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OPTIMIZATION OF PROCESS PARAMETERS FOR TUNGSTEN INERT GAS (TIG) WELDING TO JOIN A BUTT WELD BETWEEN STAINLESS STEEL (SS 304) AND MILD STEEL (MS 1018)

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ABSTRACT

Objective of the present work is to optimize the bending strength of a butt joint by analyzing welding process parameters: current, welding speed and gas flow rate in tungsten inert gas (TIG) welding. TIG welding helps in welding of difficult to weld materials (highly reactive materials) and nowadays its application has been diversified to various metals like mild steels, stainless steels, and High speed steels etc. In the present work butt joint is created between dissimilar materials stainless steel (SS 304) and mild steel (MS 1018) with mild steel filler material using Automatic TIG welding machine. Bending strength of butt joint is measured in 3 point bend fixture machine. L-9 orthogonal array and Taguchi method is used to design the experiment and optimize the bending strength in QUALITEK-4. From the results it is found that expected bending strength is 517.37 MPa at optimum conditions: welding current=170 A, welding speed=150 mm/min and gas flow rate=24 L/min. ANOVA method is employed to assess the influence of process parameters and welding current turned out to be the most influential.

KEYWORDS-*TIG, stainless steel (SS 304) and mild steel (MS 1018), bending strength, Design of experiment (DOE), Taguchi, Qualitek-4, Optimum. ANOVA, 3 point bend fixture machine*

I. INTRODUCTION

Welding is a permanent joining process used to join materials by application of heat and or pressure. TIG welding also known as gas tungsten arc welding (GTAW) was invented during World War II and with this invention; welding of difficult to weld materials like Aluminum (Al) and Magnesium (Mg) became possible. Tungsten Inert Gas Welding of dissimilar material such as stainless steel (SS-304) and mild steel (MS-1018) have the potential to hold good mechanical and metallurgical properties. TIG welding is easy to control, fumeless and spatter less clean process needs very little finishing or sometime no finishing. TIG welding gives high quality welding with the coalescence of heat generated by an electric arc established between a tungsten electrode and the metal [1]. TIG welding process used to weld material with a non consumable tungsten electrode. In which electrode is connected to a required power source and shielding gas is also employed through welding gun [2].

During welding, the work-pieces to be joined are melted at the faying surfaces and after solidification a permanent joint can be produced. In some cases a filler material is added to form a weld pool of molten material which after solidification gives a strong bond between the materials. Weldability of a material is influenced by different factors like the metallurgical changes during welding, variations in hardness in weld zone due to rapid solidification, amount of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the joint position.

Since Ar and He do not chemically react therefore they are specially used as shielding gases. In the present study, Ar is used for shielding. Functions of inert gas is to protect the welding area from air, transfers the heat during welding and also helps to start as well as maintain a stable arc [3]. In TIG welding, power is supplied from a power source to a tungsten electrode which is fitted into the welding torch. By using this power an electric arc can be created between tungsten electrode and work piece as shown in Fig 1.

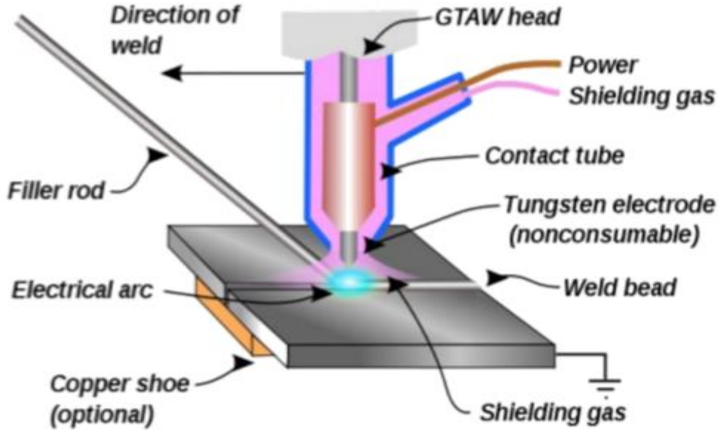

Figure 1: electric arc created between tungsten electrode and work piece in TIG

The electric arc can produce a temperature up to 20,000 ^{0}C and this heat can be concentrated to melt and join the parts with or without filler material. Generally tungsten electrodes are available in the range of 0.5 mm to 6.4 mm diameter and 150 – 200 mm length. In DC power source, electrode polarity determines the current carrying capacity of each size of electrode. In the present experimental work an electrode of 3 mm diameter is used. The performance of weld joint depends upon input process parameters [4]. In today’s scenario, application of evolutionary algorithms, Design of experiment (DOE), and computational network are used to establish the relationship between input process parameters and output variables to obtained desired weld quality [5]. A.K Srirangan and S.P Raj found that in TIG welding, welding current exerted significance influence on multiple responses followed by welding speed and Voltage [6] .S.R Gulwade et al observed the effect of welding parameters like current, voltage and flow of gas on the hardness of austenitic stainless steel 304 [7].Satish et al. optimized the welding parameters for dissimilar pipe joints in TIG welding and concluded that higher heat input results in lower tensile strength [8].Ugur Esme et al analyzed tungsten inert gas welding (TIG) welding process for an optimal parametric combination to yield favorable bead geometry of welded joints using the Grey relational analysis and Taguchi method [9].S.C. Juang et al carried out the selection of the process parameters of TIG welding and experimentally concluded that the front height, front width, back height and back width of the weld pool are greatly improved by using Taguchi Technique [10].Shanping Lu et al performed research work on TIG welding and concluded that adding a small amount of oxygen to the He–30%Ar and He–50%Ar shielding, weld shape significantly changes from a wide shallow type to a narrow deep one [11].Paulo J. Modenesi et al found that operational characteristics of the ATIG process were not very different from those of conventional TIG welding [12]. R. Singh et al investigated the effect of TIG welding parameters like welding speed, current and flux on depth of penetration and width in welding of 304L stainless steel. From the study it was observed that flux significantly affects depth of penetration followed by welding current and optimization was performed to maximize penetration with less bead width [13]. V. Subravel et.al studied the effect of welding speed on tensile and microstructural characteristics of pulsed current TIG on AZ31B magnesium alloy joints. It was found that welding speed of 135 mm/min yielded superior tensile properties compared to other joints [14].

In the present research work, 9 experiments are carried out to create a butt joint between SS 304 and MS 1018 plates at various combinations of process parameters in TIG welding as shown. These experiments are designed and optimized by using Taguchi technique.

II. EXPERIMENTAL METHODOLOGY

Two plates are butt welded at different combination of process parameters by TIG welding. Details pertaining to dimension and material of plates, welding condition, machines used etc are explained in this section.

Dimension and material used for plates: material of plates to be welded taken as stainless steel (SS-304) and mild steel (MS -1018) and each plate having dimension as 100mm×40mm×5mm. chemical compositions of SS-304 and MS-1018 alloy is shown in Tables 1 and 2, respectively.

Table1. Chemical composition of SS 304

%	C	Mn	S	P	Si	Ni	Cr	N	Fe
SS-304	0.087	2	0.03	0.045	0.75	8-10.50	18-20	0.1	Balance

Table 2: Chemical composition of MS 1018

%	Fe	C	Mn	S	P
MS-1018	98.97	0.17	0.68	0.05	0.04

Material used for filler: Mild steel filler material having diameter of 1mm is used @ 1m/min.
Shielding gas used: Argon
Electrode used: Ball shape Non consumable tungsten electrode having 3mm diameter is used
Varied Parameters: Welding current, Welding speed and Gas flow rate has varied for three levels as shown in Table 3. On the basis of these levels factors relationship, nine combinations of these factors are considered (shown in Table 4) to generate L-9 orthogonal array.

Table 3: levels of varying parameters/Factors

	Parameters/Factors		
Levels	**Current (A)**	**Speed (mm/min)**	**Gas flow rate (L/min)**
1	150	100	22
2	160	120	23
3	170	150	24

Table 4: combinations of input parameters for experiments

Experiment	Current (A)	Speed (mm/min)	Gas flow rate (L/min)
1	150	100	22
2	150	120	23
3	150	150	24
4	160	100	22
5	160	120	23
6	160	150	24
7	170	100	22
8	170	120	23
9	170	150	24

Welding machine used: FUTURE AUTO TIG 2 welding machine is used for TIG welding as shown in Fig 2. By feeding input parameters from Table 4, 9 experiments are conducted on this machine as shown in Fig 4.
Testing machine used: A point bend fixture machine is used to find out the bending strength of welded butt joints as shown in Fig 3. All the joints (shown in Fig 4) are tested and results are tabulated in Table 5.

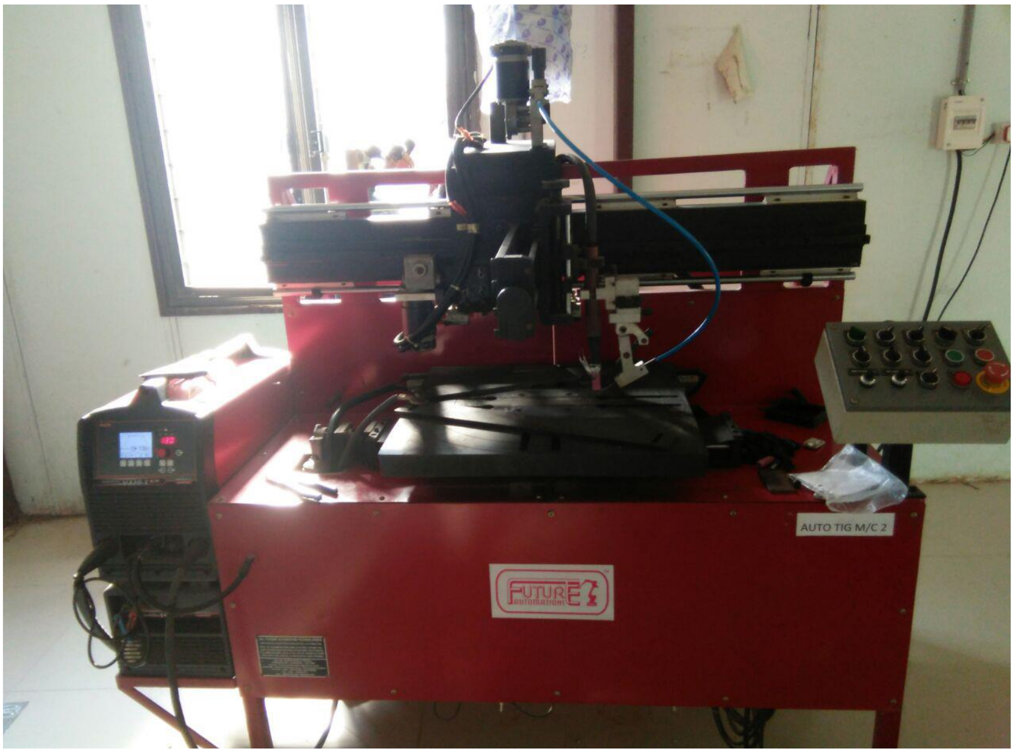

Figure 2: Future Auto TIG 2 welding Machine

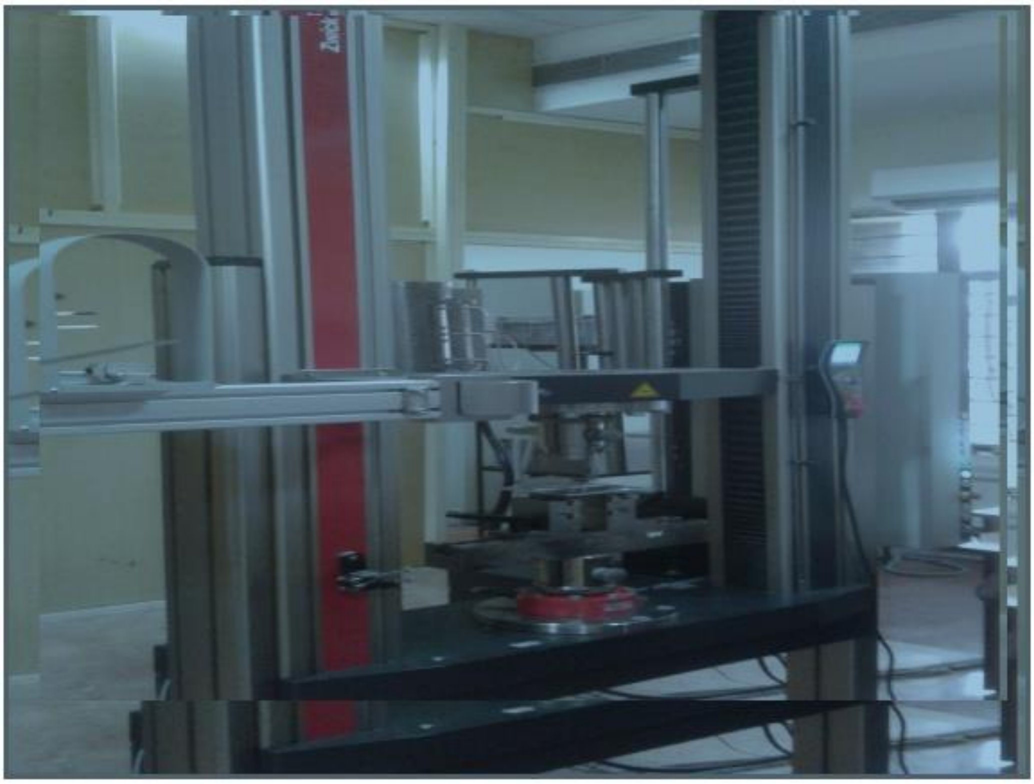

Figure 3: 3 point Bend fixture machine

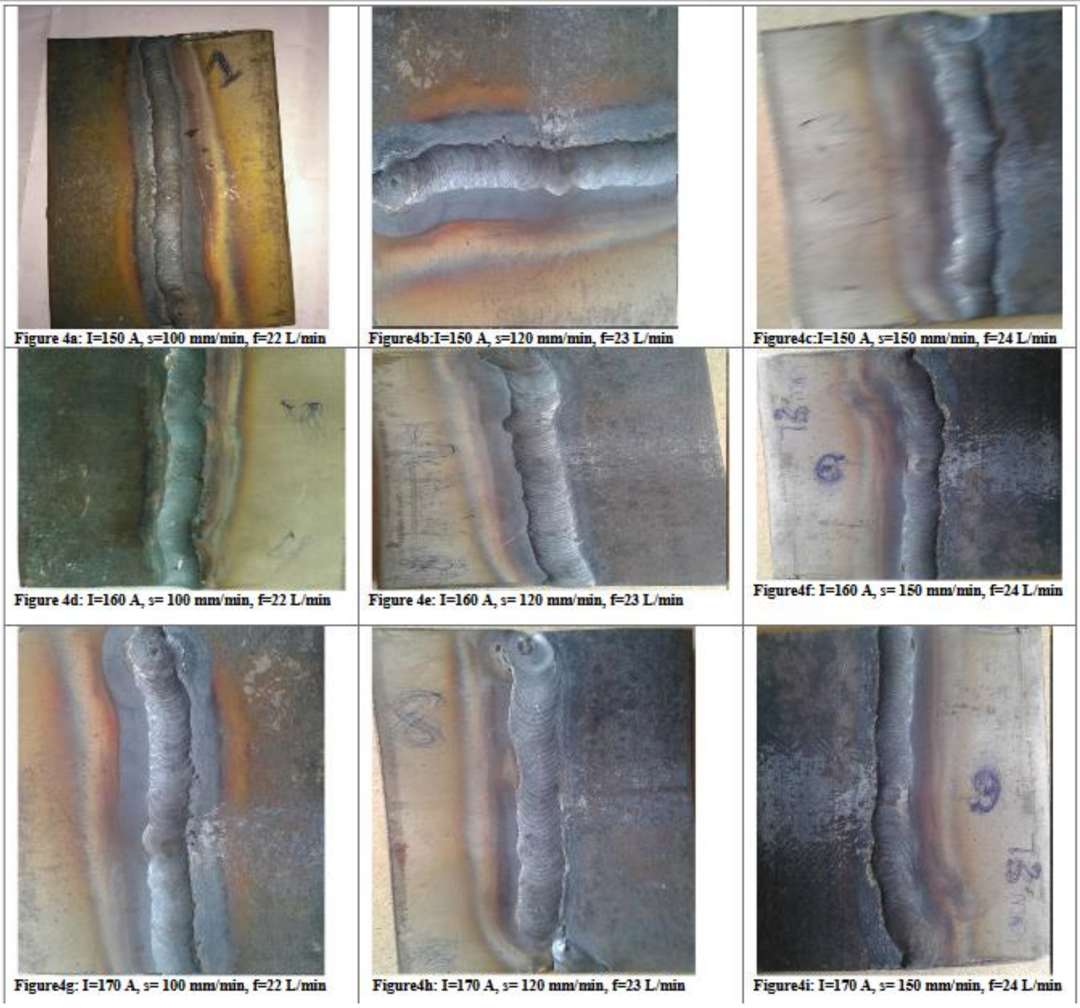

Figure 4: Butt joints welded at different process parameters, I is welding current, s is welding speed, f is gas flow rat

Table 5: Table shows the values of bending strength of welded butt joints

Experiment	Bending Strength (MPa)
1	468.93
2	471.80
3	476.67
4	451.38
5	468.72
6	479.49
7	480.69
8	502.68
9	510.00

III. EXPERIMENTAL ANALYSIS

Figure 6 shows multiple graphs of main effect. From Figure there are following key take away

1. With respect to welding current bending strength is minimum at level 2 and maximum at level 3
2. With respect to welding speed bending strength is minimum at level 1 and maximum at level 3.
3. With respect to gas flow rate bending strength is minimum at level 1 and maximum at level 3.

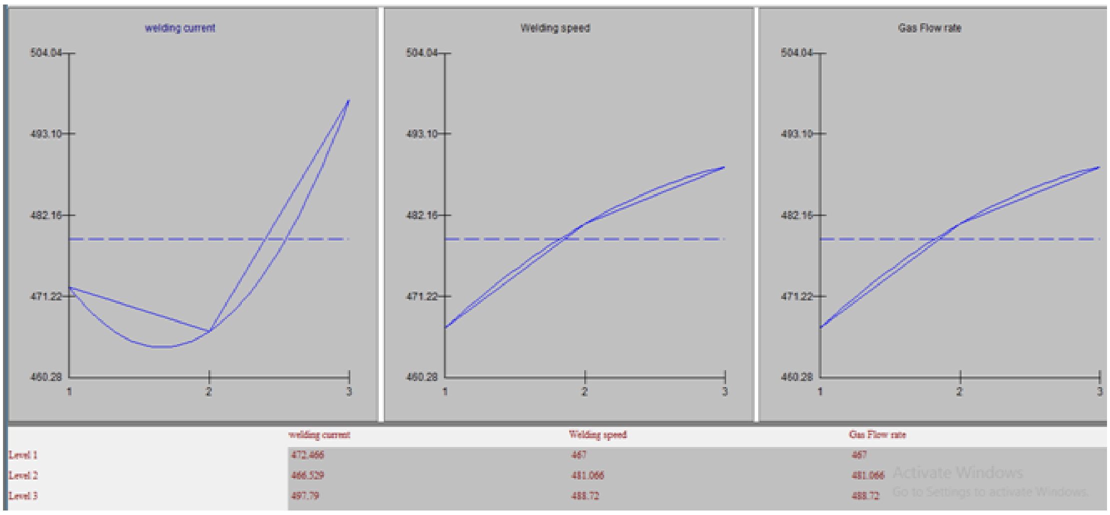

Figure 5: Multiple Graphs of main effect

Table 6 presents the analysis of variance and from this Table it is clear that percentage contribution of welding current, welding speed and gas flow rate is 53.17%, 23.41% and 23.41% respectively. Therefore contribution of welding current as compared to welding speed and gas flow rate is higher. The same has been depicted in Fig 7.

Table 6: Analysis of Variance (ANOVA)

	Factors	DOF	Sums Of Squares	Variance	F-Ratio	Pure Sum	Percent
1	welding current	2	1,653.762	826.8816	537,620.274	1,653.761	53.173
2	Welding speed	2	728.173	364.0867	281,736.536	728.173	23.413
3	Gas Flow rate	2	728.173	364.0867	281,736.536	728.173	23.413
	Other/Error	2	-0.001	-0.001			0.001
	Total:	8	3,110.109				100.000%

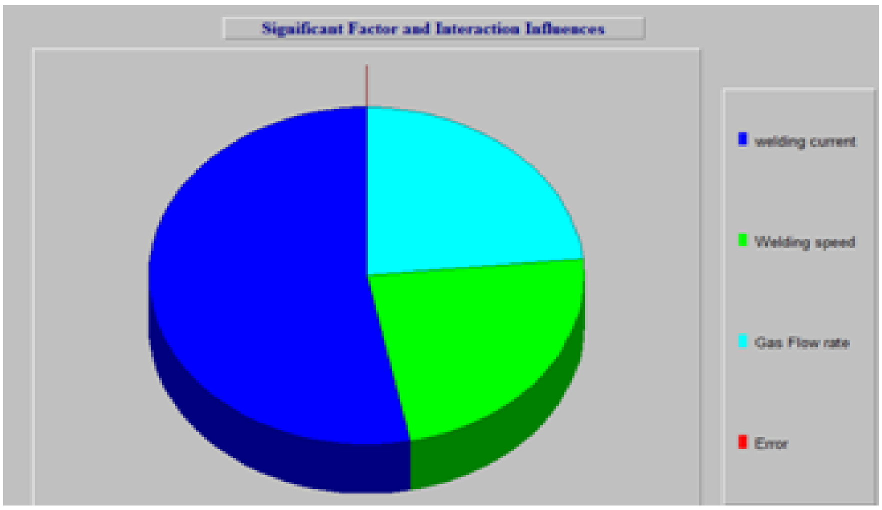

Figure 6: Relative influence of factor and interactions

In Table 7 optimum condition and performance is tabulated. From this Table it is evident that for optimum performance, levels of welding current, welding speed and gas flow rate are 3, 3 and 3 respectively. At these levels expected bending strength of butt joint is 517.37 MPa. At these levels, contribution of current, welding speed and gas flow rate is 18.86%, 9.79% and 9.79% respectively.

Table 7: Optimum condition and Performance

	Factors	Level Desc.	Level	Contribution
1	welding current	170	3	18.861
2	Welding speed	150	3	9.791
3	Gas Flow rate	24	3	9.791

Total Contribution From All Factors...	38.442
Current Grand Average Of Performance...	478.928
Expected Result At Optimum Condition...	517.371

IV. CONCLUSION

Following conclusions can be drawn from this study.

1. From the considered levels of welding current, higher the welding current better will be bending strength. But welding current should have upper limit after which if further welding current increased it will result in to defects like excessive penetration, under cut etc which may decreases the bending strength.
2. As welding speed increasing, bending strength also improving. But this trend may be seen up to a certain limit. It welding speed is higher than that limit then there are chances of lack of reinforcement which may results in to decrease in strength.
3. With gas flow rate bending strength of the joint is increasing owing to effective shielding.

   Finally it is concluded that under the given circumstances and welding conditions, welding current, welding speed as well as gas flow rate should be higher.

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