpa	11600 ksi
Hardness, Brinell	149	149
Hardness, Knoop (converted from Brinell hardness)	169	169

TIG welding process

TIG is an arc welding process, as shown in Fig. Wherein coalescence is produced by heating the work piece with an electrical arc struck between a tungsten electrode and the job. The electrical discharge generates a plasma arc between the electrode tip and the work piece to be welded. It is an arc welding process wherein coalescence is produced by heating the job with an electrical arc struck between a tungsten electrode and the job. The arc is normally initialized by a power source with a high frequency generator. This produces a small spark that provides the initial conducting path through the air for the low voltage welding current.

Fig.3. TIG welding setup

MIG WELDING

MIG welding is one of the most widely used processes in industry. It can be used with virtually any weld-able metals, including dissimilar metals, and thicknesses from upwards. MIG welding is a commonly used high deposition rate welding process. The input parameters play a very significant role in determining the quality of a welded joint. In fact, weld geometry directly affects the complexity of weld schedules and thereby the construction and manufacturing costs of aluminium structures and mechanical devices reduces. Therefore, these parameters affecting the arc and welding path should be estimated and their changing conditions during process must be known before in order to obtain optimum results, in fact a perfect arc can be achieved when all the parameters are in conformity. Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a welding process in which an electric arc is formed between a consumable wire electrode and the work piece metal(s), which heats the work piece metal(s), causing them to melt, and join. Along with the wire electrode, a shielding gas is fed through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used.

Fig.4. MIG Welding Process

On the basis of this table nine experiments was performed and cut the material by power hacksaw as per ASTM to observed their hardness and tensile load. After the orthogonal array has been selected, the second step in Taguchi parameter design is running the experiment. The 8620 alloy steel grade was used in mostly industry, homes, agriculture. All the welds were performed in plates rolled to 10 mm thick perpendicular to the rolling direction in a butt joint arrangement with straight edge preparation. Plates of 220 mm x 80 mm x 10mm were welded along their long edge. After welding, specimens were produced by cutting of power hacksaw and made it for tensile test as shown in fig.

Fig.5. Specimen of TIG Welding For Tensile Test

Fig.6. Specimen of MIG Welding For Tensile Test

RESULT AND DISCUSSION

The nine experiments were performed based on the L9 OA. The effect of different parameters such as welding current, arc voltage and welding speed of alloy steel 8620 is analyzed by TIG welding. The hardness and tensile strength of all nine weld specimen were checked carefully and the observed value of hardness and tensile strength are shown in table. 5.

On the base of ANOVA result Analysis of Variance for TIG and MIG Hardness and tensile test has been shown in table. 6 to 7 for both welding TIG and MIG welding hardness and tensile strength data individual their factor graph has been made and find out the significant factor for each output responses.

Table.5 Observed value by TIG welding

S No.	V	A	S	HARDNESS BHN	TENSILE MPa
1	30	240	2.5	126	438
2	30	245	2.8	114	450
3	30	250	3.1	116	482
4	35	240	2.8	148	476
5	35	245	3.1	134	494
6	35	250	2.5	116	432
7	40	240	3.1	112	468
8	40	245	2.5	123	480
9	40	250	2.8	137	470

Table.6 ANOVA for Hardness test

Source	DF	Seq SS	Adj SS	Adj MS	F	P
V	2	299.56	299.56	149.78	0.52	0.656
A	2	57.56	57.56	28.78	0.10	0.909
S	2	281.56	281.56	140.78	0.49	0.670
Residual Error	2	572.22	572.22	286.11		
Total	8	1210.89				

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Table.7 Response Table for TIG Hardness in BHN

Level	A	B	C
1	118.7	128.7	121.7
2	132.7	123.7	133.0
3	124.0	123.0	120.7
Delta	14.0	5.7	12.3
Rank	1	3	2

Hence, from the graph, it can be seen that the optimum welding parameter can be obtained by points or values of parameters having the peak position in the graph. Therefore a Factor level for predictions is Voltage 30, current 250 and 2.8 is welding of current for TIG hardness.

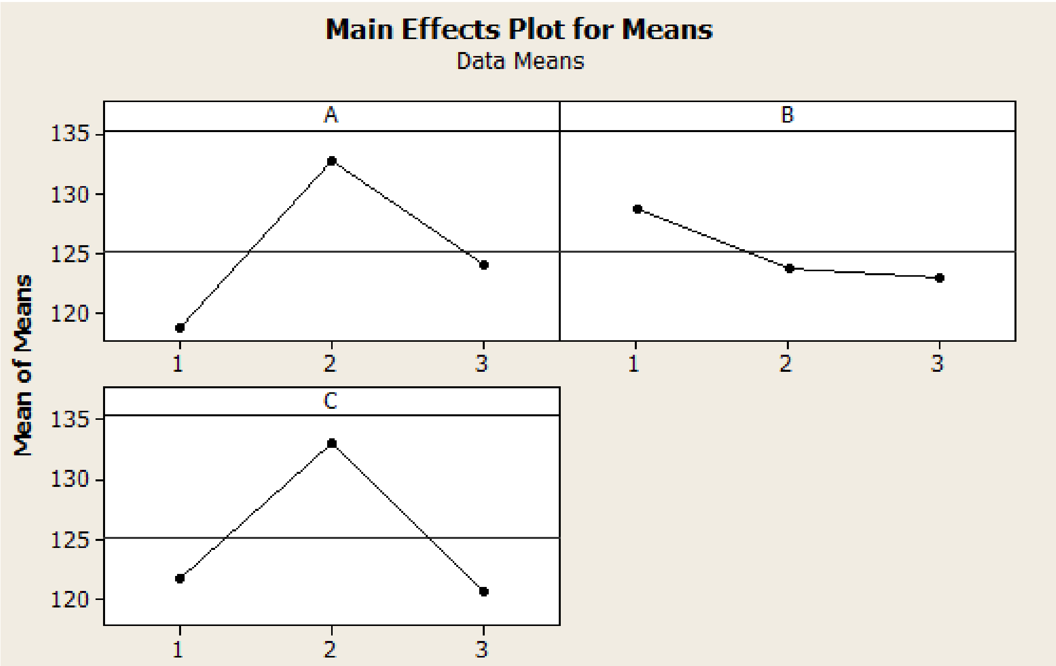

Fig.7. Mean Graph of TIG Hardness

Table.8 Analysis of Variance for TIG Tensile in Mpa

Source	DF	Seq SS	Adj SS	Adj MS	F	P
V	2	398.2	398.2	199.1	0.31	0.766
A	2	374.2	374.2	187.1	0.29	0.777
S	2	1472.9	1472.9	736.4	1.13	0.470
Residual Error	2	1304.9	1304.9	652.4		
Total	8	3550.2				

Table:-9 Response Table for TIG Tensile in Mpa.

Level	V	A	S
1	456.7	460.7	450.0
2	467.3	474.7	465.3
3	472.7	461.3	481.3
Delta	16.0	14.0	31.3
Rank	2	3	1

Hence, from the graph, it can be seen that the optimum welding parameter can be obtained by points or values of parameters having the peak position in the graph. Therefore Factor levels for predictions Voltage 35, current 250 and 2.5 is welding of current for TIG Tensile Test.

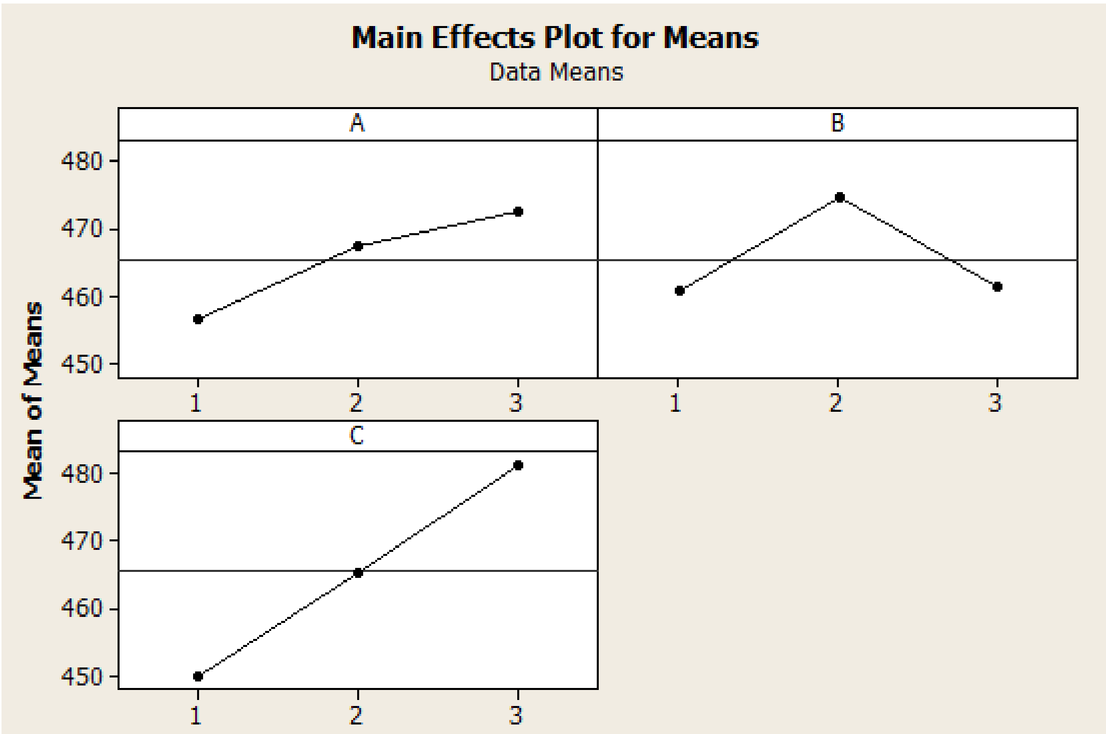

Fig.8. Mean Graph of TIG Tensile test

The nine experiments were performed based on the L9 array. The effect of different parameters such as welding current, arc voltage and welding speed of alloy steel 8620 is analysed by MIG welding. The hardness and tensile strength of all nine weld specimen were checked carefully and the observed value of hardness and tensile strength are shown in table.10.

Table.10. Observed value by MIG welding

S No.	V	A	S	HARDNESS BHN	TENSILE Mpa
1	30	240	2.5	121	468
2	30	245	2.8	118	490
3	30	250	3.1	113	510
4	35	240	2.8	142	492
5	35	245	3.1	131	468
6	35	250	2.5	126	446
7	40	240	3.1	122	486
8	40	245	2.5	133	513
9	40	250	2.8	147	474

Table.11.Analysis of Variance for MIG Hardness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
V	2	524.22	524.222	262.111	2.79	0.264
A	2	2.89	2.889	1.444	0.02	0.985
S	2	289.56	289.556	144.778	1.54	0.394
Residual Error	2	188.22	188.222	94.111		
Total	8	1004.89				

Table.12.Response Table for MIG Hardness in BHN

Level	V	A	S
1	117.3	128.3	126.7
2	133.0	127.3	135.7
3	134.0	128.7	122.0
Delta	16.7	1.3	13.7
Rank	1	3	2

Hence, from the graph, it can be seen that the optimum welding parameter can be obtained by points or values of parameters having the peak position in the graph. Therefore Factor levels for predictions Voltage 30, current 250 and 2.8 is welding of current for MIG hardness.

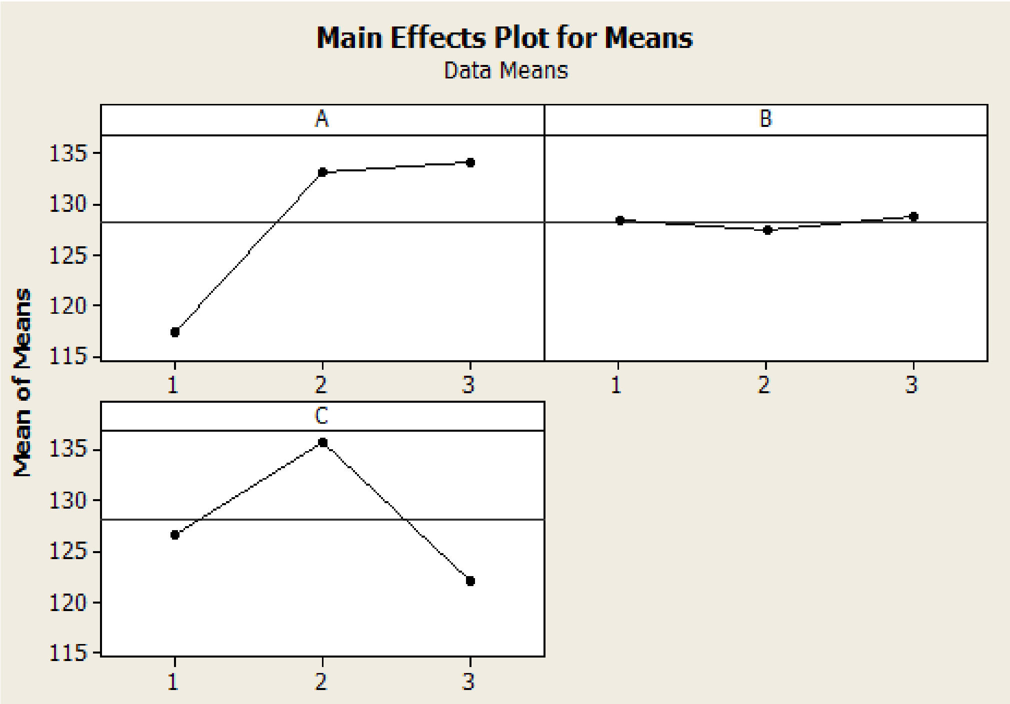

Fig.9.Mean Graph of MIG Hardness test

The data analysis of tensile test by ANOVA of P value is smaller is more significant factor so as per the ANOVA table the lowest P value is voltage so it will take as significant value. Also the response table has given their first rank is voltage second rank is prefer as current and third rank is speed of welding for Tensile test.

Table.13.Analysis of Variance for MIG Tensile Test

Source	DF	Seq SS	Adj SS	Adj MS	F	P
V	2	928.7	928.7	464.3	0.42	0.703
A	2	284.7	284.7	142.3	0.13	0.886
S	2	252.7	252.7	126.3	0.11	0.897
Residual Error	2	2202.0	2202.0	1101.0		
Total	8	3668.0				

Table.14.Response Table for MIG Tensile Test

Level	V	A	S
1	489.3	482.0	475.7
2	468.7	490.3	485.3
3	491.0	476.7	488.0
Delta	22.3	13.7	12.3
Rank	1	2	3

Hence, from the graph, it can be seen that the optimum welding parameter can be obtained by points or values of parameters having the peak position in the graph. Therefore Factor levels for predictions Voltage 30, current 245 and 3.1 is welding of current for MIG Tensile test.

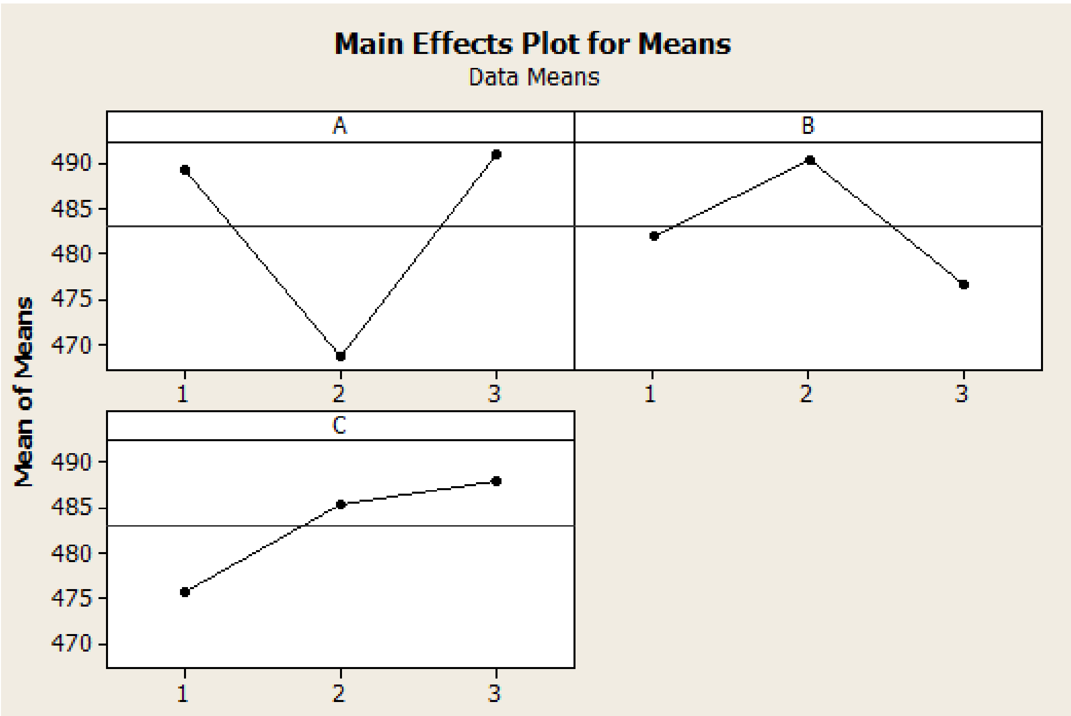

Fig.10.Mean Graph of MIG Tensile test

The purpose of the analysis of variance (ANOVA) is to examine which design parameters significantly affect the quality characteristic and estimation of optimum results. In this parameter for TIG welding gives the lesser value of Speed of welding whereas the MIG gives the Voltage parameter is more significant. Combine result of parameter ranked by ANOVA results are shown in table 13. Out of four results the Voltage factor have the majority in significant so the voltage is the significant factor for Both Welding MIG and TIG.

ANOVA analysis comparing interactions between the two welding TIG versus MIG, for hardness they gives the same and equal response of significant parameter is Voltage. The ANOVA tests for mean hardness across the welds show that interaction between TIG versus MIG welds are the same and significantly as shown in Fig.10 and Fig.13. The results from the tensile tests and statistical analysis are discussed, as well as, the factors affecting the results. The tensile tests and their examinations are discussed along with the ANOVA determinations which compared the means for the samples are different for TIG and MIG result.

Table.15. Significant Factor Table

	TIG Factor	MIG Factor
Hardness Test	Voltage	Voltage
Tensile Test	Speed Of Welding	Voltage

Table.16. Factor Comparison for each response

Type of Welding	Strength	V	A	S
MIG	Hardness	30	250	2.8
	Tensile	35	250	2.5
TIG	Hardness	30	250	2.8
	Tensile	30	245	3.1
Majority	For all	30	250	2.8

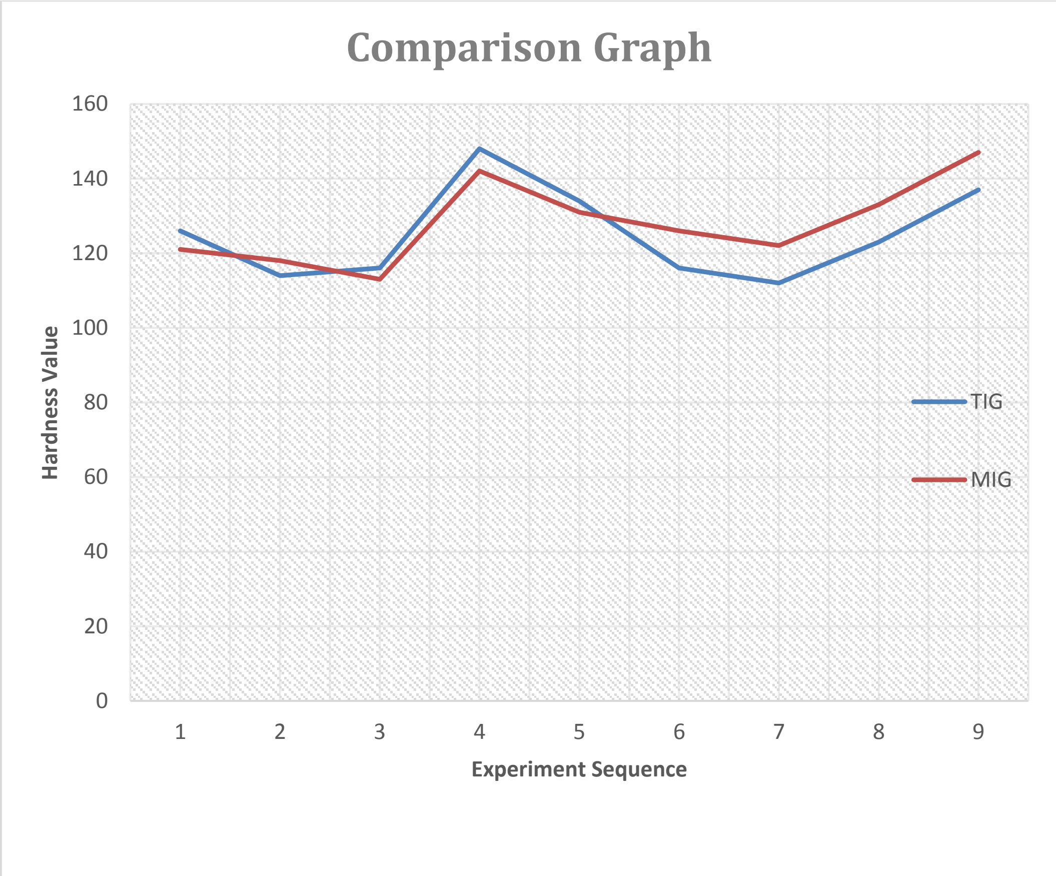

Fig.11.Comparison Chart of Hardness

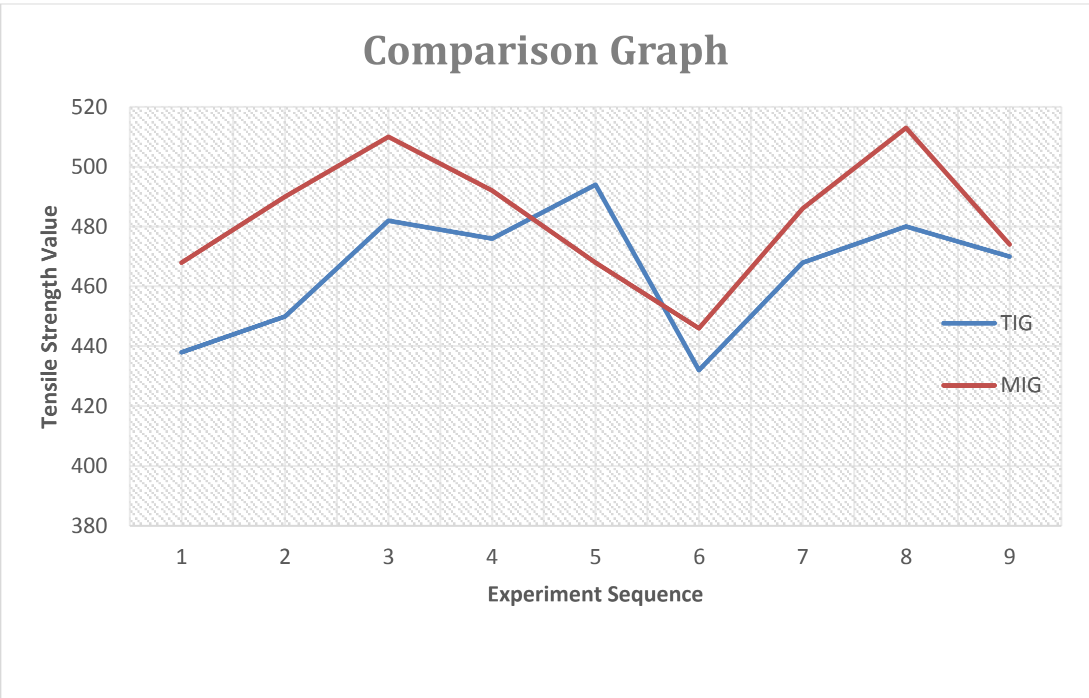

Fig.12. Comparison Chart of Tensile strength

CONCLUSIONS

MIG and TIG Welding process is apply on design of experiment to obtain their responses and analysis with ANOVA, the process parameters which significantly affects the Tensile Strength was speed, current and Voltage will be observed. By comparison it will clear that which one is the best parameter to affect the responses. Higher the responses will select as the optimize welding for given specimen.

- Welding, arc voltages, current and welding speed, are the important control parameters of Metal Inert Gas and TIG Welding process.

- They affect the weld quality in terms of mechanical properties and weld bead geometry. The value of depth of penetration increased by increasing the value of welding Voltage and welding voltage is the significant value for both welding in terms of Hardness.

- For tensile test Both welding have different significant factor for TIG Welding speed is significant, and for MIG Voltage is significant

- By comparison table 5.12 finally predict the majority of factors and select the level which gives the high strength of welding joint on voltage 30V, Current 250A and welding speed 2.8m/min.

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