Study on behaviour of Process Parameters for TIG Welded Thin plates by Using Taguchi method

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Abstract

Tungsten Inert Gas welding (TIG) process is an important module in many industrial operations. The TIG welding parameters are the most important factors affecting the quality, productivity and cost of welding. In this process proper selection of input welding parameters is necessary in order to obtain a good quality weld and subsequently increase the productivity of the process. A design of experiments based on Taguchi technique has been used to acquire the data. An L9 Orthogonal array employed to investigate the welding characteristics of similar joint and optimize the welding parameters.In present research work response graphsare considered for the study of influence of welding parameters like welding current, Gas Flow Rate and Filler Rod on strength of Mild steel thin sheet during welding. TheTensile test show that welding current and filler rod has increased the strength while effect of Gas Flow rate alone has almost no effect on welding strength but its interaction with other parameters makes it quite significant in increasing the weld strength.
Key words: TIG-Welding, Thin Plates, Taguchi Method, Process Parameters, Orthogonal Array

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Introduction

TIGwelding process is an arc welding process uses a non consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium or sometimes mixture of Argon and Helium. A filler metal may also feed manually for proper welding. GTAW most commonly called TIG welding process was developed during Second World War. With the development of TIG welding process, welding of difficult to weld materials e.g. Aluminium and Magnesium become possible. The use of TIG today has spread to a variety of metals like stainless steel, mild steel and high tensile steels, Al alloy, Titanium alloy. Like other welding system, TIG welding power sources have also improved from basic transformer types to the highly electronic controlled power source today. The Principle of TIG welding is shown in fig. 1.

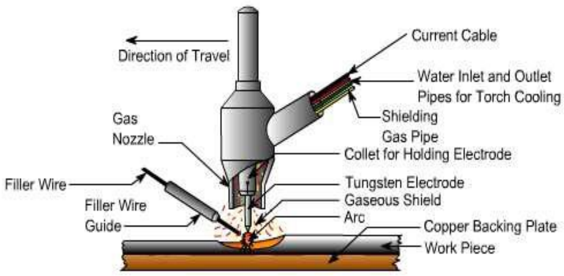

Fig. 1: Principle of TIG Welding.

Literature Review

Urenaet.al [1] investigated the influence of the interfacial reaction between the Al alloy (2014) matrix and SiC particle reinforcement on the fracture behaviour in TIG welded Al matrix composites. TIG welding was carried out on 4 mm thick AA2014/SiC/Xp sheets using current setting in the range of 37-155 A and voltage of 14-16.7 V. From experimental results it was found that, the failure occurred in the weld metal with a tensile strength lower than 50% of the parent material. Fracture of the welded joint was controlled by interface deboning through the interface reaction layer. Probability of interfacial failure increases in the weld zone due to formation of Aluminium-carbide which lowers the matrix/reinforcement interface strength.

Lothongkumet. al [2] investigated the TIG welding of 3 mm thick AISI 316L stainless steel plate at different welding position. Pure argon gas and mixture of argon with nitrogen (1-4 vol.%) were used as shielding gas with a flow rate of 8 (l/min) during top and back sides of welds. Effects of welding speeds and nitrogen contents in argon shielding gas on pulse currents were study to achieve an acceptable weld bead profile with complete penetration. It was found that increasing nitrogen contents in argon gas decreases the pulse currents and increasing welding speed will increase the pulse current.

Ahmetdurgutlu et.al [3] 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. For all shielding media, hardness of weld metal is lower than that of HAZ and base metal. Penetration depth, weld bead width and mean grain size in the weld metal increases with increasing hydrogen content. The highest tensile strength was obtained for the sample welded under shielding gas of 1.5%H2–Ar.

Wang Ruiet. al [4] investigated the effect of process parameters i.e. plate thickness, welding heat input on distortion of Al alloy 5A12 during TIG welding. For welding they used current (60-100) A, welding speed (800-1400) mm/min and thickness of w/p (2.5-6) mm. The results show that the plate thickness and welding heat input have great effect on the dynamic process and residual distortion of out-of-plane.

Kumar and Sundarrajan [5] performed pulsed TIG welding of 2.14 mm AA5456 Al alloy 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.

Sanjeevkumaret. al [6] 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) and tensile fracture occur near to fusion line of weld deposit.

Ahmed Khalid Hussainet. al [7] 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. The strength of the welded joint was tested by a universal tensile testing machine. Welding was done on specimens of single v butt joint with welding speed of 1800 - 7200 mm/min. 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.

Wang et. al [8] studied the influences of process parameters of TIG arc welding on the microstructure, tensile property and fracture of welded joints of Ni-base super-alloy. For welding plate width of 1.2-1.5 mm, welding current in the range of 55-90 A, with variable welding speed in the range 2100-2900 mm/min was used. From experimental result it was observed that, the heat input increases with increase of welding current and decrease of welding speed.

Indira Rani et. al [9] investigated the mechanical properties of the weldments of AA6351 during the GTAW /TIG welding with non-pulsed and pulsed current at different frequencies. Welding was performed with current 70-74 A, arc travel speed 700-760 mm/min, and pulse frequency 3 and 7 Hz. From the experimental results it was concluded that the tensile strength and YS of the weldments is closer to base metal. Failure location of weldments occurred at HAZ and from this we said that weldments have better weld joint strength.

Karunakaranet. al [10] 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. Lower magnitude of residual stress was found in pulsed current compared to constant current welding. Tensile and hardness properties of the joints enhanced due to formation of finer grains and breaking of dendrites for the use of pulsed current.

Raveendraet. al [11] 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.

From the literature review, it is found that welding of thin plated mild steel is a big challenge by TIG welding process. Again repeatability of welding depends on its control on welding processing parameters. In this work to perform welding of 3 mm MS plate, an automated TIG welding setup was made. Welding of the MS plate was done by changing the welding current, gas flow rate and diameter of filler rod to get a high strength joint. Effect of welding current, gas flow rate and diameter of filler rod on the tensile strength was analysed

Methodology: Taguchi's method is an efficient tool for the design of high quality manufacturing system. In this method quality is measured by the deviation of a characteristic from its target value. A loss function is developed from this deviation. Uncontrollable factors which are also known as noise cause such deviation and result into loss. Taguchi method seeks to minimize the noise because the elimination of noise factor is impractical. This method provides much reduced variance for the experiment with optimum setting of process control parameters. So Taguchi philosophy is based on integration of design of experiments (DOE) with parametric optimization of processes to get the desired results.
Using the Taguchi method for parameter design, the predicted optimum setting need not correspond to one of the rows of the matrix experiment. This often the case when highly fractioned designs are used. Therefore, as the final step, an experimental confirmation is run using the predicted optimum levels for the control parameters being studied. When we find the S/N ratio of particular output, graph can be plotted for various inputs. The slope of that graph defines how that input affects the particular output. At the same time delta and rank can be found out for the same. Optimum conditions based on S/N ratio can be found out like if smaller is better option is required then minimum point from that graph is the optimum condition of that input for respective output.
The Taguchi method is used whenever the settings of interest parameters are necessary, not only for manufacturing processes. Therefore, the Taguchi approach is used in many domains such as: environmental sciences, agricultural sciences, physics, chemistry, statistics, management and business, medicine. Choosing the proper orthogonal arrays suitable for the problem of interest is the main difficulty of the Taguchi's approach. The literature reported many orthogonal arrays; however, a full scheme that includes all the possibilities of orthogonal arrays, even for a small number of experimental runs, could not be found yet. Starting from this observation the aim of the present study was to generate the largest groups of orthogonal arrays for number of experimental runs from four to sixteen, with the maximum number of factors by using a series of homemade software.

Experimental Work:
Welding process parameters selected in present study were shown in table 1. In present study three parameters were considered viz. Current, Gas flow rate and Filler rod diameter. Every parameter is considered with three levels (level 1, level 2 and level 3) as shown in table 1.

Table .1.Weldingprocess Parameters.

S.N	Paramete	Units	Leve	Leve	Leve
1	Current	Ampere	30	40	50
2	Gas Flow	Lit./Mi	3	5	7
3	Filler	Mm	0	1.6	2.4

In present study Taguchi method is selected as designof experiments table 2 indicates the L9 orthogonal array. The table 2 explains that thecombinations of three parameters with 9 experiments based on L9 array were selected to performthe TIG welding according to ASTM E8/E8M-09 as shown in figure 2.

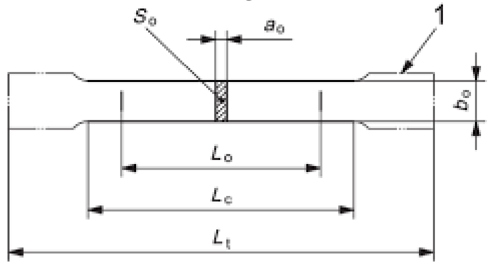

Fig.2-ASTM Standard for Tensile Test Specimen.

Table 2.Experimental Layout Using L9-Orthogonal Array.

Experime	Current(Am	Gas Flow	Filler
1	30	3	0
2	30	5	1.6
3	30	7	2.4
4	40	3	1.6
5	40	5	2.4
6	40	7	0
7	50	3	2.4
8	50	5	0
9	50	7	1.6

The specimens were prepared and welded for tensile testing according to American society oftesting and material (ASTM e8/e8m-09) as shown in figure 2.The prepared specimens were welded by TIG welding method as per L9 array shown in table 2.And the welded specimens were shown in figure 3.

Fig.3-welded specimens for tensile test.

Tensile testing, also known as tension testing, is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure.Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strainhardening characteristics. Uni-axial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials.

Fig4.Specimens after Tensile test.

RESULTS AND DISCUSSIONS

The table 3 shows the tensile test results performed on 9 experiments carried accordingto the design of experiments selected through L9 orthogonal array. The tensile test results comprises of Ultimate Load (KN), Ultimate Tensile strength (N/mm^2), Percentage of Elongation, Yield Load (KN) and Yield stress (N/mm^2).

The ultimate load (KN) for larger the better type of quality characteristic is considered.Average Response and S/N Ratio table for ultimate load (KN) is tabulated in table 4 & table 5 respectively, and the mean response graph and S/N Ratio graph for ultimate load is shown in figure 5.By observing the results it is noticed that when the current is 40 Amps to 50 Ampsthe Ultimate load is more.For the Gas flow rate (Lit/min), it is noticed that when the Gas flow rate is less (3 Lit/min)the Ultimate load is more.And for the Filler Rod Diameter (mm) it is noticed that when the Filler rod diameter is nominal (1.6 mm)the Ultimate load is more. For the ultimate load (KN)the first preferece should be given to Filler rod diameter because of its first rank, the next preference is for gas flow rate and the last preference is for Current.

The ultimate tensile strength (N/mm^2) for larger the better type of quality characteristic is considered.Average Response and S/N Ratio table for ultimate tensile strength (N/mm^2)is tabulated in table 4 & table 5 respectively, and the mean response graph and S/N Ratio graph for ultimate tensile strength (N/mm^2) is shown in figure 5.By observing the results it is noticed that when the current is 50 Amps the ultimate tensile strength (N/mm^2)is more.For the Gas flow rate (Lit/min), it is noticed that when the Gas flow rate is more (7 Lit/min)the ultimate tensile strength (N/mm^2)is more.And for the Filler Rod Diameter (mm) it is noticed that when the Filler rod diameter is more (2.4 mm)the ultimate tensile strength (N/mm^2)is more.For theultimate tensile strength (N/mm^2) the first preferece should be given to Filler rod diameter because of its first rank, the next preference is for gas flow rate and the last preference is for Current.

The yield load (KN) for larger the better type of quality characteristic is considered.Average Response and S/N Ratio table for yield load (KN) is tabulated in table 4 & table 5 respectively, and the mean response graph and S/N Ratio graph for yield load (KN) is shown in figure 5.By observing the results it is noticed that when the current is 40 Amps the yield load (KN)is more.For the Gas flow rate (Lit/min), it is noticed that when the Gas flow rate is less (3 Lit/min)the yield load (KN)is more.And for the Filler Rod Diameter (mm) it is noticed that when the Filler rod diameter is nominal (1.6 mm)the yield load (KN)is more. For the yield load (KN) the first preferece should be given to Current because of its first rank, the next preference is for filler rod diameter and the last preference is for gas flow rate.

The yield Strength (N/mm^2) for larger the better type of quality characteristic is considered.Average Response and S/N Ratio table for yield Strength (N/mm^2)is tabulated in table 4 & table 5 respectively, and the mean response graph and S/N Ratio graph for yield Strength (N/mm^2) is shown in figure 8.By observing the results it is noticed that when the current is 40 Amps the yield Strength (N/mm^2)is more.For the Gas flow rate (Lit/min), it is noticed that when the Gas flow rate is less (3 Lit/min)the yield Strength (N/mm^2)is more.And for the Filler Rod Diameter (mm) it is noticed that when the Filler rod diameter is nominal (1.6 mm)the yield Strength (N/mm^2)is more. For the yield Strength (N/mm^2) the first preferece should be given to Current because of its first rank, the next preference is for filler rod diameter and the last preference is for gas flow rate.

The Percentage of elongation (%) for lesser the better type of quality characteristic is considered.Average Response and S/N Ratio table for Percentage of elongation is tabulated in table 6.By observing the results,it is noticed that when the current is smaller (30 Amps)the Percentage of elongationis less. Whereas it is observed that at 30 amps current the percentage of elongation is less and then it increases till 40 amps after that it was reduced with increase in current. For the Gas flow rate (Lit/min), it is noticed that when the Gas flow rate is less (3 Lit/min)the Percentage of elongationis more and then reduced with increase in gas flow rate to 7 Lit/min.For the Filler Rod Diameter (mm), it is observed that without filler rod the percentage of elongation is less and then it increases when filler rod was used with less diameter of 1.6 mm and it was reduced with increase in filler rod diameter at 2.4mm.For the Percentage of elongation (%) the first preferece should be given to gas flow rate because of its first rank, the next preference is for filler rod diameter and the last preference is for current.

Table 3-Tensile Test Result

Ex.No.	Current(Amps)	Gas Flow Rate(Lit. /Min.)	Filler Rod(mm)	Observation				
				Ultimate Load(Kn)	Ultimate Tensile Strength(N/mm²)	Elongation(%)	Yield Load(Kn)	Yield Stress (N/Mm²)
1	30	3	0	4.36	381.45	16.8	3.2	279.96
2	30	5	1.6	4.32	398.52	24.4	3.24	298.89
3	30	7	2.4	4.12	416.16	10.2	3.08	311.11
4	40	3	1.6	4.48	391.26	22.4	3.6	314.41
5	40	5	2.4	4.2	396.6	17.3	3.36	317.28
6	40	7	0	4.36	410.54	23.0	3.48	327.68
7	50	3	2.4	4.36	452.75	23.7	3.1	321.91
8	50	5	0	4.28	384.54	14.8	2.92	262.35
9	50	7	1.6	4.4	418.64	16.5	3.24	308.27

Table 4.Response Table for Means

Property	Ultimate Load			Ultimate Tensile Strength			Yield Load			Yield Strength		
Level	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)	Current (Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)
1	4.267	4.400	4.333	398.7	408.5	392.2	3.173	3.300	3.200	3.173	3.300	3.200
2	4.347	4.267	4.400	399.5	393.2	402.8	3.480	3.173	3.360	3.480	3.173	3.360
3	4.347	4.293	4.227	418.6	415.1	421.8	3.087	3.267	3.180	3.087	3.267	3.180
Delta	0.080	0.133	0.173	19.9	21.9	29.7	0.393	0.127	0.180	0.393	0.127	0.180
Rank	3	2	1	3	2	1	1	3	2	1	3	2

Table 5.Response Table for Signal to Noise RatiosLarger is better

Property	Ultimate Load			Ultimate Tensile Strength			Yield Load			Yield Strength		
Level	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)

1	12.60	12.87	12.74	52.01	52.20	51.86	10.028	10.352	10.081	10.028	10.352	10.081
2	12.76	12.60	12.87	52.03	51.89	52.10	10.828	10.015	10.516	10.828	10.015	10.516
3	12.76	12.65	12.52	52.42	52.36	52.49	9.782	10.271	10.042	9.782	10.271	10.042
Delta	0.16	0.27	0.35	0.41	0.47	0.62	1.046	0.337	0.474	1.046	0.337	0.474
Rank	3	2	1	3	2	1	1	3	2	1	3	2

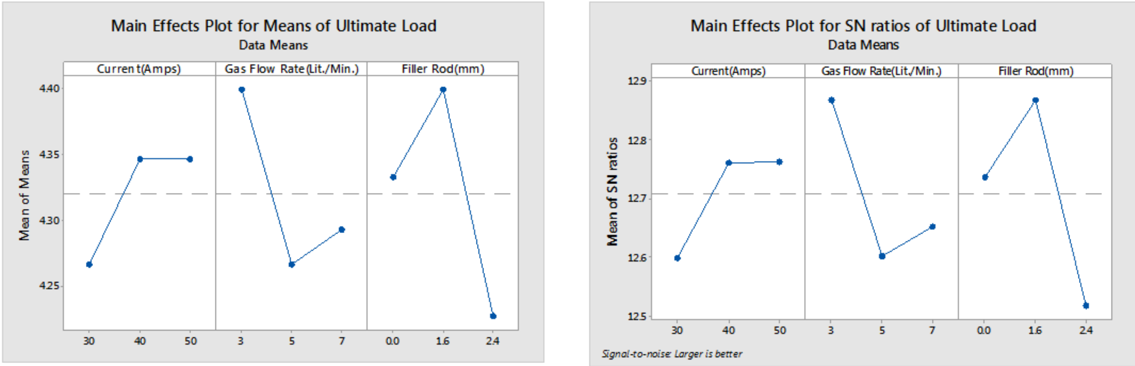

Fig 5. Response graph for ultimate load (KN)

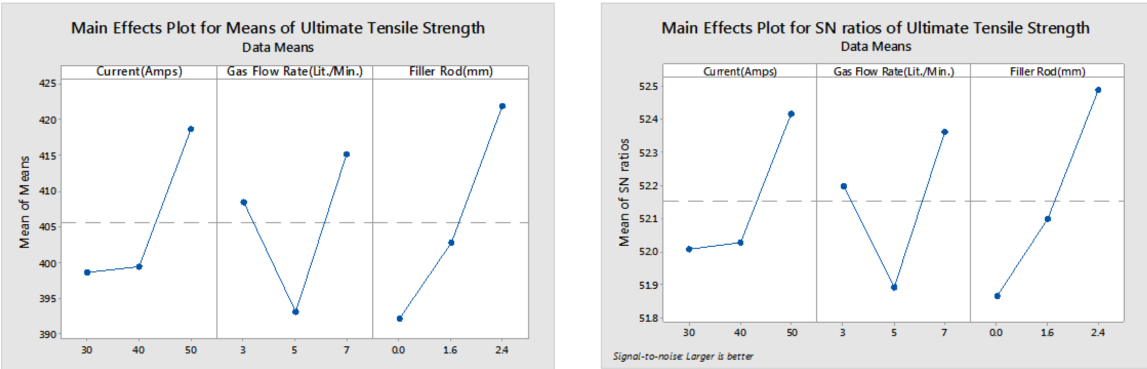

Fig 6. Response graph for ultimate tensile strength (N/mm^2)

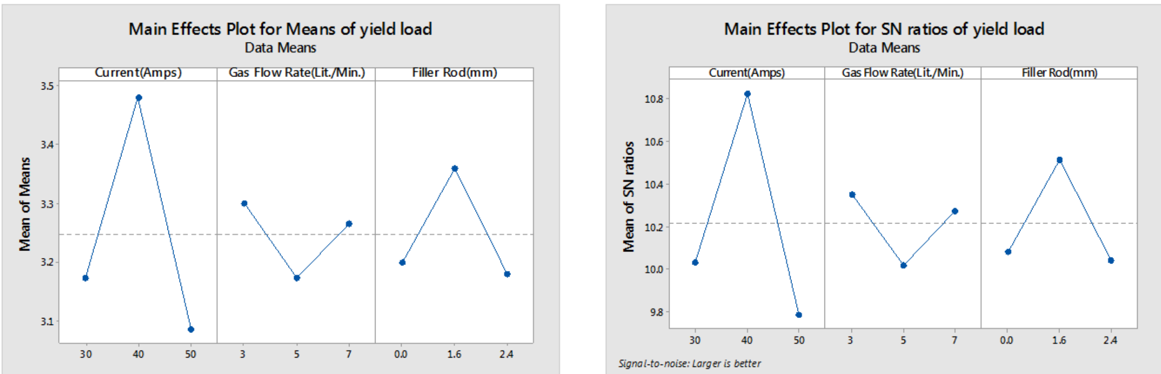

Fig 7. Response graph for yield load (KN)

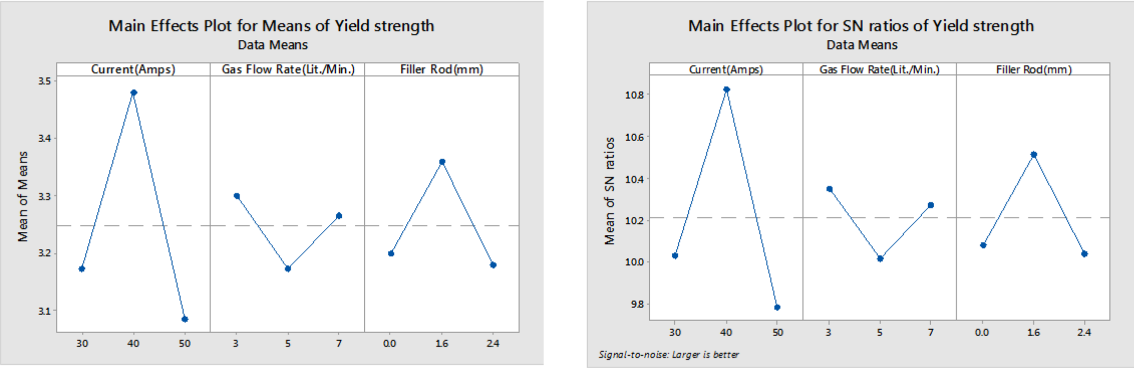

Fig8. Response graph for Yield strength (N/mm^2)

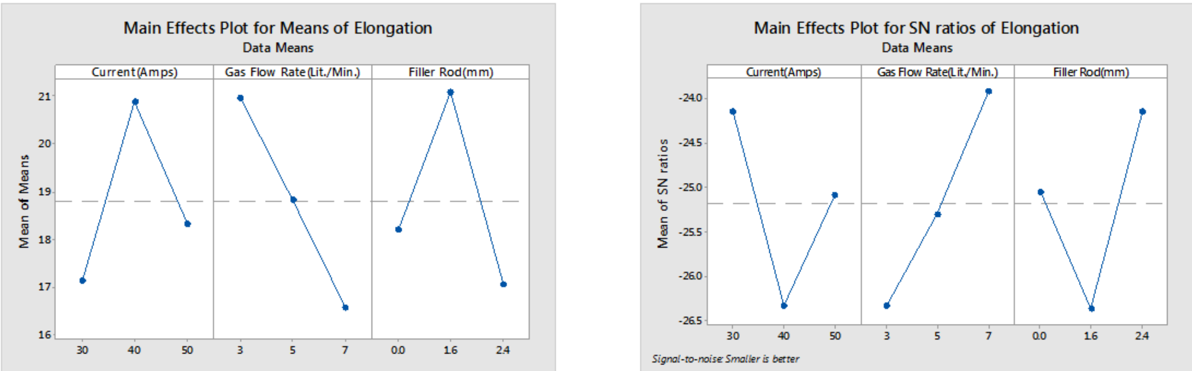

Fig 9. Response graph for Percentage of Elongation

Table 6.Response Table for Elongation (%) Mean and Signal to Noise Ratios (Smaller is better)

Property	Signal to Noise Ratiosfor Elongation (%)			Meanfor Elongation (%)		
Level	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)	Current(Amps)	Gas Flow Rate(Lit./Min.)	Filler Rod(mm)
1	-24.14	-26.34	-25.05	17.13	20.97	18.20
2	-26.33	-25.30	-26.37	20.90	18.83	21.10
3	-25.08	-23.92	-24.14	18.33	16.57	17.07
Delta	2.19	2.42	2.22	3.77	4.40	4.03
Rank	3	1	2	3	1	2

Predicted Regression equations

Ultimate Load = $4.3200 - 0.0533 A_1 + 0.0267 A_2 + 0.0267 A_3 + 0.0800 B_1 - 0.0533 B_2 - 0.0267 B_3 + 0.0133 C_1 + 0.0800 C_2 - 0.0933 C_3$.

Ultimate Tensile Strength = $405.61 - 6.9 A_1 - 6.1 A_2 + 13.0 A_3 + 2.9 B_1 - 12.4 B_2 + 9.5 B_3 - 13.4 C_1 - 2.8 C_2 + 16.2 C_3$.

Yield load = $3.2467 - 0.0733 A_1 + 0.2333 A_2 - 0.1600 A_3 + 0.0533 B_1 - 0.0733 B_2 + 0.0200 B_3 - 0.0467 C_1 + 0.1133 C_2 - 0.0667 C_3$.

Yield strength = $304.65 - 8.00 A_1 + 15.14 A_2 - 7.14 A_3 + 0.78 B_1 - 11.81 B_2 + 11.04 B_3 - 14.65 C_1 + 2.54 C_2 + 12.12 C_3$.

Elongation = $18.79 - 1.66 A_1 + 2.11 A_2 - 0.46 A_3 + 2.18 B_1 + 0.04 B_2 - 2.22 B_3 - 0.59 C_1 + 2.31 C_2 - 1.72 C_3$.

Conclusion:

During the study, mild steel sheets were joined using TIG welding process. The tensilestrength and of weldedjoints were investigated.Tungsten Inert Gas Welding is more suitable for welding of mild steel sheets, TIG welding process provides better strength. It may be because of less porosity in welds during TIG welding and carbon precipitation which comes out due to welding is also less. The low percentage of free carbon allows the product better corrosion resistivity, ductility and strength.Welding strength or tensile strength of the weld joint depends on the welding parameters like Welding current, Filler rod diameter and Gas flow rate.The tensile test results performed on the basis of L9 orthogonal array. The tensile test results comprises of Ultimate Load (KN), Ultimate Tensile strength (N/mm^2), Percentage of Elongation, Yield Load (KN) and Yield stress (N/mm^2). From the results it may conclude that, for the maximun ultimate load (KN)and ultimate tensile strength (N/mm^2) the first preferece should be given to Filler rod diameter because of its first rank, the next preference is for gas flow rate and the last preference is for Current. Similarly, for the maximum yield load (KN) and yield Strength (N/mm^2)the first preferece should be given to Current because of its first rank, the next preference is for filler rod diameter and the last preference is for gas flow rate. And for the less Percentage of elongation (%) the first preferece should be given to gas flow rate because of its first rank, the next preference is for filler rod diameter and the last preference is for current. The regression equations for Ultimate Load (KN), Ultimate Tensile strength (N/mm^2), Percentage of Elongation, Yield Load (KN) and Yield stress (N/mm^2) were predicted and presented.

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