Parametric Optimization of MIG Welding for Tensile Strength and Surface Roughness

Shailendra Agrawal[1], Pink Raj[2], Santosh Kumar Yadav[3], Adarsh Kumar[4]
[1]M.Tech Scholar, [2,3,4]Assistant Professor
Department of Mechanical Engineering,
[1]Bansal Institute of Engineering & Technology, Lucknow

Abstract: MIG welding techniques are widely used in industries for joining of metal pieces in an inert gas environment using a wire electrode. The wire electrode is constantly fed for producing arc and acts as filler metal for the weld pool. This study is carried out for optimization of MIG welding parameters for AISI 1020 Mild Steel. The input parameters reserved for this study are the welding voltage(V), welding current (I), welding speed(WS), and the data is collected through experimentation. The output responses such as Tensile Strength and surface roughness (SR) have been considered for analysis. Taguchi L9 design is employed to conduct the experiments, ANOVA is used for calculating the effects of input process parameters. From the experimental results, it is analyzed that welding voltage is the main affecting parameter for tensile strength while welding speed is least influencing for it and for the surface roughness, welding speed has major dominance while other parameters were less effective.

***Keywords* - MIG welding, ANOVA, Tensile Strength, Taguchi, AISI 1020.**

I. Introduction and Literature Survey

Throughout the world, welding is a major fabrication technology that is used extensively for the construction of structures, buildings and bridges and in the civil, automotive, aircraft, aerospace, petroleum, shipbuilding, electronic industries. During last several years, it has evolved as an interdisciplinary activity that requires mixture of knowledge from different disciplines and incorporates the most advanced equipment's of various basic applied sciences and engineering. Researchers from different fields such as arc and plasma physics, manufacturing, transport phenomena, modelling, robotics, and from various engineering fields that includes mechanical, and electrical engineering are currently making new innovations. Considering some major industries, notably automobile, welding is completed primarily by the assistance of robots or automated assemblies. Moreover, in other industries like marine where substantial equipment production and little elements fabrication is done, welding is largely done by a manual process done by human operators. Skill training of fresh welders is an important activity both for industries and for the vocational institutions. Training is majorly important for welders who are working on critical items like pressure vessels, naval ships, etc. where welding requires carefully inspection.

The advantage of welding is that, it is the most economical technique of joining components in terms of material usage as well as fabrication costs. Present time the Steel parts are now replaced with aluminum alloys in many industries as their lightweight, easy fabrication and machinability, good corrosion resistance and other superior properties are achieved as compared to steel. Considering the joining method for those industrial fields, welding is the best suited and easy application method. When the welding of steel alloys is considered, the costs are playing a vital role, hence, TIG welding and MIG welding techniques are majorly used. GMAW technique, which metal inert gas welding (MIG) is the subsystem, is the most cost-efficient method used in industries. Hence for most of the applications, MIG welding is used for joining steel alloys. Although it incorporates several defects during MIG welding such as porosities, hot cracking and so, related with some properties of particularly heat treatable mild steels, these can be reduced by controlling welding parameters and choosing correct filler materials. Although, due to the nature of welding, strength loss can be observed after welding. After welding, the main strength loss is observed in the heat affected zone and in vicinity. The strength at least in annealed condition of metal can be enough after welding, barely, the places of use are not always allowing this situation. During welding process, there are different parameters that are needed to be considered so as to obtain the objective characteristic of welding quality. To achieve a perfect arc all the parameters must be in conformity. In MIG welding technique, there are several important factors that are needed to be concern. These process parameters are generally arc voltage, welding current, weld speed, wire feed speed, weld direction, electrode extension, nozzle distance, position of welding, free wire length, and gas flow rate. Many researchers carried out researches in the field of MIG welding some of them are as follows. **Mahesh et al** [1] analyzed that with increase in the levels of parameters for MIG welding of AISI 1050, the strength of welded joint is enhanced and all the selected parameters have focus on the strength of the joint. **Singla et al** [2] found that the Welding current was most affecting variable to WDA. When a steady heat input is provided, and the welds are prepared using electrode negative polarity having a small diameter electrode and low voltage with low welding speed, it produces large bead area. **Sharma et al [3]** analyzed that Tensile strength of weld increase in proportion to the weld width, because of the higher MIG parameters and observe wider weld head during the construction weld bead hardness. Hardness values are similar in both of them. **Sivakumar et al. [4]** investigated different factors on welding penetration, and calculated the hardness of mild steel, 6mm thickness by using MIG welding. **Abbasi [5]** founded penetration depth boost with increase in speed up to an optimal value of 1450 mm/min, after that penetration starts decreasing. These researchers also found that when the heat input is considered, the depth of penetration will increase with heat input till 109 J/min. beyond this value, the penetration depth will decrease. **Valluru et al [6]** in their investigation reveals that Weld Region Hardness is higher than parent metal hardness and less than HAZ Hardness. **Mishra et al. [7]** employed Taguchi technique to plan the array of experiments and they conducted the conformations tests for getting the differentiate between the actual and predicated values so as to examine the effectiveness during the analysis of penetration.

II. Experimental setup and data collection

ESAB MIGMATIC MIG welding machine is used for welding purpose. The material pieces used for the experimental work is Mild Steel AISI 1020 with specification of (100 x 30 x 5mm), the compositions of AISI 1020 are Fe; 98%, Mn; 0.50%, C; 0.23%, P; 0.40%, S; 0.50%.

The input parameters taken into considerations are welding voltage(V), welding current(I) and welding speed(WS). Three levels are selected Low, medium, high levels as given in Table 1. Taguchi L9 design is adopted for creating design of matrix, for each experiment data is measured as shown in Table 2.

Table 1. Process Parameters and their levels

S.No.	Parameters	Units	Level 1	Level 2	Level 3
1	Welding Voltage (V)	V	16	20	24
2	Welding Current (I)	A	100	150	200
3	Welding Speed (W.S)	mm/sec	5	10	15

Table 2. Design of matrix and output responses

EXP NO.	Welding Voltage(V)	Welding Current(I)	Welding Speed (W.S)	Tensile Strength (T.S) N/mm^2	Surface Roughness (S.R) µm
1	16	100	5	10.42	3.71
2	16	150	10	11.1	1.52
3	16	200	15	11.5	1.78
4	20	100	10	11.87	1.23
5	20	150	15	12.45	2.59
6	20	200	5	13.13	3.68
7	24	100	15	13.97	2.41
8	24	150	2	15.1	2.79
9	24	200	10	15.97	3.93

Tensile Strength is calculated by using the formula :

$$\textit{Tensile Strength} = \frac{\textit{Maximum tensile load}}{\textit{Area subjected to tensile load}}$$

III. Results and Discussion

Optimal parameters settings are find using Taguchi techniques. In the Taguchi technique, the term 'signal' represents the required value (mean) for the output characteristic and therefore the term 'noise' represents the undesirable value (standard Deviation) for the output characteristic. The S/N ratio primarily depends upon the standard attributes of the method to be optimized. Generally, there are three categories of performance attributes for the investigation of the S/N ratio; they are the lower is better, the nominal is better, and the higher is better. S/N ratio for each response is typically computed differently as per the classification of the execution attributes and so no matter the class the larger S/N ratio will relate to better process performance characteristic.

Calculation of S/N ratio:

To obtain optimal welding performance, higher-the better-quality characteristic for tensile strength and lower-the better-quality for surface roughness must be taken. The equation for the calculation of S/N ratio is:

For Tensile Strength (larger the better): **S/NLB = -10 log (Σ (1/yi ²))**

For Surface Roughness is (Smaller the better): **S/NSB = -10 log ((1/n) Σ yi ²)**

The Signal noise ratio for Tensile Strength and Surface Roughness is given as Table 3.

Table 3. S/N ratio for Tensile Strength and Surface Roughness

Experiment No.	Tensile Strength (T.S)	S/N ratio for Tensile Strength	Surface Roughness (S.R) µm	S/N ratio for Surface Roughness
1	10.42	20.3574	3.71	-11.3875
2	11.1	20.9065	1.52	-3.6369
3	11.5	21.214	1.78	-5.0084
4	11.87	21.489	1.23	-1.7981
5	12.45	21.9034	2.59	-8.2660
6	13.13	22.3653	3.68	-11.3170
7	13.97	22.9039	2.41	-7.6403
8	15.1	23.5795	2.79	-8.9121
9	15.97	24.0661	3.93	-11.8879

Calculation of Mean S/N ratio:

Mean S/N ratio is determining by using the given formula: $nf_i = (nf_1+nf_2+nf_3)/3$

Where nf is mean S/N ratio for factor f at the level value i of the chosen factor. nf_1, nf_2, nf_3 are S/N ratio for factor f at level u. The factors which affect the machining parameters show in the board as their respective ranks. Rank of the parameters relies upon the value of delta. If the delta estimation of one parameter is more than the other that shows first rank. Higher estimation of S/N proportion of each factor shows the ideal level of the factor. Welding voltage demonstrates the primary impact in the below response table followed by welding current. Weld speed is least effective as compared to other parameters.

Table 4. Means of S/N ratio

Responses	Level	Welding Voltage (V)	Welding Current (I)	Welding Speed (W.S)
Tensile Strength	1	20.83	21.58	22.10
	2	21.92	22.13	22.15
	3	23.52	22.55	22.01
	Delta	2.69	0.97	0.15
	Rank	1	2	3
Surface Roughness	1	-6.678	-6.942	-10.539
	2	-7.127	-6.938	-5.774
	3	-9.480	-9.404	-6.972
	Delta	2.803	2.466	4.765
	Rank	2	3	1

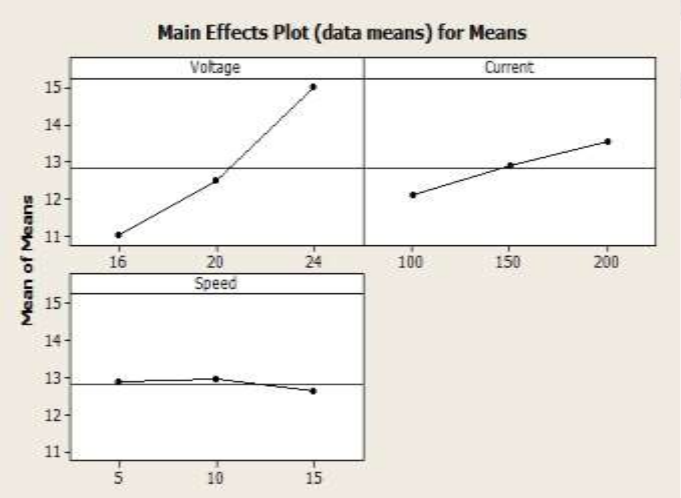


Fig.1. Main effects plot for Tensile Strength

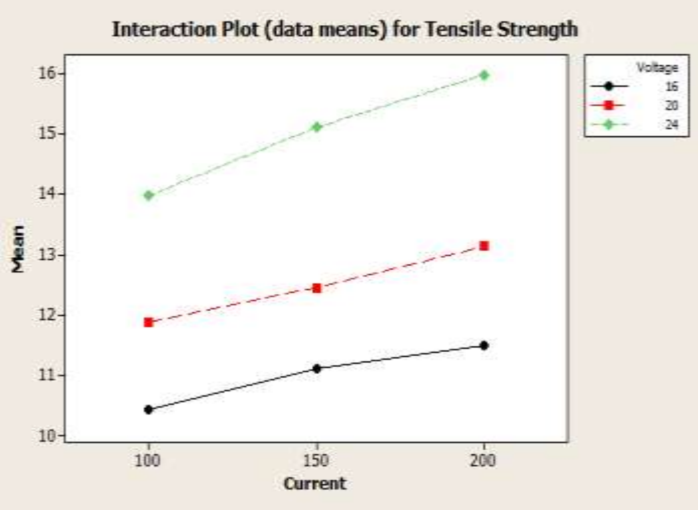
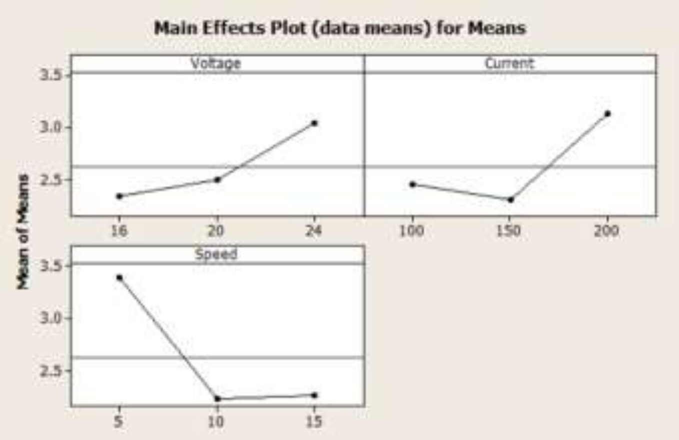


Fig. 2. Interaction plot for parameters and Tensile Strength

Fig.1. demonstrates that the Tensile Strength increases with both welding voltage and welding current and welding speed not much influence on Tensile Strength. Fig.2. depicts the interaction plot between tensile strength and welding current at various levels of welding voltage. The plot shows that the Tensile Strength increases with welding current at each level of welding voltage.



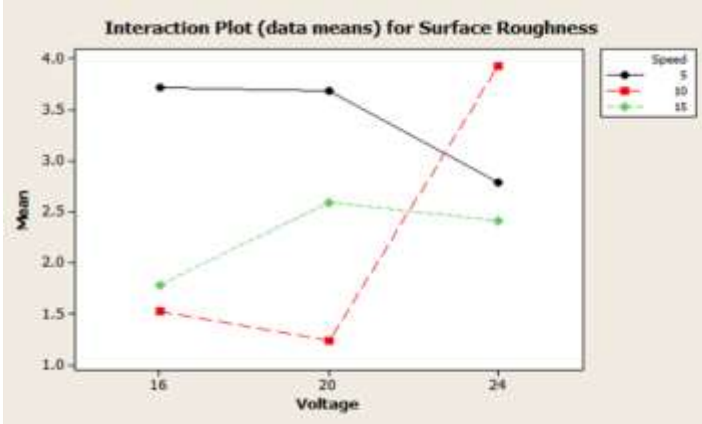


Fig.3. Main effects plot for Surface Roughness

Fig.4. Interaction plot for parameters and Surface Roughness

Fig.3. illustrates that if we increase the level of welding voltage poor surface finish is obtained. For welding current, the surface finish initially improves enhances yet with additionally increment in the benefit of welding current the surface gets degraded. Welding speed is the most dominating parameter for surface roughness of MIG welded joint for the present set of parameters. Fig.4. shows the interaction plot between surface roughness and welding voltage at various levels of welding speed. It depicts that at lower level of welding speed, the surface roughness is higher. When the welding voltage value is increased at lower level of speed, the surface roughness gets improved.

Optimal parameters settings obtained from the Taguchi analysis, for Tensile Strength: wielding voltage (V); 24V, welding current; 200A, welding speed; 10 mm/sec, and for the Surface Roughness the optimum parameters settings are: wielding voltage (V); 16V, welding current; 150A, welding speed; 10 mm/sec.

Analysis of Variance:

ANOVA conducted on MINITAB 16.0. The outcome demonstrates that the most influencing parameter for Tensile Strength is welding voltage and for Surface Roughness the most influencing parameter is welding current.

Table 5. ANOVA analysis for Responses

Responses	Parameters	DOF	SS	Adj. MS	F Value	Contribution
Tensile Strength	Welding Voltage	2	24.6348	12.3174	357.95	87.86%
	Welding Current	2	3.1500	1.5750	45.77	11.23%
	Welding Speed	2	0.1842	0.0921	2.68	0.65%
	Error	2	0.0688	0.0344		0.26%
	Total	8	28.0378			100%
Surface Roughness	Welding Voltage	2	0.821	0.411	0.25	10.32%
	Welding Current	2	1.174	0.587	0.35	14.77%
	Welding Speed	2	2.647	1.323	0.80	33.29%
	Error	2	3.307	1.654		41.62%
	Total	8	7.949			100%

Confirmation Test:

Confirmation tests have been performed for Tensile Strength and Surface Roughness with their optimum levels of process variables. On the taking the optimum parameters value for Tensile Strength the results come out 15.97 N/mm^2 which is near to the expected value 16.21 N/mm^2 and on the tanking the optimum parameters for Surface Roughness the results come out 1.52 µm which is near to 1.64 µm.

IV. Conclusion

It is concluded that the Tensile Strength increase with welding voltage and welding current, and welding voltage have main contribution (87.86%) for Tensile Strength. For Surface Roughness welding speed is the major impacting parameter with a commitment of 33.29%**.** As we increment the level of welding voltage poor surface finish is obtained. For welding current, the surface roughness initially improves but with further increase in the value of welding current the surface gets degraded. The surface roughness first reduces with increment in the value of welding speed. But on further increase in level of welding speed above 10 mm/sec, the surface roughness slightly increases. From the S/N ratio analysis the optimal parameters settings obtained for Tensile Strength are: wielding voltage (V); 24V, welding current; 200A, welding speed; 10 mm/sec, and for the Surface Roughness the optimum parameters settings are: wielding voltage (V); 16V, welding current; 150A, welding speed; 10 mm/sec.

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