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Experimental Analysis and Optimization of A-MIG Welding Process for Hardness of SS 316 by Taguchi Method

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Abstract: ***The MIG welding is leading in the development in an arc welding process due to its high productivity, low cost and good in quality. The present work is planned to investigate and optimize the effect of different parameters such as current, gas flow rate and flux on hardness of Stainless Steel 316. In this research work the Taguchi L9 orthogonal array is used to optimize hardness. ANOVA (Analysis of Variance) is used to determine most significant input parameter in experiment. The effect of individual parameters on hardness is also investigated. In this design of experiment the three factors with three levels current (120,150,180A), gas flow rate (12, 14, 16 Lit/min) and flux (SiO_2, ZnO, Al_2O_3) are consider for experiment. The ANOVA results shows the welding current is the most significant parameter followed by gas flow rate and flux which influence hardness.***
Keywords: Gas Metal Arc Welding (GMAW), Taguchi Method, Hardness, Activated Flux, Signal to Noise Ratio (S/N Ratio), Analysis of Variance (ANOVA).

I. INTRODUCTION

MIG (Metal Inert Gas) welding is the most widely used welding process in industry and also known as GMAW (Gas Metal Arc Welding). It is suitable for ferrous and non-ferrous material. In MIG welding process, it generates electric arc by using power supply between consumable electrode and workpiece. The different types of shielding gases used in Metal Inert Gas welding are carbon-di-oxide, argon, helium along with different mixture proportion is considered depending on material composition. Basically quality and performance of MIG welding process is always rely on the number of welding parameters like welding current, welding voltage, welding speed, gas flow rate, nozzle distance, types of shielding gas, electrode angle etc.

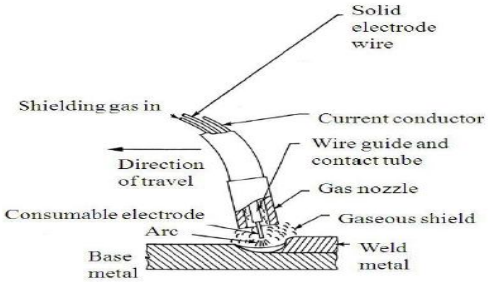


Fig.1: Mechanism of MIG welding

II. LITERATURE REVIEW

D.Bahar et al. studied the effect of Metal Inert Gas Welding process parameters for Micro-hardness and Tensile strength by using Grey relational analysis. The Stainless Steel (SS 316) and Mild Steel (MS1020) two dissimilar material was taken for this work with L16 orthogonal array is constructed. The ANOVA shows GFR has most influence on hardness and ultimate tensile strength. In multi response optimization for hardness as well as ultimate tensile strength contribution factor of welding speed is higher followed by wire feed rate, GFR and welding voltage [1].

Sandip Shelar et al. investigated and optimize the effect of activated MIG welding process by using Taguchi method on Fe 410 Mild Steel Weld. In present work effect of welding current, flux and gas flow rate on UTS and Hardness by using flux powder such as $MgCO_3$, Fe_2O_3 and mixture of both flux powder in 50%-50% proportion is used. In DOE (Deign of Experiment) Taguchi L9 OA is constructed and ANOVA is used to calculate percentage contribution factor for each input [2].

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Izzatul Aini Ibrahim et al. studied the Gas Metal Arc Welding (GMAW) processes and effects of different welding parameters on it. The welding current, welding voltage and welding speed are taken as a input parameters while depth of penetration and hardness are considered as a output parameters. As a results show the depth of penetration (DOP) is increased by increasing welding current. The maximum penetration get at current of 210A, voltage of 26V and welding speed of 60cm/min. In hardness, the higher value of hardness is at current of 90A, voltage of 26V and 60cm/min [3].

Her-Yueh Huang studied the effect of activating flux powder on the welded joint in Metal Inert Gas (MIG) welding process by using Taguchi method. In this work, three kinds of flux powder (Fe_2O_3, SiO_2, $MgCO_3$) were used to evaluate and optimize effect of this fluxes on mechanical properties in AISI 1020 Carbon Steel. The experimental results shows, $MgCO_3$ flux gives the noticeable effect on penetration as well as hardness and reduces angular distortion in the welding area [4].

III.EXPERIMENTAL PLAN, SETUP AND PROCEDURE

A. Taguchi Method

Taguchi method is invented by a Japanese scientist Dr.Genichi Taguchi. It is statistical method which is commonly applicable in many engineering problems. The Taguchi design of experiment gives competent and methodical path to optimize design of performance, quality and cost. Taguchi method is mainly based on the Orthogonal Array experiments which provide balanced design for the experiment and optimal number of process control parameters. Taguchi method uses signal-to-noise (S/N) which takes ratio of mean (signal) to the standard deviation (noise). Generally there are three Signal-to-Noise ratio are used for optimization.

1) Signal-to-Noise Ratio for Smaller-The-Better Characteristics: n = -10log10 [Mean of sum of square of measured data]
2) Signal-to-Noise Ratio for Larger-The-Better Characteristics: n = -10log10 [Mean of sum of reciprocal of measured data]
3) Signal-to-Noise Ratio for Nominal-The-Best Characteristics: n =10log10 (Square of mean) / Variance

B. Material Selection

The work material used for present work is Stainless Steel 316 having dimension of 100mm ×60mm×5mm thickness. The mixture of argon and carbon-di-oxide is used as shielding gas in (80%-20%) proportion. The chemical composition of base material is shown in Table1.

Element	Wt%
C	0.047
Mn	1.58
P	0.027
S	0.016
Si	0.428
Cr	16.425
Ni	11.90
Mo	2.27

Table 1: Chemical Composition

C. Experimental Procedure

The workpieces are cut into required dimension by wire EDM machine to perform a welding operation .The wire EDM machine used for cutting operation is manufactured by Sparkonix India Pvt. Ltd. Silicon carbide paper and acetone is used to clean surface of workpiece material to avoid surface contamination and removal of impurities. The V-butt joint was made to join material using MIG welding setup. Before welding the flux powder is mixed with acetone and make thin layer of flux paste over area of the material to be welded.

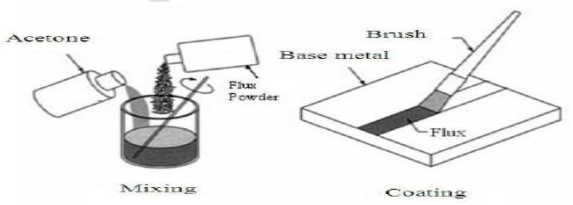


Fig.2: Method of Applying Flux

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The parameters that mostly affects the quality characteristics was optimized by S/N ratio. The lower the hardness value it emphasizes better will be the welding performance. So, smaller-the-better S/N ratio is selected for hardness to maximizing the response.

Input Parameters	Levels of Parameters		
	Level 1	Level 2	Level 3
Current (Ampere)	120	150	180
Gas flow rate (Lit/min)	12	14	16
Flux used (gm/cm^2)	SiO_2	ZnO	Al_2O_3

Table 2: Levels for DOE

D. Design of Experiment (DOE)



Fig.3: Based on L9 orthogonal array 9 samples for Hardness test

In DOE the parameters are arranged by using orthogonal array according to sample range. The Taguchi method is applied because it reduces the number experiment and which reduces cost as well as time of experiment. In this experiment, three levels are used along with three factors consider and based on that L9 OA is selected. The below table shows DOE of L9 orthogonal array with three input parameters which have to employed for welding the samples.

No. of Experiment	Welding Current	Gas flow rate	Flux
1	120	12	SiO_2
2	120	14	ZnO
3	120	16	Al_2O_3
4	150	12	ZnO
5	150	14	Al_2O_3
6	150	16	SiO_2
7	180	12	Al_2O_3
8	180	14	SiO_2
9	180	16	ZnO

Table 3: L9 Orthogonal array

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IV. RESULT AND DISCUSSION

A. Result and Analysis for Hardness

The micro-hardness analysis was done to know the characteristics of hardness in different zones in workpiece such as base metal zone, heat affected zone and weld metal zone. The micro-hardness test is performed on Vickers hardness tester and test was performed on all nine samples. The hardness test is performed at SN Metallurgical Services, Waluj, Aurangabad and Vickers hardness tester used for test is manufactured by Fuel Instruments & Engineers Pvt, Ltd.

Sample No.	Micro hardness (HV)		
	Base metal zone	Heat affected zone	Weld metal zone
1	205	247	272
2	197	232	260
3	184	202	225
4	224	283	309
5	190	208	256
6	192	213	237
7	220	281	306
8	236	290	322
9	213	264	294

Table 4: Hardness results

From above table it is seen that sample number 3 gives the lowest hardness with Al_2O_3 flux at 120A current and 16 lit/min gas flow rate respectively.

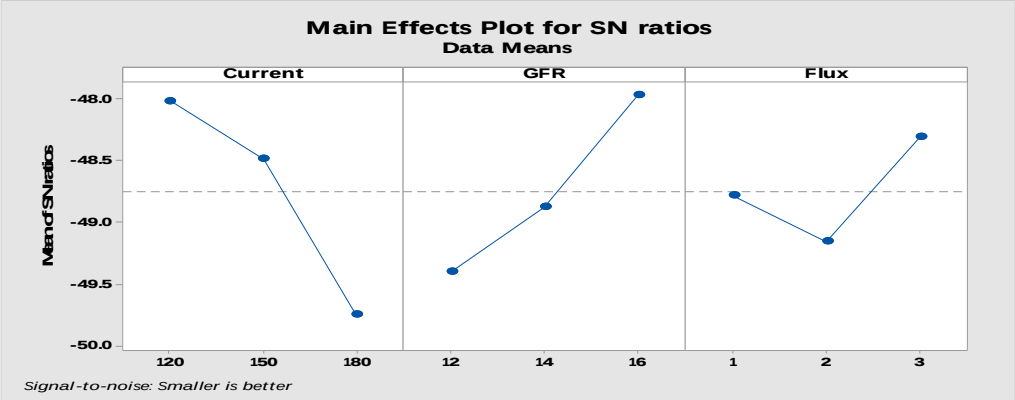


Chart 1: Main effects plot for S/N ratios of Hardness

From the above chart we get optimum value for micro-hardness for different input parameters. The mean of S/N ratio graph shows optimum parameters are 120 amp current, Al_2O_3 flux and 16 litre/min of gas flow rate.

B. Analysis of Variance (ANOVA)

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value	Contribution
Current	2	4850.0	4850.0	2425.0	10.09	0.090	52.59%
GFR	2	2920.7	2920.7	1460.3	6.08	0.141	31.67%
Flux	2	970.7	970.7	485.3	2.02	0.331	10.53%
Error	2	480.7	480.7	240.3			5.21%
Total	8	9222.0					100.00%
S=15.5027			R-Sq=94.79%			R-Sq (Adj)=79.15%	

Table 5: ANOVA Results for Hardness

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ANOVA is statistical method to calculate percentage contribution factor of each parameter. The all Analysis of Variance (ANOVA) calculations for hardness test was performed in excel sheet in MINITAB 18 software. Table 5 shows that current is the most significant factor with 52.59%, followed by gas flow rate with 31.67% and activated flux with 5.21%.

C. Confirmation Test

The confirmation test was performed at optimum value of process parameter which are current of 120A, gas flow rate of 16 lit/min and Al_2O_3 flux. To perform a confirmation test, the regression equation for hardness is calculated by using MINITAB 18 software. The regression equation gives the predicted value of test.

Hardness (HV) =305.7 + 0.917 Current - 10.92 GFR - 7.33 Flux

Table below shows results obtained from confirmation test.

Test	Predicted Value	Experimental Value	Error
Hardness (HV)	233.69	216	7.56%

Table 6: Confirmation Test Results for Hardnes

V. CONCLUSION

The present work is on the effect of MIG welding parameters on hardness of Stainless Steel 316 grade and the results were optimized by using Taguchi method. Based on investigation and optimization following conclusion were drawn based on the results of this experiment:

A. For optimum hardness, considering all input parameters welding current is most significant factor on hardness followed by gas flow rate and flux.
B. The optimum welding parameters are found to be current of 120A, gas flow rate of 16lit/min and Al_2O_3 flux.
C. The hardness is gradually increases from base metal zone to the weld metal zone.

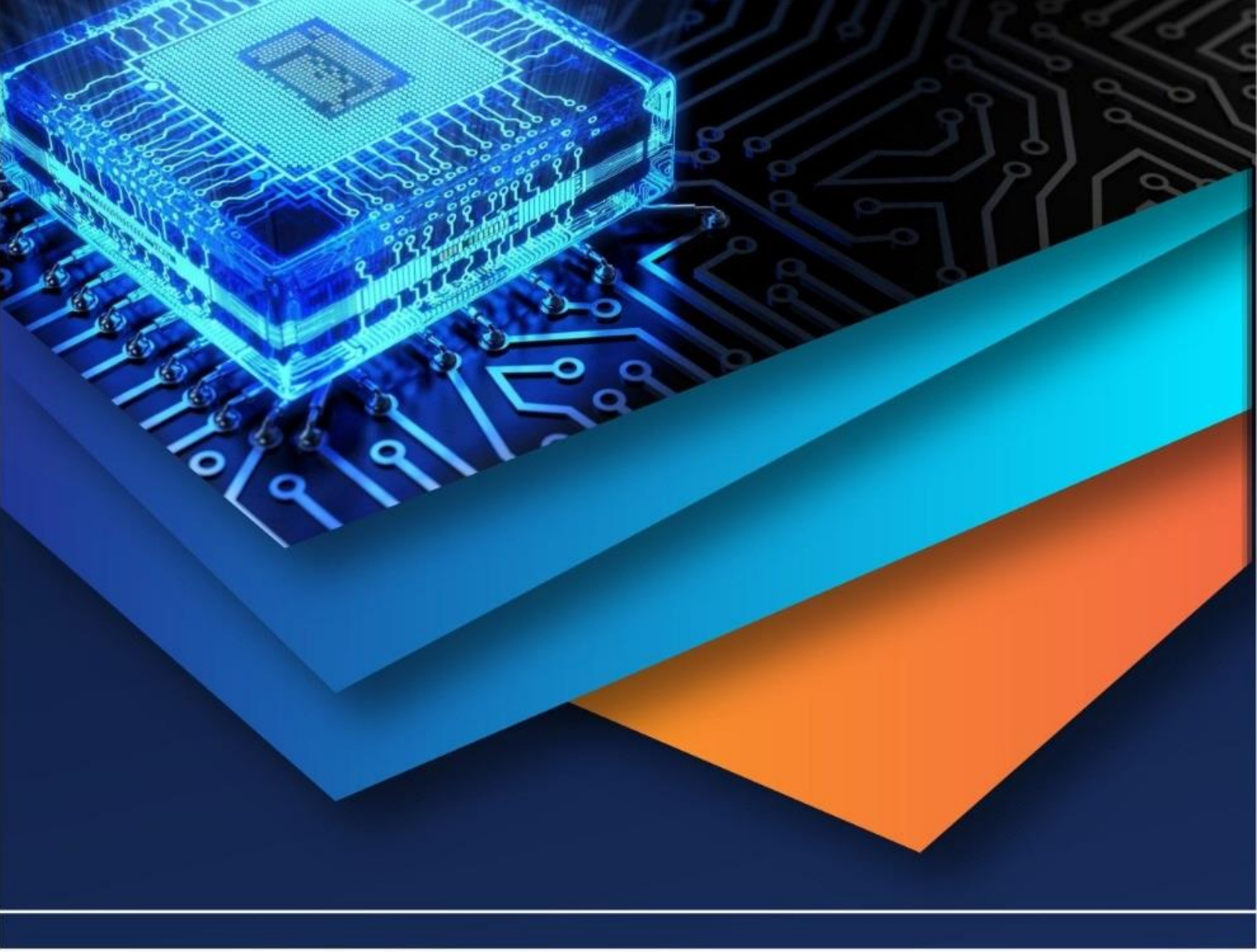
VI. ACKNOWLEDGEMENT

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