© IJEDR 2018 | Volume 6, Issue 2 | ISSN: 2321-9939

Taguchi Method & Fuzzy Logic Parametric Augmenting & Supplementing of MIG Welding On 304 AISI Stainless Steel

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Abstract: This paper deals the Metal Inert Gas (MIG) welding with Taguchi method& Fuzzy logic parametric augmenting& supplementing. Experimental investigations are carried-out to find Tensile strength and Percentage elongation during the universal testing machine and Hardness during the Brinell hardness test using welding joint 304 AISI Stainless Steel work piece. To optimize the welding process parameters for effective welding joint of the work piece, a powerful tool, known as Design of Experiments (DOE) for experimental design is used. Considering the Welding voltage, Welding current and welding speed the experimental work has been conducted and shown, and found the performance characteristics such as Tensile strength, Percentage elongation and Hardness. The Taguchi Method was also used for DOE and considered L_{27} orthogonal array matrix and Signal-to-Noise (S/N) Ratio, the tensile strength, percentage of elongation, and hardness of the predicted values have been creditably acquired via Fuzzy representation.

Keywords: **AISI 304 SS, MIG welding, DOE, Tensile Strength, Percentage of elongation, Hardness, Fuzzy logic**

1. *INTRODUCTION*

Welding is a process that is used to permanently join metal parts. This is used in various industries like bulldozers, cranes, material handling equipment, paper making and printing equipment, textiles and office machinery. Welding is also used in metal industry like steel mills, iron and steel foundries, smelting and refining plants.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. It is shown in Fig 1.

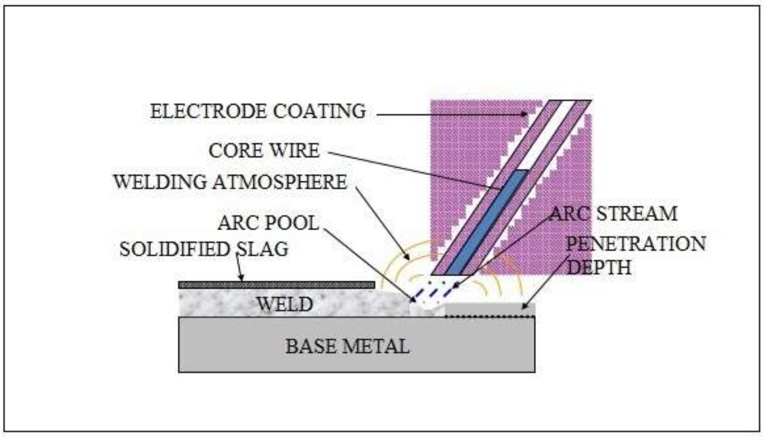

Fig-1: Fusion Welding

Frequently the matching composition of filler wire is deliberately altered from that of the base alloy. 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. 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*

Aghakhani et al. [1] have carried out research on optimization of GMAW process parameters to enhance quality and productivity. They have chosen ST-37 steel plate as work piece, 80% argon combination with 20% CO_2 as shield gas depends on type of base metal being welded. The experiment was designed by Taguchi with L_{27} orthogonal array and it was carried out by Analysis of Variance (ANOVA) by considering weld dilution as output characteristic and wire feed rate, welding voltage, nozzle to plate distance, welding speed, and gas flow rate were as the input parameters. They reported that, the wire feed rate has no much significant effect on the weld dilution while gas flow has no effect at all on it. In another research made by Ajithooda *et al*. [2], AISI 1040 medium carbon steel was used for welding, output characteristic tensile strength was predicted with response surface model. The welding voltage, current, wires speed and gas flow rate were kept as input parameters. Tensile strengths in transverse and in longitudinal were almost same with input parameters explored by face centered designmatrix.

Optimization of process parameters in MIG welding of dissimilar metals such as AISI SS with grade 304 and 316 have been studied, Artificial Neural Network (ANN) and Genitic Algorithm (GA) were used to predict tensile strength and the ANN was successfully integrated as other regression model by Amit kumar *et al*. [3]. Arya *et al*. [4] reported that, the optimization of tensile strength and higher penetration of filler metal was prosperously analyzed by Taguchi method followed by grey relational analysis, after completion of MIG welding with its process parameters. The weld ability of MIG welded EN-3A mild steel specimens have been studied to see the influence of process parameters on depth of penetration of welding joint. They were analyzed this issue with help of surface plots, reported by Das *et al*. [5]. Parametric optimization of MIG welded 316L Austenitic stainless steel was studied by Taguchi method. The optimal parameters were identified for maximum tensile strength and percent of elongation in case when Butt welded joints have been made by several levels of current, gas flow rate, and nozzle to plate distance by Ghosh et al.[6].

Kapil et al. [7] carried out research to identify the factors that have most significant effect on welding of AISI 316 Austenitic stain less steel and its welding quality and productivity. Similarly, two different materials like AISI 304 steel and low carbon steel were used for MIG welding with CO_2 as shielding gas. TheexperimentwasdesignedwithL$_9$ orthogonal array which is for very small values by Pawnkumar *et al.* [8]. Pradeep *et al.* [9] investigated on effect of process parameters on tensile strength of SS 3Cr12 specimen after MIG welding. Reported that, the tensile strength was increasing by increasing of welding speed and flow rate, but it was remains increasing with decreasing of voltage and wire feed rate. It was revealed through central composite matrix using Minitabsoftware.

Irfan et al. [10] found that the penetration depth was increasing with welding speed, current and voltage in case of MIG welding of galvanized steel. Experimental investigation for welding aspect of AISI 304 and 316 grades was done for die penetrate testing by using Taguchi technique for the process of TIG and MIG welding by Suresh et al. [11]. Vinita et al. [12] preferred aluminum alloys of 6061 and 5082 grades for MIG welding, with aluminum 4043 wire as filler material of diameter 1.2 mm and an orthogonal array of L_9 was used to conduct to optimize the process parameters via Taguchi through statistical software minitab-17. They were identified for maximum tensile strength and reported that the welding current and voltage were shown major influence on tensile strength of weld joint by Viveksaxena *et al.*[13].

In the present work, AISI 304 SS work pieces after MIG welding carried out were studied for tensile strength, percent of elongation, and hardness (performance characteristics) with influence of process parameters. Taguchi Method was used for DOE and considered L_{27} orthogonal array matrix and Signal-to-Noise Ratio to optimize process parameters.

3. *EXPERIMENTATAL METHODOLOGY*

The experimental setup relating to the MIG Welding Operation. Output parameters of experiment and Fuzzy logic are explained in the following. Fig 2 shows MIG welding equipment.

Fig-2:MIG welding equipment

3.1 Material selection

AISI 304 Stainless Steel of 3.5 mm thickness sheet is used in this investigation. Chemical composition of AISI 304 Stainless Steel is listed in Table 1.

Table 1. Chemical composition of AISI 304 SS

Component	C	Mn	P	S	Si	Cr	Ni
Weight. %	0.08	2	0.045	0.03	1.0	18-20	8-10.5

3.2 Experimental parameter

MIG welding process parameters are listed in Table 2.

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

Table 2. MIG welding process parameters

Parameters	Units	Code	Level-1	Level-2	Level-3

WeldingVoltage	volts	A	26	25	24
WeldingCurrent	amps	B	140	130	120
Welding Speed	mm/min	C	110	100	90

3.3Taguchi Methodology

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

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

3.4 Experimental Work

Tensile specimens were prepared with help of Electric Discharge Machine as per ASTM standards shown in Figure 2. Hardness of weld zone recorded using Vickers hardness (HV), 200gr load, and dwelling time of 10 sec. were measured by using, MVD-402TS-Level-2 micro hardness measuring system HNDS Kelly Instruments, china Expert.MIG welding is done, the arc and weld pool is shielded from the atmospheric contamination by an externally supplied shield gas (CO_2) and welding specifications listed in Table 3.The MIG welding setup and welded component is shown in Figure 4 (a), (b) and the specimen is shown in Fig5.

Table 3. Specifications of MIG Welding Machine

Item	*Description*
Model	SB-10
Rated welding current	350A/500A
Feeding voltage of motor	DC 24V
Rated drawing force	100N
Wire feeding speed	1.5-15 m/min
Cable length	3m
Wire type	Soft steel solid core, flux cored

Fig-4: (a). MIG welding setup, (b). Welded component.

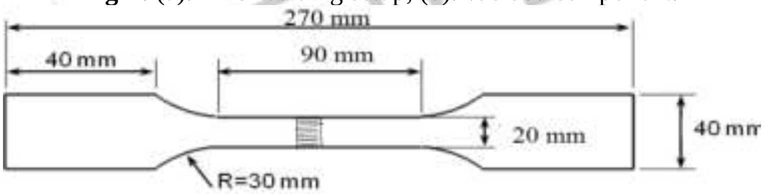

Fig-5: Tensile test specimen dimensions

Tensile test was carried out by using SM 1000-S3 UTM TQ228687-001, Tec Quipment Ltd., UK

4 *RESULTS ANDDISCUSSIONS*

Experiments were conducted to join the AISI 304 stainless steel by MIG welding technique, total experiments were conducted based on the Taguchi method. Moreover, the experimental results obtained by considering L_{27} orthogonal array matrix. The response averages of Tensile strength, Percentage of Elongation and Hardness were exhibited via S/N ratios.

The results are blocked in terms graphs and have been shown in Figure 6, 7and 8. The X-axis represents Welding voltage for (a), Welding current for (b) and Welding speed for (c), it is common for all figures such as 6, 7 and 8. Only Y-axis is varying for figure 6, 7 and 8 as referred as Tensile strength for Fig. 6, Percent of elongation for Fig. 7and Hardness for Fig. 8respectively.

A. S/N Ratio Average Values for TensileStrength

In Fig. 6, S/N ratio of tensile strength clears that, the welding voltage is the more influential parameter followed by welding current and welding speed on MIG welding of AISI 304 SS.

Table 4. Numerical representation of Responses for S/N ratio average

Parameter / S/N Ratios	Welding Voltage	Welding Current	Welding Speed
S/N Ratio Level 1	**53.37**	**53.64**	**53.59**
S/N Ratio Level 2	**53.90**	53.56	**53.52**
S/N Ratio Level 3	53.40	**53.48**	53.56
Delta = S/N (Max)-S/N (Min)	0.53	0.16	0.07
Rank	**1**	**2**	**3**

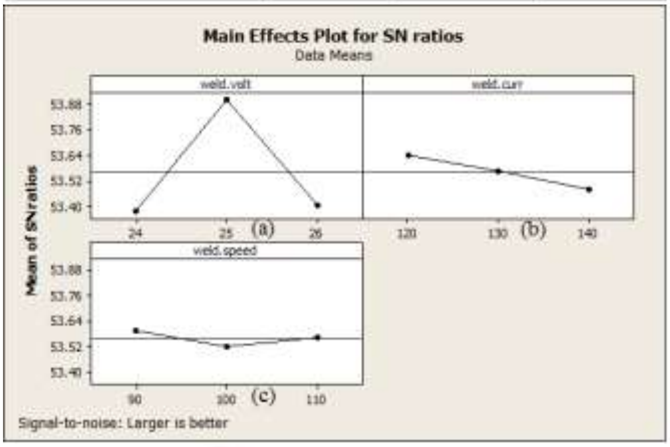

Fig-6: Variation of mean of S/N ratios Vs tensile strength

B. S/N Ratio Average Values for Percentage ofElongation

In Fig. 7, S/N ratio of tensile strength clears that, the Welding speed is more influencing parameter followed by Welding voltage and Welding current on MIG welding of AISI 304SS.

Table 5. Numerical representation of Response for mean of percentage of Elongation

Parameter / Mean	Welding Voltage	Welding Current	Welding Speed
Mean level 1	**33.67**	**32.23**	31.67
Mean Level 2	**30.56**	32.44	**35.11**
Mean Level 3	33.00	**32.56**	**30.44**
Delta = S/N (Max)-S/N (Min)	3.11	0.33	4.67
Rank	2	3	1

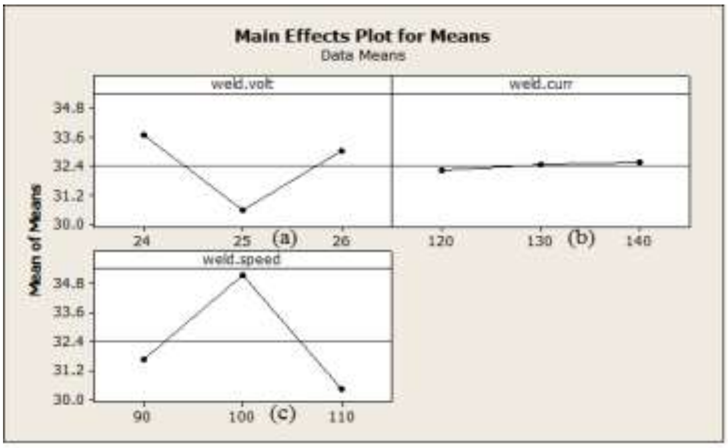

Fig-7: Variation of mean of S/N ratio Vs Percentage elongation

C. N Ratio Average Values forHardness

In Fig.8, S/N ratio of tensile strength clears that, the Welding speed is more influencing parameter followed by Welding voltage is the more influencing parameter followed by Welding speed and Welding current on MIG welding of AISI 304 SS.

Table 6. Numerical representation of Response for S/N ratio average

Parameter / S/N Ratios	Welding Voltage	Welding Current	Welding Speed
S/N Ratio Level 1	**45.78**	**45.67**	**45.58**
S/N Ratio Level 2	**45.40**	45.63	45.60
S/N Ratio Level 3	45.73	**45.60**	**45.71**
Delta = S/N (Max)-S/N (Min)	0.38	0.07	0.13
Rank	**1**	**3**	**2**

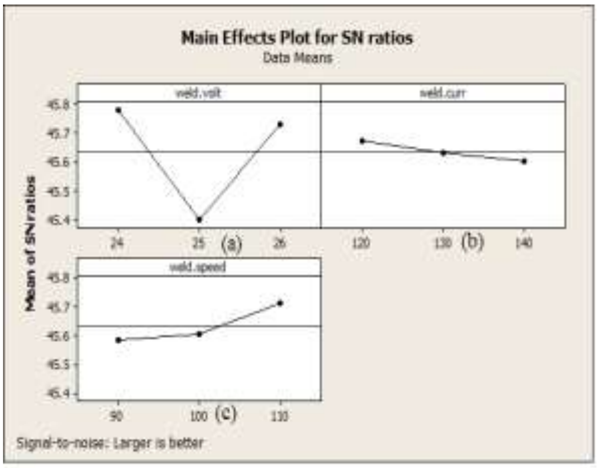

Fig-8: Response for mean of Hardness

D. Experimental (Exp.) and Predicted Values from FuzzyModel

Though the experiments conducted for 27 runs, but considered only 9 with 3 runs intervals for simplicity. From the figure 9, it can be seen that the graph for experimental and predicted values have been increased up to the end of Exp. 5 then the same trend is observed from experiment No.6. From the Exp. 9, again it was raised and continued for 18 run and then again there is a sudden falling at Exp. 21 until Exp. 27 but not like Exp.6 can beobserved.

Further, it can be seen that the graph for two results follow the same path. Thus trend shows that the experimental and modeling results are in correlation and therefore it can be said the experiments conducted are found to be correct.

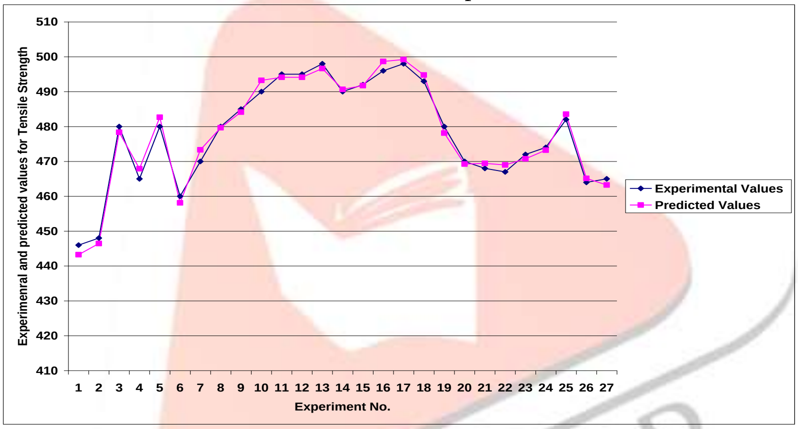

Fig-9: Comparison of Experimental results and predicted results for Tensile strength

From the figure 10, it can be seen that the graph for experimental and predicted values show that the increasing trend at the beginning and then drastically decreased at Exp. 15. Then the same trend is observed from experiment No.15 and till Exp. 27.Further, it can be seen that the graph for two results follow the space path. Thus trend shows that the experimental and modelling results are in correlation and therefore it can be said the experiments conducted are found to be correct.

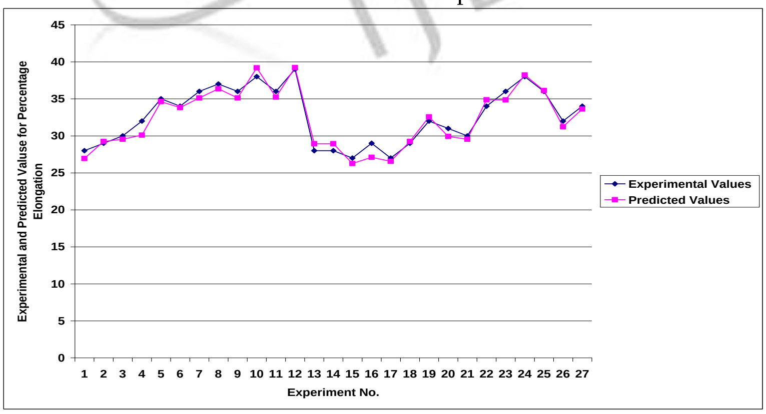

Fig-10: Comparison of Experimental results and predicted results for Percentage elongation

From the figure 11, it can be seen that the graph for experimental and predicted values show that the increasing trend at the beginning and then decreasing Exp. 9. Then continued until beginning of Exp. 18. Further, it can be seen that the two results follow the space path. The trend is also exhibited abnormal pattern, observed from Exp. 3 till experiment No.27. But the difference is not much considerable. Thus trend shows that the experimental and modeling results are in correlation and therefore it can be said the experiments conducted are found to be correct.

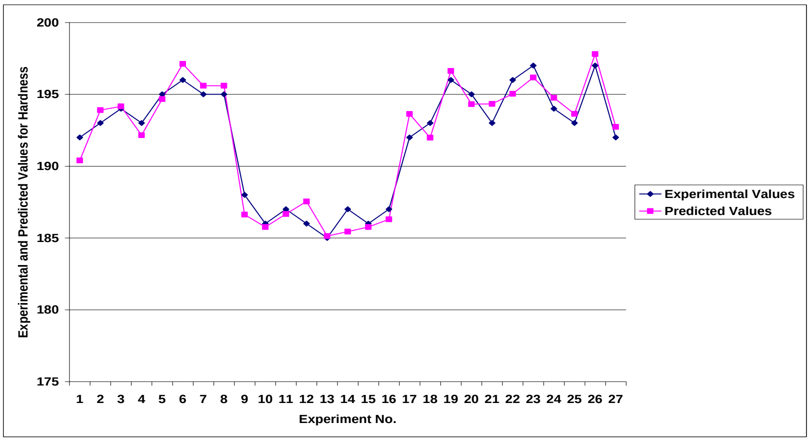

Fig-11: Comparison of Experimental results and predicted results for Hardness

CONCLUSION

The following conclusions are drawn from results of performance characteristics:

- ✓ The welding voltage has exerted the greatest effect on Tensile strength followed by welding current and welding speed.
- ✓ The welding speed has exerted the greatest effect on Percentage of elongation followed by welding voltage and welding current.
- ✓ The welding voltage has exerted the greatest effect on Hardness followed by welding speed and welding current.

The predicted value agree fairly well with the experimental value for Tensile strength, Percentage of elongation and Hardness due to the Fuzzy representation of Tensile strength, Percentage of elongation and Hardness of the predicted values can be obtained well.

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