Influence of MIG Welding Process Parameters on Tensile Properties of Mild Steel.

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Abstract—**Metal Inert Gas welding (MIG) is a widely used welding method for mild steel (low carbon steel) in industry due to its high weld quality, good penetration and comparatively low investment. It is an arc welding process wherein coalescence is produced by heating the job with an electrical arc struck between a filler rod and the job. A Shielding gas (argon, carbon dioxide) is used to avoid atmospheric contamination of the molten weld pool. A filler material is added for joining the work piece by MIG welding. Many researchers investigated on different welding process parameters on mechanical & microstructural characteristics. Some researchers used the welding speed, welding current welding voltage, number of welding passes & work peace thickness for stainless steel, naval grade steel & aluminum. But the shielding gas flow rate & gas mixture also important factor which affects mechanical properties of mild steel. For this study, process parameters such as welding current, gas flow rate and gas combination used in the range 170-210A, 13-17 Lit/min & 0-100 % of CO2 respectively. The material used E-250 grade mild steel with 12 mm thickness. The effect of the welding parameter is investigated by designing the experiments using central composite matrix. Using the data generated by the experimentation, an empirical relation is obtained for tensile strength. The optimum value of tensile strength 356 N/mm^2 is observed at 190A welding current, 15 Lit/min gas flow rate & 50% CO2+50% Argon gas combination.**

Index Terms—**Co2 Welding, v-butt Welds, welding current, gas flow rate, Gas combination, Tensile strength.**

I. Introduction

In many Industries of tower carinas, lifting device requires fabricated part such as jib nose, anchorage frame, lugs etc. which is used for the irrigation & support purpose .These parts fabricated by CO2 welding, and material used is mild steels. The present condition high grade material is used to archive maximum tensile strength which cost is maximum.

Also present trend in the fabrication industries is the use of automated welding processes to obtain high precision production rates and high production rates. A welding process is essential to establish the relationship between process parameters to control weld quality. The CO2 welding process is found in any industry whose products require metal joining process in a large scale. It establishes the weld pool, an electric arc between a continuous filler metal electrode and with shielding from an externally supplies gas, which may be an inert gas, an active gas combination or a mixture. The heat of the arc melts the end of the electrode and surface of the base metal. Co2 welding is a welding process which joins metals by heating the metals to their melting point. The arc is between a continuous, the metal being welded and consumable electrode wire. Generally, the quality of a weld joint which is directly influenced by the welding input parameters during the welding process; therefore, welding can be considered as a multi-input multi-output process.

Welded joints are finding applications in critical components where failures are catastrophe. Hence, the inspection methods to acceptable standards are increasing. These acceptance standards based upon test of welded specimen containing some discontinuities which is represent the minimum weld quality. Welding involves a wide range of variables such as welding speed, Welding current, Welding voltage, temperature, electrode, pulse frequency, power input, gas flow rate and gas combination that influence the eventual properties of the weld metal. There is the need to select welding parameters for a given a good weld quality.

Unfortunately, a common problem that has faced the manufacturer is control of the process input parameters to obtain a good welded joint with the required bead geometry and weld quality with maximum tensile strength.

A. Literature Review

Reference [3] performed experiments in the effects of different parameters on welding penetration, The hardness measurement and micro structure was measured in mild steel that having the 6mm thickness of the base metal by using the robotic gas welding. The changes in welding process parameters are influenced the effect of the microstructure of weld metal. As increased welding current, welding speed and arc voltage on the grain size of microstructure.

From this experiments we can conclude that depth of penetration increased by increasing the value of welding current. Also penetration influences by the factors from welding speed and arc voltage. When the variable welding parameters changed the grain boundaries of microstructures changes from bigger size to smallest size.

Reference [4] studied on low alloy steel by all types' fusion welding. The joint fabricated exhibited higher strength values by FSW process.

Reference [5] investigated CO2 laser–GMAW hybrid welding process the bead geometry for microstructure and mechanical properties of AISI 904 L super austenitic

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stainless steel joint. The different gas mixture ratio (50%He+50%Ar, 50%He+45%Ar+5%O_2, and 45%He+45%Ar+10%N_2) with 5 mm thickness sheet Carried out for welding process. The experiment result analysed by scanning electron microscope images of weld specimen. Results conclude that the joint by laser–GMAW hybrid had higher tensile than the base metal. This hybrid welding is suitable for welding of AISI 904 L super austenitic stainless steel owing to their high welding speed and excellent mechanical properties of weld metal.

Reference [6] investigated that effect of welding speed on the tensile strength. This Experiments was conducted on specimens of single v butt joint having different bevel heights and bevel angles. The material Aluminium AA6351 Alloy is selected for preparing the test specimen. The welded joint specimens are tested by a universal tensile testing machine and the results are evaluated. At weld speed of 0.6 cm/sec (for 40 0 bevel and 1.5 bevel height) Maximum Tensile strength of 230 Mpa was observed.

Reference [7] studied for the material ASSI 3cr12 grade steel and take input different parameter such as wire feed wire, welding voltage, welding speed and gas flow rate. The tensile test is carried out after the welding & using MINITAB Software the effect of welding input process parameters on tensile strength show on the interactive graphs.

Reference [8] investigated the effect of welding process parameters on back bead geometry for CO_2 welding. They developed a model using multiple regression analysis to predict welding process parameters such as current, arc voltage and welding speed for desired weld bead geometry in butt welding. They have focused their study on systematically identifying the complicated relation between the welding process parameter and weld pool geometry. Further it developed the equation for predicting the optimal weld pool geometry by using multiple regression analysis. It is observed that the results obtained by multiple regression analysis are close to the actual values, the error observed is less than 6.5%.

Reference [9] studied the effect of welding on mechanical properties of ribbed bars of two cold-deformed austenitic stainless steels (new low nickel AISI 204Cu and traditional 304 type) and two duplex stainless steels (SAF 2205 type, cold and hot worked). Welding has been carried out using shielded metal arc welding. The effect of welding on local mechanical properties has been studied. Results show that heat during welding promotes recrystallization of the microstructure, effect that depends on degree of deformation. It describes relationship between hardness, absorbed energies and microstructure in material, 304 stainless steel can suffer reductions of yield strength down from 500 MPa, although tensile strength vs. yield strength ratio values will keep high enough to comply with ductility requirement. The change in properties of the material due to welding leads to corrosion, which influence the performance of the material used in concrete.

Reference [10] studied on widely used connecting of boiler part made of A516-Gr70 carbon steel. At optimum current 130A, welding speed of 9.4 cm/min and gaas flow rate 15.1 l/min achieved desired tensile strength and hardness.

Reference [11] was worked carried out on plate welds AISI 304 & Low Carbon Steel plates using gas metal arc welding (GMAW) process. The experimental design by Taguchi method is used to formulate. Design of experiments using orthogonal array is employed to develop the weldments. By using Taguchi method this problem solved. Subsequently, using analysis of variance the significant coefficients for each input parameter on tensile strength & Hardness (WZ & HAZ) were determined and validated.

II. Material and Experimental Procedure

A. *Materials*

Rolled Plates of IS2062 E-250 mild steel with 12 mm thickness were cut into specimens 250 x 125 x 12 by machining. Square butt joint configuration was prepared according to welding standard. Argon and co2 combination was used as shielding gas. The filler metal was an ASW classification E71T-1C with a 1.2 mm diameter electrode. The composition & mechanical properties of base metal & filler metal are listed in Table I & Table II respectively.

TABLE I: Chemical Composition Base Metal & Filler Metal

Material	C	Si	Mn	P	S	Cr
IS2062 E250	0.12	0.25	0.60	0.005	0.05	
E71T-1C	0.042	0.38	1.39	0.008	0.007	0.014

TABLE II: Mechanical Properties OF Base Metal & Filer Metal

Material	Yield stress	Tensile stress	Elongation (%)
IS2062 E250	210	300	28
E71T-1C	490	560	26.4

B. *Welding procedure*

Twenty pairs of specimens were CO2 welded based on parameters designed. The gas flow rate and welding current were measured by using a regulator and an anemometer. The gas combination cylinder are used as per design (argon & CO2). Each butt weld was formed by two passes of CO2 welding, one over the other. Single ‘‘V’’ butt weld (welded only one sides) preparation was used. All welds of specimen were inspected and approved by visual inspection.

C. *Tensile test*

Tensile test specimens were prepared in accordance with ASME Section 9). Tensile test were carried out at a strain rate of 0.1 S^{-1} by digital compression tensile tester machine.

III. Results and discussion

A. *Working limits of parameters*

A large number of trial of sample were carried out using 5 mm thick rolled plates of IS2062 E250 Grade to find out feasible working limits of CO2 welding parameters. Different welding parameters were used to carry out the trial runs. The visual inspection were used to identify the working limits of the welding parameters. By trail the results obtained are as following. If the current is less than

170A, there will be lack of fusion and incomplete penetration. For current greater than 210 A, spatter and undercut will be observed on the weld bead surface. If the gas flow rate of shielding gas is lower than 13 l/min, porosities and inclusions will be observed and flow rate of shielding gas combination more than 17 l/min will lead to porosities generation due to agitated flow gas. Considering all the conditions above, feasible limits of the parameters were selected in a manner that the E250grade mild steel is welded without any weld defects. Among a wide range of parameters, central composite design matrix were selected three parameters and five levels to optimize the experimental conditions. Table III lists the range of selected parameters

TABLE III: IMPORTANT CO2 WELDING PARAMETERS AND THEIR WORKING RANGE

Parameters	Notation	Level				
		-2	-1	0	1	2
Current	I	170	180	190	200	210
Gas flow	G	13	14	15	16	17
% of Co2	M	100	80	50	20	0

The results of tensile testing performed on welded specim ens are tabulated below Table IV.

TABLE IV: CENTRAL DESIGN MATRIX AND EXPERIMENTAL RESULT

Ex. No.	Coded value			Actual Value			U.T.S N/mm^2
	I	G	M	I(A)	G (L/Min)	M	
1	-1	-1	-1	180	14	80%	345
2	1	-1	-1	200	14	80%	290
3	-1	1	-1	180	16	80%	284
4	1	1	-1	200	16	80%	300
5	-1	-1	1	180	14	20%	315
6	1	-1	1	200	14	20%	300
7	-1	1	1	180	16	20%	236
8	1	1	1	200	16	20%	320
9	-2	0	0	170	15	50%	300
10	2	0	0	210	15	50%	240
11	0	-2	0	190	13	50%	310
12	0	2	0	190	17	50%	270
13	0	0	-2	190	15	100 %	290
14	0	0	2	190	15	0%	270
15	0	0	0	190	15	50%	333
16	0	0	0	190	15	50%	335
17	0	0	0	190	15	50%	356
18	0	0	0	190	15	50%	343
19	0	0	0	190	15	50%	350
20	0	0	0	190	15	50%	350

Table IV shows 20 sets of coded conditions used to prepare the design matrix. The convenience of recording and processing experimental data by considering upper and lower levels of the parameters were coded as +2 and -2, respectively. The effects of welding parameters namely gas flow, welding current and Gas combination on the tensile strength be explained.

1. The effect of welding current on Tensile strength.

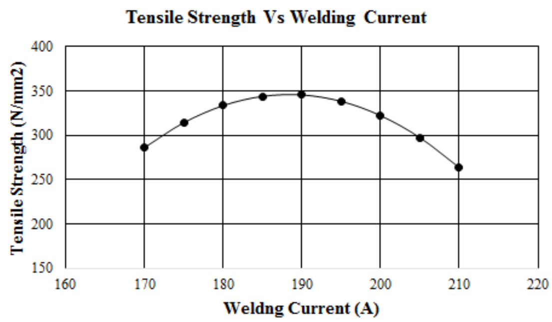


Fig. 1. The effect of welding current on Tensile strength

Fig.1 indicates that with increase in welding current tensile strength goes on increasing; attains its maximum value and then goes on reducing. The maximum value of TS is obtained at the welding current of 190 A. The maximum value of TS is found to be 356 N/mm2. The reason of increase in tensile strength is that with increase in welding current, heat input to weld metal increases. For obtaining proper joint at higher heat input welding speed needs to be increased and with increase in welding speed tensile strength of welded joints increases.

2. Effect of Gas flow rate on tensile strength.

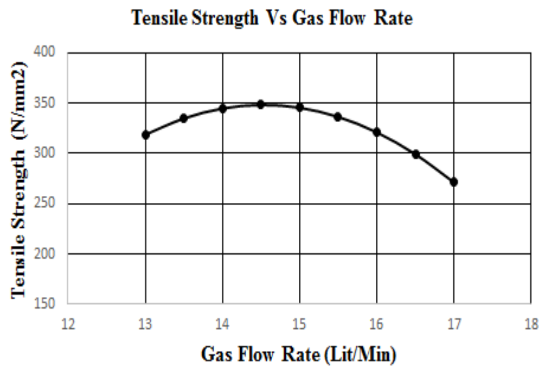


Fig. 2. Effect of Gas flow rate on tensile strength

Fig.2 shows relationship between tensile strength and shielding gas flow rate. It seems that with increase in shielding gas flow rate; TS increases up to certain limit and then goes on decreasing. The maximum value of TS is achieved at the shielding gas flow rate of 15 lit/min. Shielding gases are used for prohibiting the oxidation and for achieving more penetration in the welded joints. Welded joints with good penetration are always stronger than other [10]. If proper fusion occurs with good penetration, the joints show higher strengths. The reason behind reduction in tensile strength at higher shielding gas flow rates could be improper fusion.

3. Effect of Gas Combination on tensile Strength.

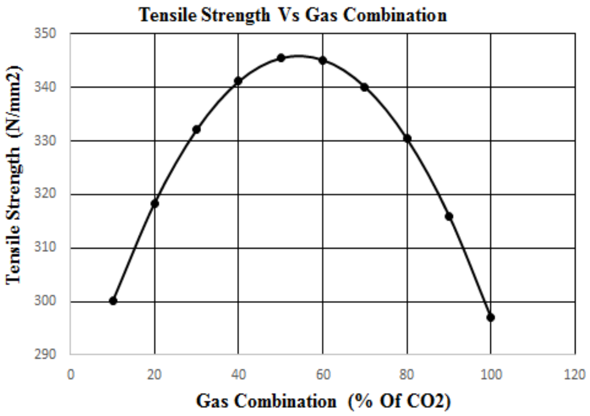


Fig.3. Effect of Gas Combination on tensile Strength

B. *Development of an empirical relationship*

In this experiment, the response the response function of weld joint, Tensile strength (σ) is function of Welding current (I), gas flow (G) and gas combination (M) and it can be expressed as.

$$\sigma = f(I, G, M,) \quad (1)$$

Second order polynomial equation that represents the response surface 'Y' is:

$$Y = b_0 + \sum b_i x_i + \sum b_{ii} x_i^2 + \sum b_{ij} x_i x_j \quad (2)$$

Selected polynomial could be expressed by considering three parameters,

$$\sigma = b_0 + b_1(I) + b_2(G) + b_3(M) + b_{11}(I^2) + b_{22}(G^2) + b_{33}(M^2) + b_{12}(IG) + b_{13}(IM) + b_{23}(GM) \quad (3)$$

Where, σ, I, G and M. are tensile strength (MPa), current (A), flow rate of shielding gas (l/min) and Gas combination, respectively.

R1 (TS) = - (3007.18227) + (36.91413 *I) - (37.54193*G) + (10.59166*M) + (2.12500*I*G) - (0.04500*I*M) + (0.033333* G*M) – (0.17658 *I2) - (12.65832 * G2) – (0.023417*M2) (4)

C. *Validation of the developed relationship*

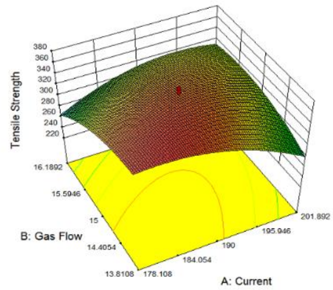
TABLE V: RESULT OF VALIDATION EXPERIMENT FOR TS

Sr. No.	I (A)	G (Lit/ Min)	M (% Co2)	TS by Analysis (KN)	TS by Experiment (KN)	% Error
S1	170	15	50	286.09	300	4.64
S2	190	15	50	345.50	356	3.08
S3	210	15	50	263.64	240	8.99
S4	190	13	50	318.62	310	2.70
S5	180	16	20	246.10	236	4.10
S6	190	17	50	271.12	270	0.41
S7	190	15	0	276.96	270	2.51

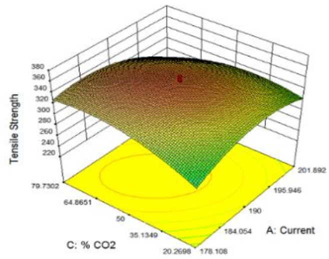
In Table V the error observed is less than 09%. Maximum error observed 8.99 % with 210 Amp welding current, 15 Lit/min gas flow rate & 50% CO2 gas combination. Minimum error observed is 0.41 % with 190 Amp welding current, 15 Lit/min gas flow rate & 100% CO2 gas combination. As the value of the error is less than 10% it can be stated that the obtained equation is close to the actual equation. Therefore, values generated by the response surface method can be accepted.

D. *3D Surface Plot*

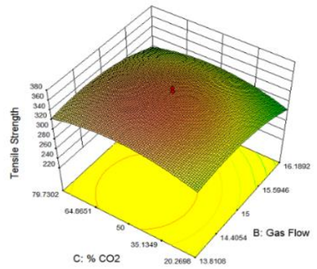
Fig.3 shows relationship between tensile strength and gas combination (% of CO2). It seems that with increase in % of CO2 in Argon gas; TS increases up to certain limit and then goes on decreasing. The maximum value of TS is achieved at the 50% of CO2 & 50% Argon gas mixture. The maximum value of TS is found to be 356 N/mm2. The reason of increase in tensile strength is that with increase in % of CO2, proper fusion occurs with good penetration, the joints show higher strengths.



(a)



(b)



(c)

Fig. 4. 3-D Response Surfaces Showing Interaction Effects of Welding Current, Gas Flow Rate & Gas Combination on Tensile Strength.

Fig. 4. (a), (b) and (c) shows the effect of three independent process parameters on the tensile strength of the welded joints. It is observed that with increase in welding current TS of welded joints increases and at the end decreases slightly. With increase in shielding gas flow rate TS increases up to certain limit and then decreases. It is also observed that with increase in % of CO2; tensile strength first increases and then decreases

IV. CONCLUSION

It is found that the gas flow rate has greater contribution in increasing the tensile strength of welded joint followed by welding current & gas combination. Gas flow rate has 93% contribution followed by welding current & gas combination

An empirical relation is developed for correlating the tensile strength of welded joint with the process parameters. The correlation coefficients found close to 0.9 signifies that the developed model is significant. Hence the model can be effectively used for predicting the response within the domain of the welding parameters.

The optimum values for welding parameters determined using statistical analysis are welding current 190 A, shielding gas flow rate 15 lit/min & 50% CO2 +50% Argon gas mixture, for getting maximum tensile strength of welded joint

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