OPTIMIZATION OF THE PROCESS PARAMETERS FOR MIG WELDING OF AISI 304 AND IS 1079 USING FUZZY LOGIC METHOD

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Abstract - ***Dissimilar metal welded joints are integral parts of modern-day power and process plant equipment. Among the various types of material combinations, welded joints of austenitic stainless steels and mild steel are very common in nuclear and chemical industries. The dissimilar metal joints have been emerged as a structural material for various industrial applications which provides good combination of mechanical properties like strength, corrosion resistance with lower cost. Selections of joining process for such materials are difficult because of their physical and chemical properties. Dissimilar material joints of stainless steel and mild steel are commonly uses as structural applications. Joining of stainless steel and mild steel is very critical because of carbon precipitation and loss of chromium leads to increase in porosity which affects the quality of joint leads deteriorates strength. Shielding gases are necessary in GMAW process to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity and weld metal embitterment. In the present study, stainless steel plate of AISI-304 has been welded with mild steel plate of IS: 1079 by Metal Inert Gas (MIG) welding processes. The tensile strength and hardness of dissimilar metal joints have investigated. The results were compared for different joints made by MIG welding processes and finally optimize the best combination of input parameters.***

Key Words: *SS 304, MS 1079, GMAW, Tensile, Hardness, Taguchi, ANOVA, FUZZY*

1. INTRODUCTION

Welding is a process of joining similar or dissimilar materials. Welding is carried out by the use of heat or pressure or both and with or without added metal. Joining of dissimilar metals is very indispensable in manufacturing and constructing advanced equipment and machinery. Different kinds of metals feature different chemical, physical, and metallurgical properties are usually join through various metals joining process. Joining dissimilar metals is, therefore to compose different properties of metals in order to minimize material costs and at the same time maximize the performance of the equipment and machinery. Presently, the methods of joining dissimilar metals include fusion welding, brazing, and soldering. This article, however, discusses fusion welding only, because it is uses in wide range of industries. Dissimilar metal welding refers to the joining of two different alloy systems. Actually all fusion welds are dissimilar metal welds because the metals are being joined have a wrought structure and the welds have a cast structure. Frequently the matching composition of filler wire is deliberately altered from that of the base alloy **[1]**. The presence of nickel (6-22%), along with chromium (16-26%), enhances its corrosion and stain resistance.

MIG welding is an arc welding process where the heat for welding is generated by an arc between a consumable electrode and the work material. The electrode, a solid wire that is continuously fed to the weld area, becomes the filler metal as it is consumed. The electrode, weld puddle, arc and adjacent areas of the base metal are protected from atmospheric contamination by a gaseous shield provided by a stream of gas, or mixture of gases, fed through the electrode holder [**2**].

Gas metal arc welding overcomes the restriction of using an electrode of limited length, as in shielded metal-arc welding, and overcomes the inability to weld in various positions, which is a limitation of submerged arc welding.

2. LITERATURE REVIEW

Vikas Chauhan et al. [**3**] have optimized process parameters of MIG welding for Stainless Steel (SS-304) and low carbon steel using Taguchi design method. Three parameters of MIG welding viz. current, voltage and travel speed were taken for the analysis. The analysis for signal-to-noise ratio was done for higher-the-better quality characteristics. The significance of each parameter was studied by using the ANOVA (Analysis Of Variance). Finally the confirmation tests were performed to compare the predicted values with the experimental values which confirm its effectiveness.

L.Suresh Kumar et al. [4] have investigated for welding aspects of AISI 304 & 316 by Taguchi technique for the process of TIG & MIG welding. Mechanical properties of austenitic stainless steel for the process of TIG and MIG welding have discussed here. The voltage has taken constant and various characteristics such as strength, hardness, ductility, grain structure, tensile strength breaking point, HAZ have observed in these two processes.

Radha Raman Mishra et al. [5] have studied on dissimilar metal joint as a structural material for various industrial applications which provided good combination of mechanical properties like strength, corrosion resistance with lower cost. In the present study, stainless steel of grades 202, 304, 310 and 316 were welded with mild steel by Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welding processes. The percentage dilutions of joints were calculated and tensile strength of dissimilar metal joints was investigated. The results were compared for different joints made by TIG and MIG welding processes and it was observed that TIG welded dissimilar metal joints have better physical properties than MIG welded joints.

Pawan Kumar et al. [6] have obtained the use of Taguchi's parameter design methodology for parametric study of Gas Metal Arc Welding of Stainless Steel & Low Carbon Steel. The input process variables considered here include welding current, welding voltage and gas flow rate. A total no. of 9 experimental runs were conducted using an L9 orthogonal array, and calculate the signal-to-noise ratio. Subsequently, using Analysis Of Variance (ANOVA) the significant coefficients for each input parameter on tensile strength & Hardness (PM, WZ & HAZ) were determined.

Dinesh Mohan Arya et al. [7] have performed the optimization process parameters for Metal Inert Gas (MIG) Welding. This paper presented 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 width, Bead height, Penetration and Heat Affected Zone (HAZ) for quality target. Analysis Of Variance (ANOVA) has also applied to identify the welding current is the most significant factor. Experiment with the optimized parameter setting, which have been obtained from the analysis.

3. EXPERIMENTAL SETUP

The experiments have been conducted using a CPT 400 model having 400A maximum current with air type cooling and semi-automated Welding Set up. In this welding machine automated Metal Inert Gas torches as well as automatic feeler wire feeding units have provided. For experimentation, servo motors are used for maintaining welding speed during actual welding.

3.1 Material selection

The present study has been carried out with mild steel plate of IS: 1079 Gr. O and stainless steel plate of AISI-304, having 3mm thickness. This material is used as general industrial purpose.

Table -1: Chemical compositions

Material composition	C	Mn	Si	Cr	Ni	P	S
Weight % AISI- 304	0.06	1.24	0.23	19.44	9.12	0.035	0.025
Weight % IS: 1079	0.11	0.41	-	-	-	0.03	0.023

3.2 Proposed Design of Experiment

For the present investigation, three number of process parameters or control factors each having three levels is taken into consideration. The L_9 (3^3) orthogonal array[8] was used.

3.3 Experimental parameter

Input parameters: Welding current, welding voltage and weld speed.
Output parameters: Tensile strength and Hardness

Table -2: Control Factors and their level

Sl. No	Factors	Symbol	Unit	Level 1	Level 2	Level 3
1	Welding Current	A	Ampere	130	135	140
2	Welding Voltage	B	Volt	22	24	26
3	Welding Speed	C	Cm/min	25	30	35

3.4 Taguchi Methodology

The standard S/N ratios generally used are as follows:

- Smaller is better
- Larger is better
- Nominal is best

The S/N ratio (η) is mathematically represented as

$\eta = -10\log_{10}(MSD)$ [9]

Larger is better type:

$$MSD = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{Y_i^2}$$

Where y_i = Observed data (quality characteristics) at the i^{th} trial
n = Number of trials
MSD= Mean Square Deviation from the desired value and commonly known as quality loss function.

3.5 Experimental Work

Welding specimen has been prepared to fabricate MIG welded joints. The specimen in the form of block with dimensions 125mm x 75mm x 3mm were considered for welding with butt joints.
Welding process has been carried out in MIG welding machine. Experiments were conducted based on full factorial design.

Table -3: Experimental Results

exp no.	A (welding current)	B (welding voltage)	C (welding speed)	tensile strength (MPa)	hardness (HRB)
1	130	22	25	458	96
2	130	24	30	451	94
3	130	26	35	454	100
4	135	22	30	466	110
5	135	24	35	444	107
6	135	26	25	451	102
7	140	22	35	433	114
8	140	24	25	420	98
9	140	26	30	440	102

4. EXPERIMENTAL RESULTS AND DISCUSSION

In the present investigation tensile strength and hardness for all the nine experiments already have been calculated separately. In this section Fuzzy Logic multi response optimization, ANOVA and confirmation test have been done.

4.1 Fuzzy Logic for Multi Response Optimization

In this experiment MAMDANI type of Fuzzy interference system with two inputs, one output and nine rules have been used to find out the MRPI (Multi Response Performance Index) of the best combination of hardness and tensile strength. The basic block diagram shown in Fig. 1.

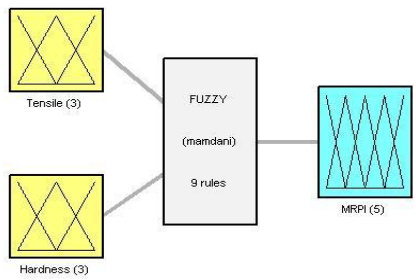

Fig -1: System Fuzzy: 2 inputs, 1 output, 9 rules

In this work triangular membership function have used for the representation of input and output functions. Three membership functions called NB (Negative Big), ZO (Zero) and PB (Positive Big) have used for the representation of each input and output function. For the representation of the combination of two output functions, five membership functions called NB (Negative Big), NS (Negative Small), ZO (Zero), PS (Positive Small) and PB (Positive Big) have used.

4.1.2 Decision maker rule base

The rules have been made here according to the various results of tensile strength and hardness from the nine different combinations of input parameters.

Table -4: Decision maker rule base of FIS

Hardness / Tensile	*NB*	*ZO*	*PB*
NB	NB	NS	ZO
ZO	NS	ZO	PS
PB	ZO	PS	PB

Fig.2 represents the surface view of the fuzzy inference system. X-axis represents S/N ratio of tensile strength while Y-axis represents S/N ratio of hardness. Z-axis represents MRPI, which is actually output of the system.

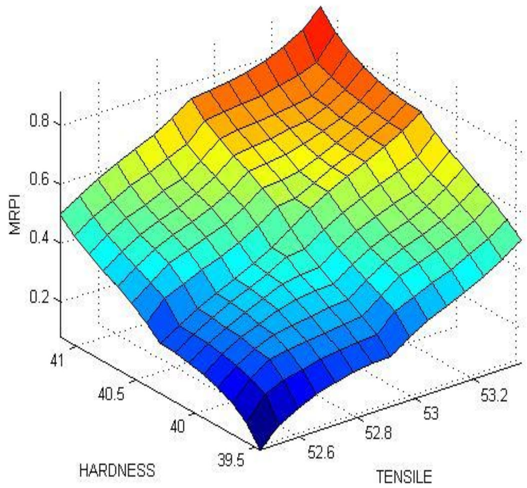

Fig -2: Surface view of FIS

By applying decision maker rule base of FIS the MRPI (Multi Response Performance Index) [**10**] and the mean of all nine combinations of hardness and tensile strength have been calculated.

Table -5: MRPI of tensile strength and hardness

exp. no.	A (welding current)	B (welding voltage)	C (welding speed)	S/N ratio (dB) tensie strength	S/N ratio (dB) hardness	MRPI	mean
1	130	22	25	53.2173	39.6454	0.448	0.448
2	130	24	30	53.0835	39.4626	0.336	0.336
3	130	26	35	53.1411	40.0000	0.508	0.508
4	135	22	30	53.3677	40.8279	0.796	0.796
5	135	24	35	52.9477	40.5877	0.584	0.584
6	135	26	25	53.0835	40.1720	0.530	0.530
7	140	22	35	52.7298	41.1381	0.616	0.616
8	140	24	25	52.4650	39.8245	0.208	0.208
9	140	26	30	52.8691	40.1720	0.438	0.438

4.2 ANOVA Analysis

The analysis of variance is the statistical treatment most commonly applied to the results of the experiment to determine the percent contribution of each factors [11]. Study of ANOVA table for a given analysis helps to determine which of the factors need control and which do not.

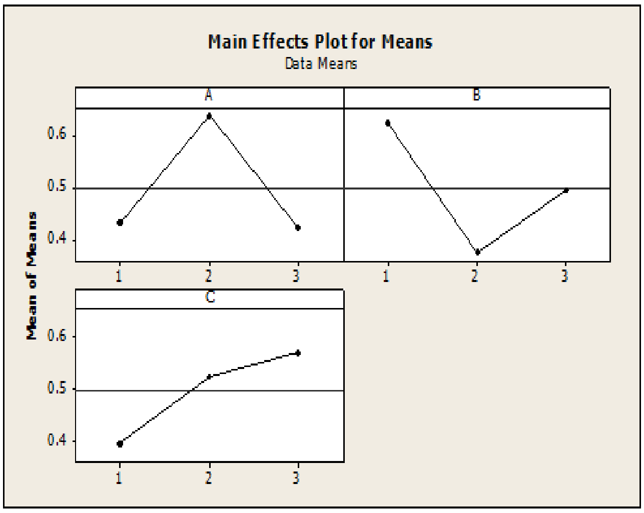

Fig -3: Main effect plot for Mean of MRPI

From Table 5 the maximum value and minimum value of the MRPI for all possible combinations of tensile strength and hardness are 0.796 and 0.208 respectively.

Table -6: Response for the mean of MRPI

SYMBOL	FACTORS	MEAN of MRPI			MAXIMUM - MINIMUM	RANK
		LEVEL 1	LEVEL 2	LEVEL 3		
A	CURRENT	0.4307	0.6367	0.4207	0.2160	2
B	VOLTAGE	0.6200	0.3760	0.4920	0.2440	1
C	SPEED	0.3953	0.5233	0.5693	0.1740	3

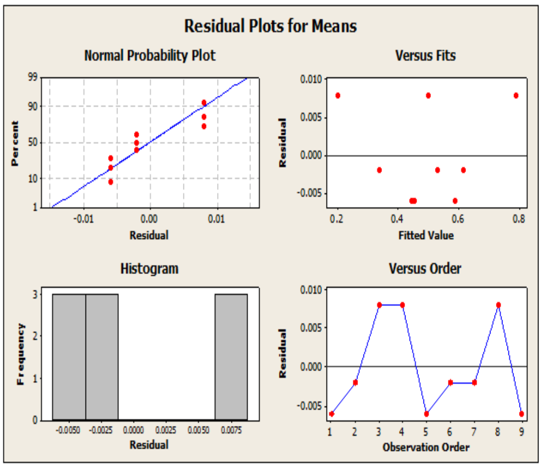

Fig. 4: Residual plot for Means of MRPI

The maximum average MRPI for hardness has obtained at level 2 of welding current, levels 1 of welding voltage and level 3 of welding speed, i.e. the optimum process parameters setting for maximum hardness is $A_2B_1C_3$.

From Table 6 it has clearly shown that for MRPI optimal current is 135 Amp, welding voltage is 22 volt, welding speed is 35 cm/min.

Table -7: Analysis of Variance for Mean of MRPI

source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage contribution
A	2	0.089192	0.089192	0.044596	285.87	0.003	39.18 %
B	2	0.089376	0.089376	0.044688	286.46	0.003	39.26 %
C	2	0.048776	0.048776	0.024388	156.33	0.006	21.42 %
Residual Error	2	0.000312	0.000312	0.000156			0.14 %
Total	8	0.227656					100 %

The percentage contribution of the three input parameters have calculated with the help of Analysis of Variance are given in Table 7.

Table -8: Conformation Test for MRPI

	Initial parameter setting	Optimal MIG welding parameters	
		Predict value	Experiment value
Level	$A_1B_1C_1$	$A_2B_1C_3$	$A_2B_1C_3$
Tensile Strength(MPa)	53.2173	53.4831	53.3677
Hardness(HRB)	39.6454	41.1063	40.9102
MRPI	0.448	0.834	0.813
Improvement of MRPI	0.365		

The MRPI of the combination of corresponding tensile strength value and hardness value for initial parameter setting, by prediction and by conformation test are given in Table 8. The conformation test indicates that it is possible to increase MRPI significantly by using the proposed statistical technique.

5. CONCLUSION

The experiment designed by Taguchi method fulfills the desired objective. Fuzzy interference system has been used to find out the MRPI (Multi Response Performance Index) of the best combination of hardness and tensile strength. The all possible values of MRPI have been calculated by using MATLAB 7.5.0 software. Analysis of variance (ANOVA) helps to find out the significance level of the each parameter. The optimum value was predicted using MINITAB-16 software.

The improvement in MRPI from the starting welding parameters to the level of optimal welding parameters is 0.365 for the combination of tensile strength and hardness.

Welding current 135 Amp, welding voltage 22 volt and welding speed 35 cm/min have the optimal value of control factors for maximum MRPI.

The effect of parameters on the MRPI can be ranked in decreasing order as follows: voltage > current >speed.

The experimental results confirmed the validity of the used Taguchi method for enhancing the welding performance and optimizing the welding parameters in MIG welding

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