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Experimental Investigation of Welding Parameters on Mild Steel Using Metal Active Gas Welding

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Abstract

Gas shielded welding is a widely applied fabrication processes in manufacturing industry. The present study will elucidate on an investigative approach to find the mechanical properties, influenced by several input parameters like welding current, voltage and wire spool speed in the Metal Active Gas Welding (MAG) of Mild Steel. Taguchi's L9 orthogonal array has been employed to analyse the process parameters. The levels of consequences of input parameters were investigated by applying analysis of variance (ANOVA). The microstructural orientations and mechanical properties of weld specimen are explored in this work. Welding current is an influential parameter to control tensile strength followed by welding voltage and federate of electrode. Furthermore, hardness of weld material has a greater effect of voltage including wire speed and current.

Keywords: *Manufacturing, Metal Active Gas, Shielded Welding, Welding Current*

1.0 Introduction

Metal active gas welding is a widely used process of welding where consumable electrode wire is supplied from an automated spool. Automatically supplied wire consumes and deposited to produce the weld joint. The weld zone is protected by the inert or gas mixture gases to prevent oxidation. A continuous feed filler wire (consumable) electrode and the work piece form an arc as part of the MIG/MAG welding process. Automatically fed from the machine, the electrode exits the MIG/MAG gun's contact point after passing through a liner. A flow of an inert gas, or gas mixture, shields the metal weld from the atmosphere. A proper arc length is maintained during normal operation by the operator. The standard procedure of parametric approach of Taguchi Method were employed for designing the experiment to analyze the data. The average values of the response attributes for every parameter at different intensity are computed from experimental findings. Final responses of influences of process parameters were plotted, and corresponding response curves are investigated. The effect on the response attributes were studied by the analysis of variance (ANOVA) of raw data. The optimum parameters in terms of mean response attributes is determined by scrutinizing the response curves and the ANOVA Tables. Ramarao *et al.*[1] studied impact strength of dissimilar joining of alloy steel SA387 and optimized welding process parameters like welding current, voltage with varying bevel angles. Radhakrishnan *et al.*[2] applied Taguchi method in an optimization study of mechanical properties after varying the process parameters in welding. The impact of welding of Aluminium 6061 – T6 metal. Timothy *et al.*[3] conducted an ooptimization study of gas metal arc welding of titanium-reinforced mild steel sheets. V. Subravel *et al.*[4] elucidate the effects

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of process variables on some mechanical microstructural characteristics of pulsed GTAW joints and reported the change in tensile strength with varying welding speed. V. Kanwal[5] illustrated the consequences of welding current on hardness of welding joint. B. Mishra, *et al*.[6] explained the change in mechanical properties in ferrous and nonferrous metals with varying process parameters. Subodh Kumar *et al.*[7] concluded the lower heat input gives better tensile strength and reduced HAZ in 304 stainless steel joint in GTAW. Based on the recommendation of Chuaiphana *et al.*[8], optimum welding speed of 3.5 mm/s for AISI 201 to be maintained to achieve best mechanical and corrosion resistance properties in GTAW. Juang, S.C.[9] has investigated on the geometry of the weld pool by varying the TIG welding parameters using stainless steel. Ghosh *et al.*[10] concluded that applying Taguchi method is an efficient process for designing of experiments and analyzing the parameters in metal inert gas welding of AISI 409. In the work of Ibrahim *et al.*[11] welding on thick plates has been performed to understand temperature behaviour. The review reveals that the balance of welding parameters results in a quality weld and therefore the investigation has been performed in this study. The present study deliberates on the influences of various input process parameters on the strength and hardness of the weld performed on mild steel in case of metal active gas welding.

2.0 Methodology

In 20th century the breakthrough approach in quality engineering presented by Genichi Taguchi[12]. This method mainly focuses of effective employment of engineering approach rather stats-based methodology. It converges both upstream and shop-floor quality engineering. In case of small-scale cases upstream methods, efficiently reduce inconstancy, and favours robust designs for large-scale production. Shop-floor techniques yield cost-based, real-time methods for scrutiny and provide quality during production. The philosophy of Genichi Taguchi has the following fundamental notions:

Quality needs to be implemented during design of product not in inspection.

Minimizing the anomaly from the target is the key of quality. The product or process variables needs to be selected as such it takes care of uncontrollable environmental attributes.

The deviation from standard is the measure of cost of quality whereas losses are should be system-wide. The measured variance in a given variable into parts that can be attributed to several sources of variation. The effectiveness of the model is examined using the analysis of variance technique. The phrase "signal" stands for the preferred mean value, whereas the term "noise" stands for the unwanted value. The degree of variance existing in the performance characteristics is thus represented by the S/N ratio.

2.1 Experimental Design Approach

Orthogonal Arrays (OA) for laying out of experiments were applied as per Taguchi concept. These orthogonal arrays are generalized Graeco-Latin squares. Selecting the best suited orthogonal array is principal of design of experiment and selecting parameters and results in the appropriate columns.

The following objectives may be achieved by analysing the experimental results in Taguchi method:

- To estimate the optimal conditions for the product and processes.
- To measure the influences of individual process parameters.
- To measure the optimized output criteria.

By examining each parameter's influence, the ideal situation is found. The effects show each parameter's overall direction of impact. The type of control to be put on a manufacturing process depends on the understanding of the contribution of each individual parameter. The statistical procedure most frequently used to analyse experimental results to ascertain the current contribution of every parameter to a certain degree of confidence is the analysis of variance. To identify the parameters that require control, an analysis's ANOVA table can be studied.

2.2 Experimental Observations

100x100x5 mm size sample of mild steel has been welded. Total 9 experiments have been performed on the basis of L9 orthogonal array technique of Taguchi Methodology. Voltage, current and wire feed rate are chosen as input process parameters variable whereas micro hardness of

Table 1. L9 Orthogonal Array Design Matrix

Experiment no.	Welding Voltage (Volt)	Welding Current (Amp)	Wire feed rate (m/min)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 2. L9 Matrix with Actual Value of Parameters

Experiment no.	Welding Voltage (Volt)	Welding Current (Amp)	Wire feed rate (m/min)
1	20	160	2
2	20	170	4
3	20	180	6
4	30	160	4
5	30	170	6
6	30	180	2
7	40	160	6
8	40	170	2
9	40	180	4

Table 3. Experimental observations

Experiment no.	Welding Voltage	Welding Current	Wire feed rate	Hardness at WZ	Tensile Strength
1	20	160	2	169.45	384.43
2	20	170	4	167.91	394.69
3	20	180	6	183.29	390.83
4	30	160	4	201.62	389.73
5	30	170	6	205.24	399.25
6	30	180	2	182.5	402.15
7	40	160	6	194.39	383.27
8	40	170	2	161.48	398.19
9	40	180	4	172.85	395.52

Figure 1. Sample View of MAG welded mild steel

welded zone and Tensile strength are selected as output parameters at different levels are used.

Welded samples are further used for observations and for that samples are measured for Tensile strength by UTS machine and for micro hardness by Vickers hardness tester. Trial and error were employed to fine-tune the welding parameter's working ranges, and the satisfying results were used to carry out the experimental work. Table 1 details the 3 variables with 3 different levels of input parameters which is employed to form L9 orthogonal array and the experimental values of selected input parameters are presented in Table 2.

Based on L9 array total nine observations were taken. The impact of selected process parameters such as welding current, arc voltage and wire feed rate are analyzed. Table 3 details the measured value of strength in tension and hardness with their S/N ratios for all the samples. Figure 1 shows photograph of welded sample.

To measure the Microhardness the samples are prepared by finishing the samples using emery paper of various size numbers. Further, Vickers micro-harnesses numbers has been measured.

3.0 Results and Discussions

From Figure 2, it is observed that hardness of weld zone is increased up to second level of arc voltage whereas decreases with increase in welding current and linearly increases with increase in wire feed rate.

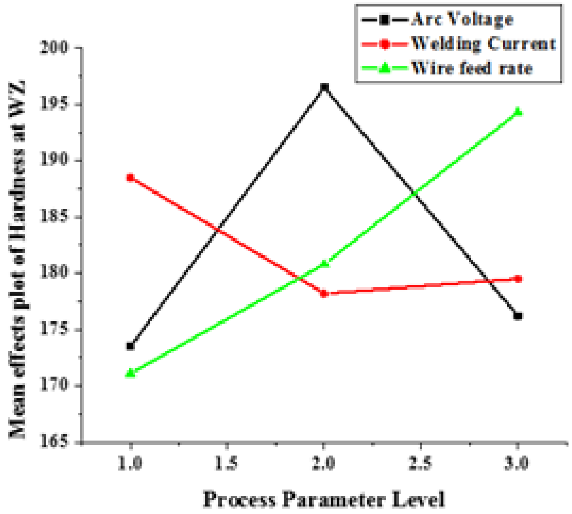

Figure 2. Variation of process parameters and Hardness.

Table 4. ANOVA for Means for Hardness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Welding Voltage	2	940.38	940.378	470.189	745.14	0.001
Welding Current	2	187.32	187.320	93.660	148.43	0.007
Wire Feed Rate	2	812.27	812.273	406.136	643.63	0.002
Residual Error	2	1.26	1.262	0.631	-	-
Total	8	1941.23	-	-	-	-

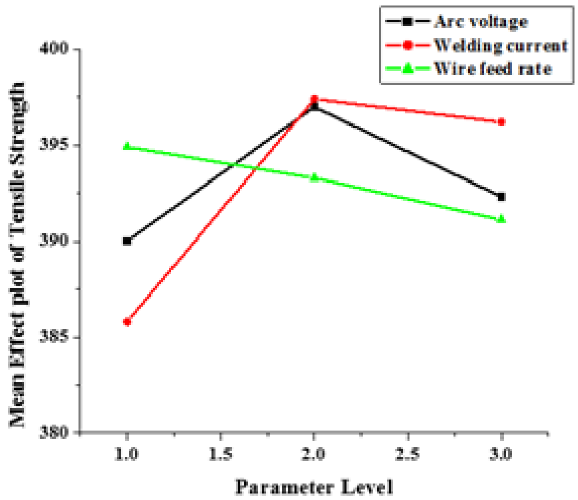

Figure 3. Variation of process parameters on tensile strength S/N ratio.

But further increase in welding current may help to change microstructure during weld metal solidification and such marginal increase in hardness observed. On the other hand, with increase in arc voltage increases due to lesser embitterment with decreased cooling rate may be the reason observed phenomenon whereas further increase in arc voltage results in wider weld bed with less penetration. Thus, low hardness may be achieved. As the penetration mostly depends on wire feed rate linearly the phenomenon observed. One of most popular technique for statistically analyzing quantitative data is analysis of variance (ANOVA). The ANOVA test has been run for the result at a 95% confidence level to assess the relative significances of the joining process factors taken into consideration during experimentation. The percentage contribution column in the ANOVA result Table 4, shows how much each process parameter has an impact on the machining characteristics. It is observed from Table 4 that all the process parameters are statistically noteworthy over machining response. The r square value indicates at the feasibility of the adopted design for performing experimental study. It is found that the welding arc voltage is the most striking factor that influences the hardness maximum followed by wire feed rate and then welding current with percent contribution of 48.54, 41.83 and 9.6 ratio respectively.

Figure 3 indicates that tensile strength primarily increases with increase in arc voltage and welding current whereas tensile strength is marginally, decrease with increase wire feed rate.

As voltage and weld current increases, the energy density at weld spot is unique and chances of proper bonding of weld metals in very high, results in increase in tensile strength. Whenever the voltage or current flow is increased the chances of volatile energy density at weld zone is very high, thus tensile strength is marginally decreased. Increase in wire feed rate results in non-uniform electrode deposition on weld zone during MAG welding. Due to the said fact tensile strength is decreased slightly. It is observed from Table 5 that all the process parameters are statistically significant at 95% confidence level and welding current is the most noteworthy factor which effects tensile strength maximum with percent contribution of 70.84% followed by arc voltage with percent contribution of 22.46% then Wire feed rate with percent contribution of 6.40%.

Table 5. ANOVA for Means for tensile Strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Welding Voltage	2	77.582	77.582	38.791	242.43	0.004
Welding Current	2	242.512	242.512	121.256	757.80	0.001
Wire Feed Rate	2	21.908	21.908	10.954	68.46	0.014
Residual Error	2	0.320	0.320	0.160	-	-
Total	8	342.322	-	-	-	-

Table 6. Optimization responses

Machining attributes	Optimal parametric settings	Optimal value
Hardness at WZ	A2B1C3	215.084
Tensile Strength	A2B2C1	403.108

The optimized design parameters that are chosen from the S/N ratio graph are Welding Voltage 30 V Welding Current 160 amps and Wire feed rate 6 m/min, for obtaining higher Hardness and for Tensile Strength the parametric settings become Welding Voltage 30 V Welding Current 170 amps and Wire feed rate 2 m/min. Hardness at WZ is higher the better quality. Tensile Strength is also higher the better quality. Single objective optimization results are listed in Table 6.

4.0 Conclusions

The present study gives the insight understanding of welding process parameters on the strength of weld in case of metal active gas welding performed on mild steel sample. ANOVA analysis confers that welding current is the influencing parameter that affects tensile strength of the weld whereas voltage is the responsible parameter for hardness of the weld. In this present study, second level of voltage (30 volt), first level of current (160 amp), and third level of wire feed rate (6 m/min) gives the higher hardness. Accordingly, optimum condition of input parameters is A2B1C3 is recommended. Microstructure study of weld has shown a fine grain of ferrite and pearlite.

5.0 References

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