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Experimental Investigation of Combined Welding on Mild Steel

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Abstract: ***Welding is one of the important sectors in today's industrial world. Welding is a positive metal joining process. It uses the principle of heat generation by pressure, heat and electric arc. TIG can produce the high quality weld and MIG has high efficiency of weld. In last two decades new processes and techniques have been implemented to take the advantages of both welding. First, hybrid welding developed but later on due to its handling difficulties, the combined welding is investigated. So, the project is related to the combined effect of TIG and MIG welding of mild steel plates. Welding current, gas flow rate, root gap, groove angle are taken as an input parameter. The tensile strength and hardness are response variable. Design of experiments by using Taguchi's method has used to find the optimal set of parameters. Analysis of parameters on the response and their contributions has been studied.***

Keywords: Combined welding, Metal Inert Gas, Optimization, Root Welding, Tungsten Inert Gas Welding

1. Introduction

In the ever-growing world of industrialization, the competition has been increasing at a faster rate due to rapid technological development. In order to sustain in this competitive world, the many researches have been carried out in various field. The manufacturing processes have the major contribution in this research field. Among the various manufacturing processes, welding is one of the important processes. Welding is a positive manufacturing process to create a permanent joint by the application of heat or pressure or by means of an electric arc. It can be performed in open air, under water and outer space also. Until the end of the 19th century, the only welding process was forge welding. Then in later, various other welding techniques were came and now a days it can be extensively used as a substitute for casting, forging and many other mechanical joining methods. Among the various applications, one of the applications in industries that are the pressure vessels, container, pipes are connected to each other by the welding techniques which offers leak-proof joint. Many welding techniques like gas welding, shielded metal arc welding, tungsten inert gas welding, metal inert gas welding are used [1, 2].

The selection of the process is based on the material and type of application. For this pipelines application, TIG and MIG process are mostly used. The researchers found limitations by using single process only. In later work, the hybrid process were developed which provide the advantages of both the TIG and MIG process. But the handling of both torches simultaneously makes the process difficult for welder. So, later work is done on the same process with slight modification known as combined TIG and MIG welding. In this the root pass is done by TIG and remaining gap is filled by MIG welding. These welding provide the flawless joint, high quality and high strength joint. The other combinations of welding are also used like TIG and SMAW. The process for filling the gap depends on the procedure and wall thickness. The problem that has faced by the industry is the control of input parameters to obtain a good weld joint [2].

Traditionally, the various trial and error experiments were done to check the quality of the weld joint. The process becomes very time-consuming and costly. This problem is simplified by using the optimization methods to specify the relationship between the input and output parameters. Taguchi method of optimization is most widely used for getting desired combinations of experiments in the less time.

2. Literature Review

Sudharshan and Devaiah [1] optimize MIG welding of some important similar materials or dissimilar materials in an industry through applying a statistical approach to SPSS software, develop mathematical models and optimize the welding operation. Patil and Waghmare [2] optimized the MIG welding parameters for improving the strength of welded joints of AISI 1030 mild steel material. Rao and Deivanathan [3] investigated the optimized welding parameters for joining similar grades of stainless steel by TIG welding. Anand and Mittal [4] used the Taguchi method of optimization to optimized welding parameters for the joint of stainless steel (AISI 316) and mild steel. Mishra et al. [5] studied the tensile strength and dilution of MIG and TIG welded dissimilar joints of mild steel and different grades of stainless steel. Khan et al. [6] has done the experimental investigation of combined TIG-MIG welding for 304 stainless steel plates.Pascual et al. [7] compares the weld ability of ductile cast iron for root TIG welding using an Inconel 625 source rod followed by SMAW using Ni67.6 and SMAW alone.

3. Experimental Work

The Fronius 320i welding setup is used for welding. This is a compact design and both TIG and MIG process can be done on it, only by changing the hose pack for the respective welding process. The material selected is mild steel because in pipeline works, the main focus is on leak proof joint, the strength of joint after welding, easy availability of material and cost of material, all this properties can fulfilled by MS. The mils steel plate has a dimension of 100×20×6 mm. For the dissertation purpose, the filler wire selected is of nearly same composition of base metal to provide a sound weld so, ER70S6 is used. The composition of ER70S6 filler is shown in table 3.1.

Table 3.1: Composition of ER70S6 filler

C	Mn	Si	S	Cu	P
0.06-0.15	1.4-1.85	0.8-1.15	0.025 Max	0.5 Max	0.03 Max

The Taguchi design of experiments is used for experimentation. The input parameters are and their levels are shown in table 3.2 are selected based on literature survey and trial experiments.

Table 3.2: Input parameters and their levels

Sr. No.	Parameters	Level 1	Level 2	Level 3
1	Groove angle (Degree)	30	45	-
2	Welding current (Amp)	140	160	180
3	Gas flow rate (L/min)	9	12	15
4	Root gap (mm)	1	2	3

The root run is performed by TIG welding with the selected input parameters. The fig 3.1 shows the samples after root run TIG welding. Then the cleaning action takes place on the root weld to maintain the homogeneity and to prepare defect free weld. And after that the MIG is done to fill the remaining gap. The fig 3.2 shows the samples after final run of MIG welding. Then the samples are tested for hardness and tensile strength.

Figure 3.1: Samples after root run TIG welding

Figure 3.2: Samples after final run of MIG welding

The hardness was measured on Rockwell hardness tester. For mild steel, Scale B is used. In scale B, the ball indenter is 1/16- inch diameter with 100kg load. The tensile strength is measured on the universal testing machine. Machine type is TUE-C-400. The machine has the maximum capacity of 400KN.

4. Results and Discussion

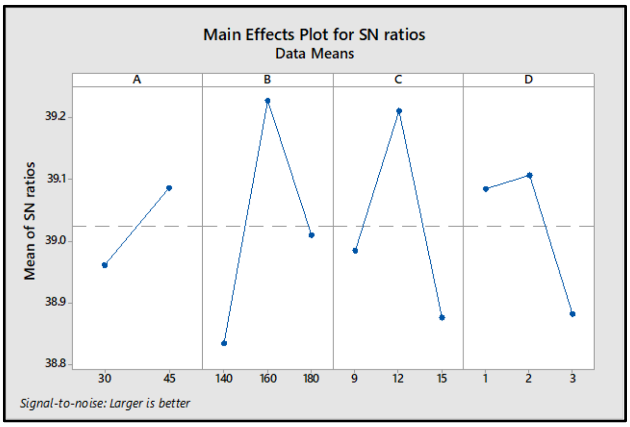
The table 4.1 shows the measured response variables tensile strength and hardness for combined welding and their S/N ratios.

Table 4.1: Measured response variables for combined welding

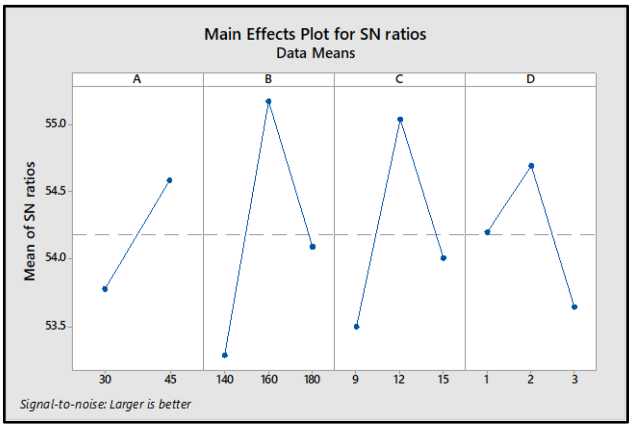
Expt. No.	Groove angle (Deg)	Welding current (Amp)	Gas flow rate (L/min)	Root gap (mm)	Hardness (HRB)	Tensile Strength (N/mm^2)	SN ratio for Hardness	SN ratio for TS
1	30	140	9	1	90.0	370.752	39.0849	51.3817
2	30	140	12	2	89.0	540.736	38.9878	54.6597
3	30	140	15	3	82.0	391.296	38.2763	51.8501
4	30	160	9	1	89.0	528.320	38.9878	54.4579
5	30	160	12	2	93.0	600.256	39.3697	55.5667
6	30	160	15	3	89.0	527.680	38.9878	54.4474
7	30	180	9	2	89.0	493.952	38.9878	53.8737
8	30	180	12	3	90.0	498.624	39.0849	53.9555
9	30	180	15	1	88.0	489.408	38.8897	53.7934
10	45	140	9	3	87.0	470.464	38.7904	53.4505
11	45	140	12	1	90.0	557.000	39.0849	54.9171
12	45	140	15	2	87.0	470.464	38.7904	53.4505
13	45	160	9	2	93.0	591.232	39.3697	55.4352
14	45	160	12	3	94.0	615.488	39.4626	55.7844
15	45	160	15	1	91.0	583.872	39.1808	55.3264
16	45	180	9	3	86.0	416.320	38.6900	52.3885
17	45	180	12	1	92.0	584.960	39.2758	55.3425
18	45	180	15	2	90.5	574.272	39.1330	55.1824

4.1 Analysis of Hardness and tensile strength by ANOVA

The hardness and tensile strength are directly proportional to each other.



Graph 4.5: Main effect plots for hardness



Graph 4.6: Main effect plots for tensile strength

It could be observed that from graph 4.5 and 4.6, the hardness and tensile strength are increases with increase in groove angle because for the less groove angle the weld material is not properly deposited at the root of plate so the gap is not full filled and the weld is not take place so the tensile strength is less so the hardness also less. Both are increased with increase in welding current and gas flow rate and root gap up to a certain limit and then it decreases. The low welding current is not sufficient to develop the arc between electrode and mild steel plate which causes arc instability and the resulting welding have some defects so, they decreases. So, the graph has increasing trend. After 160 amp the grain refinement causes with rise in current so graph has increasing trend. Too much of gas flow rate cause the turbulence and hinders the weld quality.

According to the analysis, the most effective parameters for the tensile strength and hardness in their descending order are welding current, groove angle, root gap and gas flow rate**.** The table 4.2 and 4.3 shows the ANOVA Analysis for hardness and tensile strength of combined welding.

Table 4.2: ANOVA Analysis for hardness of combined welding

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
A	1	7.347	5.28%	7.347	7.347	2.56	0.141
B	2	48.250	34.68%	48.250	24.125	8.41	0.007
C	2	36.583	26.30%	36.583	18.292	6.37	0.016
D	2	18.250	13.12%	18.250	9.125	3.18	0.085
Error	10	28.694	20.62%	28.694	2.869		
Total	17	139.125	100.00%				

Table 4.3: ANOVA Analysis for tensile strength of combined welding

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
A	1	9943	11.02%	9943	9943	9.41	0.012
B	2	35279	39.11%	35279	17639	16.69	0.001
C	2	24105	26.72%	24105	12053	11.40	0.003
D	2	10309	11.43%	10309	5154	4.88	0.033
Error	10	10570	11.72%	10570	1057		
Total	17	90206	100.00%				

Here, (A: Groove angle, B: Welding current, C: Gas flow rate, D: Root gap) For hardness, the most influencing factor is welding current of contribution 34.68% having p value 0.007. The second most important factor is gas flow rate of contribution 26.30%. The least influencing factor is groove angle with contribution 5.28%. And for tensile strength, the welding current has a major contribution of 39.11% having p value 0.001. The GFR is second most important factor of contribution 26.72%. The root gap and groove angle has the contribution of about 11.43% and 11.02% respectively. The table 4.4 shows the optimum parameters for hardness and tensile strength.

Table 4.4: Optimum parameters for hardness and tensile strength

	Hardness	Tensile strength
Groove angle (Degree)	45	45
Welding current (Ampere)	160	160
Gas flow rate (l/min)	12	12
Root gap (mm)	2	2

5. Conclusions

Combined TIG –MIG welding process was applied to weld mild steel plates and the analysis has been done. The results shows that

1) Welding current has a major contribution in welding.
2) For 45 deg groove angle the results are better.
3) The welding current,GFR and Root gap should be kept within limit.
4) For the best hardness and tensile strength, the optimum parameters are 45 deg groove angle, 160 amps welding current, 15 l/min GFR and 2mm root gap.

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