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APPLICATION OF TAGUCHI TECHNIQUE TO OPTIMIZE THE PROCESS PARAMETERS OF MIG WEDGING ON IS2062 STEEL

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ABSTRACT

This study focuses on optimizing welding parameters which affect the weldability of IS2062. Taguchi technique was employed to optimize the welding parameters. A series of experiments have been carried out. L_{16} orthogonal array was applied for it. The statistical methods of signal to noise ratio (SNR) and the analysis of variance (ANOVA) are applied to investigate effects of welding parameters gas flow rate, wire feed speed, heat input and welding current on weldability. Tensile strength, impact strength, micro hardness, and mode of fracture were examined to determine the weldability. The results show that the welding current and welding voltage have significant effect whereas gas flow rate has insignificant effect on tensile strength of the weld and the optimum process parameters were found to be 27 V, 300 mm/min travel speed of wire and 10l/min gas flow rate for tensile strength.

KEYWORDS: GMAW, Shielding Gas, Mechanical Properties, Taguchi Technique, Steel.

INTRODUCTION

Gas metal arc welding (GMAW) is an advanced version of arc welding in which no pressure is applied during the welding process and arc is created between a continuous copper coated wire and the work piece. This GMAW is a commonly used method for joining the steel structural components for the automotive industry [1-4]. In order to achieve high productivity and avoid melt-through in thin sheet materials, welding conditions with fast welding speeds ensuring low heat input are required. In this study, IS2062 structural steel is used as its price is relatively low while it provides material properties that are acceptable for many applications. Two main features are associated with Metal Inert Gas (MIG) process: first is high short circuit current which corresponds to a high heat input and second one is short circuit which opens in a rather uncontrolled manner, resulting in lots of spatters in the conventional dip arc process. There is no heat treatment on pre and post-welding, which is regarded as an important welding technique in practice [5].

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During the welding of mild steel, different welding parameters were studied which influence weldability such as welding current, voltage, wire feed speed and gas flow rate by using Taguchi design method and result shows that the welding voltage has a large effect on penetration [7].

Al-65032 alloy welded by MIG welding and their mechanical properties were tested and Taguchi technique was employed to optimize the parameter and result shows that current is the most influencing parameter for ultimate tensile strength [8].

EXPERIMENTAL PROCEDURES

MATERIAL

The material used for this research was IS 2062 structural steel plate of 10 mm thick and the filler wire used was 2.0 mm nominal in diameter. Table 1 shows the chemical composition of IS2062 and Table 2 shows the chemical composition of the filler wire used in welding process. 75% Ar and 25% CO_2 is used as shielding gas at different flow rate. 300 × 60 × 10 mm^3 size of test piece is used for welding purpose and the material is machined on horizontal milling machine for V-groove. Figures 1 and 2 show the milling process.

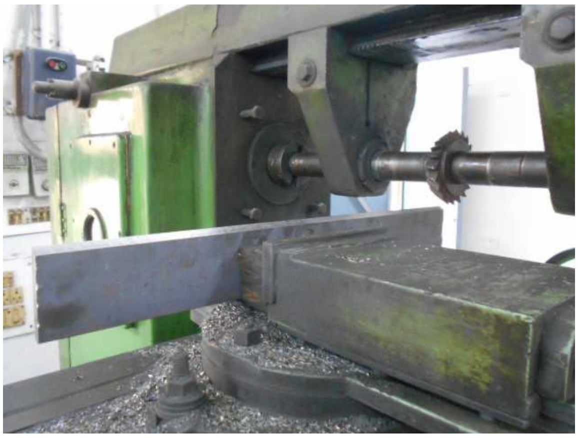

Figure 1.V-groove making on milling machine

Figure 2.Samples after milling

Table 1.Chemical Composition of IS 2062 steel Grade A

IS 2062 Steel for Structural Steel Purpose				
% C Max	**% Mn Max**	**% S Max**	**% P Max**	**% Si Max**
0.22	1.5	0.049	0.050	0.37

Table 2.Chemical Composition of Consumable Electrode

Electrode Chemical Composition of Filler Wire					
E70S6					
C	**Si**	**Mn**	**Cu**	**P**	**S**
0.19	0.98	1.61	0.025	0.025	0.025

EQUIPMENT

The MIG welding configuration is shown in Fig. 3. The MIG welding experiments were conducted in IIT Delhi at welding research laboratory.

Figure 3.Actual Experimental Set up of GMA Welding

RESEARCH METHODOLOGY

This research study starts with the concept of Design of Experiment (DOE). The preliminary result determines the welding parameter levels. After the preliminary results are known, levels of parameter are then entered into robust design Taguchi Method (Minitab 16) to generate the design matrix table. Then experiments were conducted based on input parameter and level setup. Total 16 experiments were conducted based on L_{16} orthogonal arrays as shown in Table 4. The primary effect of various welding parameters such as welding current, gas flow rate and wire feed speed of IS 2062 structural was analyzed. The tensile strength and hardness of all sixteen weld specimens were checked carefully and the observed values of tensile strength and hardness with their S/N ratios are shown in Table 5 and Table 6, which are used for the improving the quality characteristics of welding Taguchi analysis. Taguchi method is a systematic method for design and analysis of experiments. Now-a-days Taguchi method has became a very powerful tool for improving the quality output without enhancing the cost of experiment by reducing the number of experiments [9-10]. Taguchi technique is used to optimize the process parameters such as arc gap, gas flow rate, welding speed and current during the welding of SS by TIG welding process [11]. Figure 4 shows the various steps in the Taguchi method.

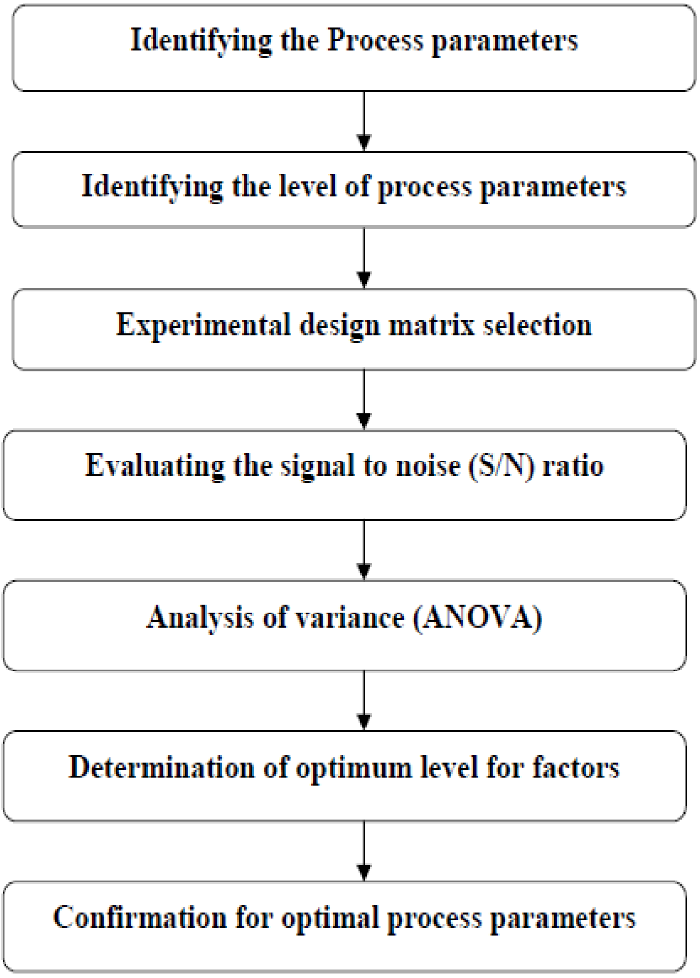

Figure 4.Various Steps of Taguchi Method

Table 3.Input (welding) Parameters and their Level

Variable	**Unit**	**Level I**	**Level II**	**Level III**	**Level IV**
Voltage(V)	Volt	25	26	27	28
Gas flow rate (L/min)	l/m	10	15	20	25
Wire feed rate (mm/min)	ipm	300	350	400	450

Taguchi method recommends the signal-to-noise (S/N) ratio, which is a performance characteristic, instead of the average value. Optimum conditions were determined using the S/N ratio from experimental results [13]. AVOVA is a powerful statistical tool to analyze the S/N ratio. The term signal means the desirable value while noise means undesirable value. Different welding parameters are optimized by using Taguchi orthogonal array (OA) experimental design and other statistical tools such as Analysis of Variance (ANOVA) and Pooled ANOVA techniques [12].

Figure 5 shows a schematic diagram of tensile specimen fabricated as per ASTM [6] while Fig. 6 shows the actual figure of tensile test specimens which are fabricated from the welded part. Tensile tests were tested on UTM machine as room temperature.

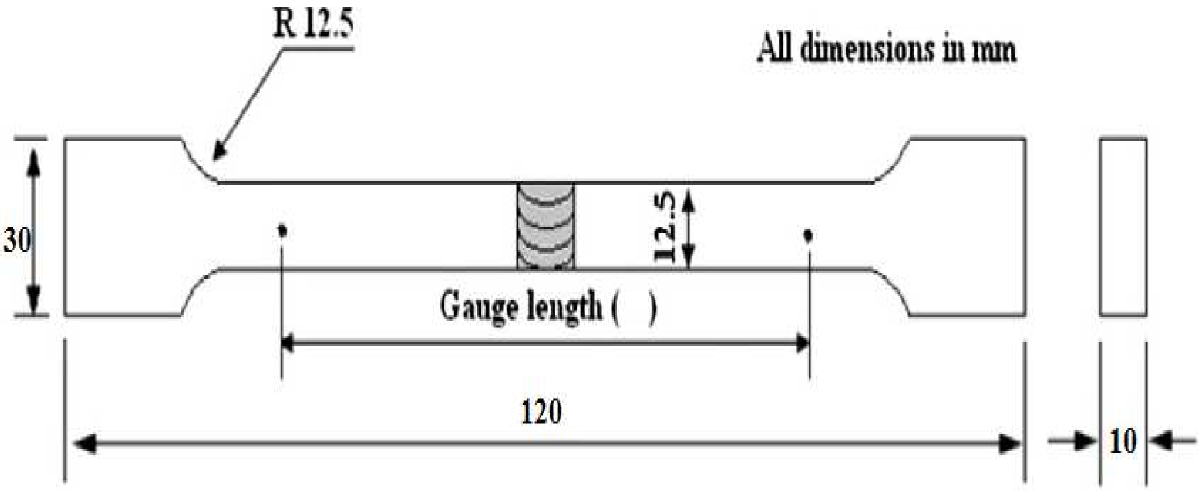

Figure 5.Schematic Illustration of Tensile Test Specimen as per ASTM [6]

Figure 6.Actual Figure of Tensile Test Specimen

EVALUATING THE SIGNAL-TO-NOISE (S/N) RATIOS

In present research, an L_{16} OA with 4 columns and 16 rows was used. This array can handle four level process parameters. Fourteen experiments were conducted to study the welding parameters using the L_{16} OA. In order to evaluate the influence of each selected factor on the responses, the S/N ratio for each control factor was calculated.

In the present research work, tensile strength and hardness of the welded pieces were identified as the responses, therefore, for tensile strength "higher the better" and for hardness "nominal the best" characteristic was chosen for analysis purpose.

Larger is better

$$S/N=10\log_{10}\left(\frac{1}{n}\sum_{i=0}^{n}\frac{1}{Y_i^2}\right)$$

Table 4.L_{16} Orthogonal Array design of experiment (DOE)

S. No.	Voltage(V)	Gas flow rate (L/Min)	Wire feed Speed (m/min)	UTS (MPa)	VHN
1	25	10	300	526	171
2	25	15	350	390	183
3	25	20	400	410	181
4	25	25	450	470	180
5	26	10	350	480	199
6	26	15	300	497	167
7	26	20	450	498	181
8	26	25	400	532	166
9	27	10	400	510	192
10	27	15	450	438	178
11	27	20	300	408	183
12	27	25	350	388	165
13	28	10	450	535	178
14	28	15	400	422	180
15	28	20	350	463	188
16	28	25	300	570	175

TAGUCHI DESIGN

Taguchi Orthogonal Array Design

L_{16} (4**3)

Factors: 3

Runs: 16

Columns of L_{16} (4**5) Array

RESULT AND DISCUSSION

EFFECT OF GAS FLOW RATE

In the present research work, the effect of input parameters on tensile strength and hardness were analyzed. The signal to noise ratio for all the responses are given in Table 5. It clearly shows that the optimum welding condition for maximization of tensile strength is A3B1C1. Analysis of variance for tensile strength is given in Table 8. From this table gas flow is of significance after the tensile strength following current and voltage. Similarly are yield strength and elongation. Table 6 shows the analysis of variance for tensile strength. It clearly shows the gas flow rate most significantly affects TS with p value of 0.143 followed by current with p value of 0.258.

It is very clear from Fig. 7 and Fig. 8 that tensile strength is minimum at 15 l/min and it further increases at 20 l/min, bearing the highest value (UTS) at 25 l/min.

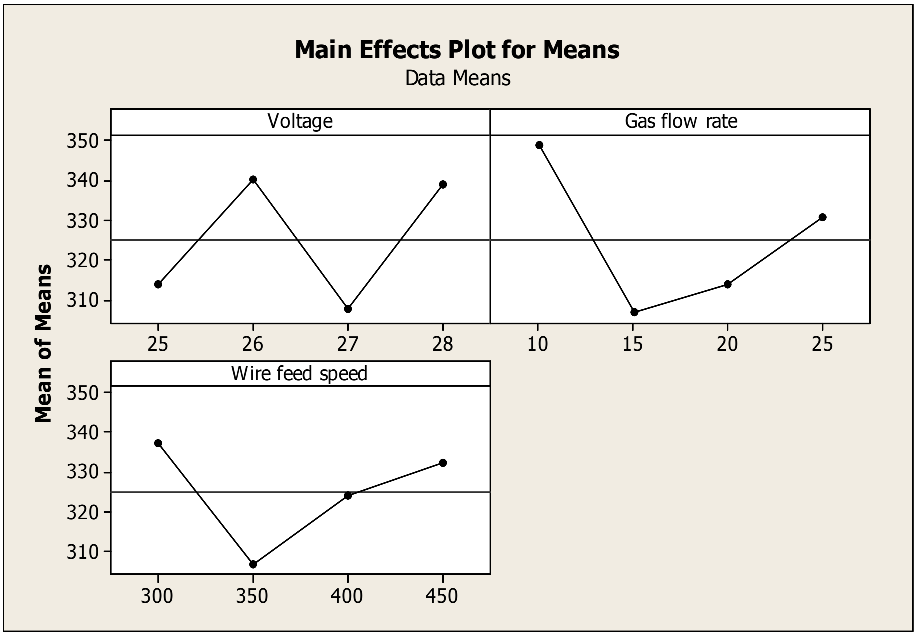

Figure 7.Main Effect Plot for Means

Table 5.Response Table for Means

Level	Voltage	Gas Flow Rate	Wire Feed Speed
1	475.4	512.8	500.3
2	436.0	436.8	430.3
3	497.5	444.8	468.5
4		490.0	485.0
Delta	61.5	76.0	70.0
Rank	3	1	2

EFFECT OF WELDING SPEED

It is very clear from Fig. 7 and Fig. 8 that ultimate tensile strength is minimum at a speed of 350m/min of welding wire, and has the highest value at 300 m/min of welding wire speed. From the data, the optimum set of welding parameters was found as: Voltage 27 V, Gas flow rate 10 l/min, and welding speed 300 m/min as shown in Table 7.

Table 6.Response Table for Signal to Noise Ratios

Level	Voltage	Gas Flow Rate	Wire Feed Speed
1	53.49	54.19	53.92
2	52.74	52.77	52.63
3	53.88	52.93	53.36
4		53.71	53.7
Delta	1.13	1.42	1.29
Rank	3	1	2

EFFECT OF VOLTAGE

Basically arc voltage setting depends up on the type of material, shielding gas and transfer mode. Trial runs are necessary to adjust voltage to produce most favorable arc characteristics. In this research work from Fig. 7 and Fig. 8, it is very clear that till the voltage of 27 V the strength decreases and then it increases till 28 V.

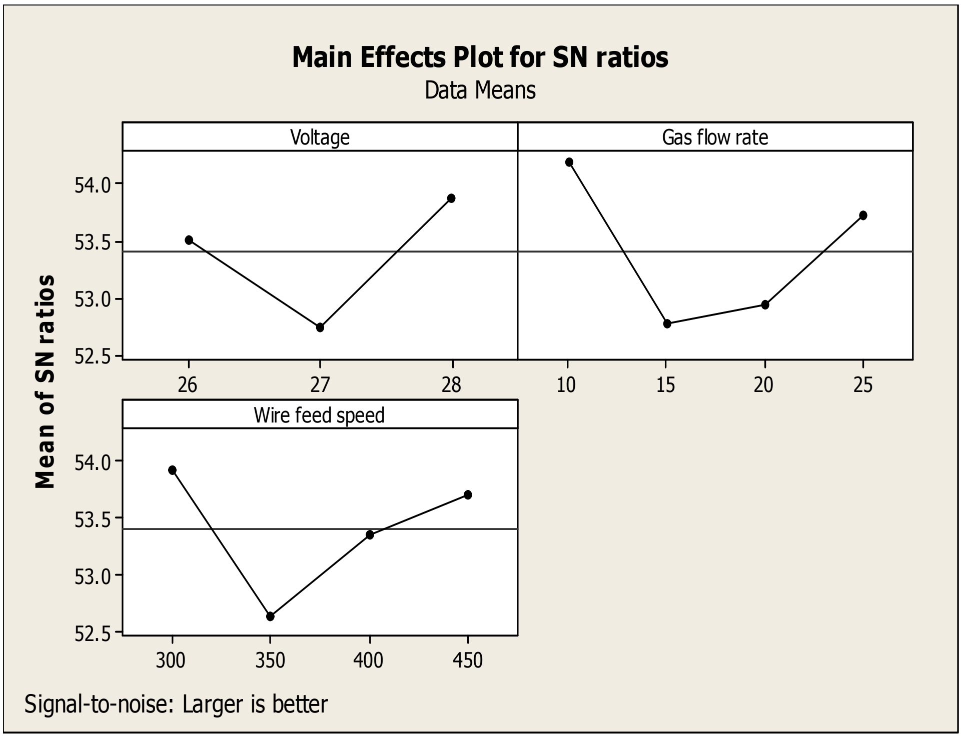

Figure 8.Main Effect Plot for Signal to Noise Ratio

Table 7.Predicted Optimum Parameter Value

Voltage (V)	Gas flow rate (L/Min)	Wire feed speed (m/min)
28	10	300

LINEAR MODEL ANALYSIS: SN RATIOS VERSUS VOLTAGE, GAS FLOW RATE, WIRE FEED SPEED

ESTIMATED MODEL COEFFICIENTS FOR SN RATIOS

Table 8.Model Coefficients for SN ratios

Term	Coef.	SE Coef.	T	P
Constant	47.4558	0.1132	419.322	0.000
Voltage 25	-0.0706	0.1960	-0.360	0.731
Voltage 26	0.0273	0.1960	0.139	0.894
Voltage 27	-0.0666	0.1960	-0.340	0.746
Gas Flow rate10	0.3431	0.1960	1.750	0.131
Gas Flow rate15	-0.1709	0.1960	-0.872	0.417
Gas Flow rate20	0.1215	0.1960	0.620	0.558
Wire Feed Speed 300	-0.1616	0.1960	-0.824	0.441
Wire Feed Speed 350	0.0847	0.1960	0.432	0.681
Wire Feed Speed 400	0.0167	0.1960	0.085	0.935

S = 0.4527   R-Sq = 50.0%   R-Sq(adj) = 0.0%

ANALYSIS OF VARIANCE FOR SN RATIOS

Table 9.Analysis of Variance for Tensile Strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage	3	0.08902	0.08902	0.02967	0.14	0.929
Gas flow rate	3	0.99209	0.99209	0.33070	1.61	0.282
Wire Fees speed	3	0.14875	0.14875	0.04958	0.24	0.864
Residual Error	6	1.22958	1.22958	0.20493		
Total	15	2.45943				

Table 10.Response Table for Means

Level	VHN	UTS
1	161.6	161.6
2	198.0	166.9
3	189.5	171.5
4	197.9	171.4
5	210.0	174.2
6	189.9	177.7
7	180.2	186.7
8	182.5	186.3
9	169.2	193.9
10	186.7	189.5
11	199.6	193.6
12	193.9	199.6
13	197.9	-------
14	198.0	-------
15	202.0	-------
16	210.0	-------
Delta	48.4	48.4
Rank	1.5	1.5

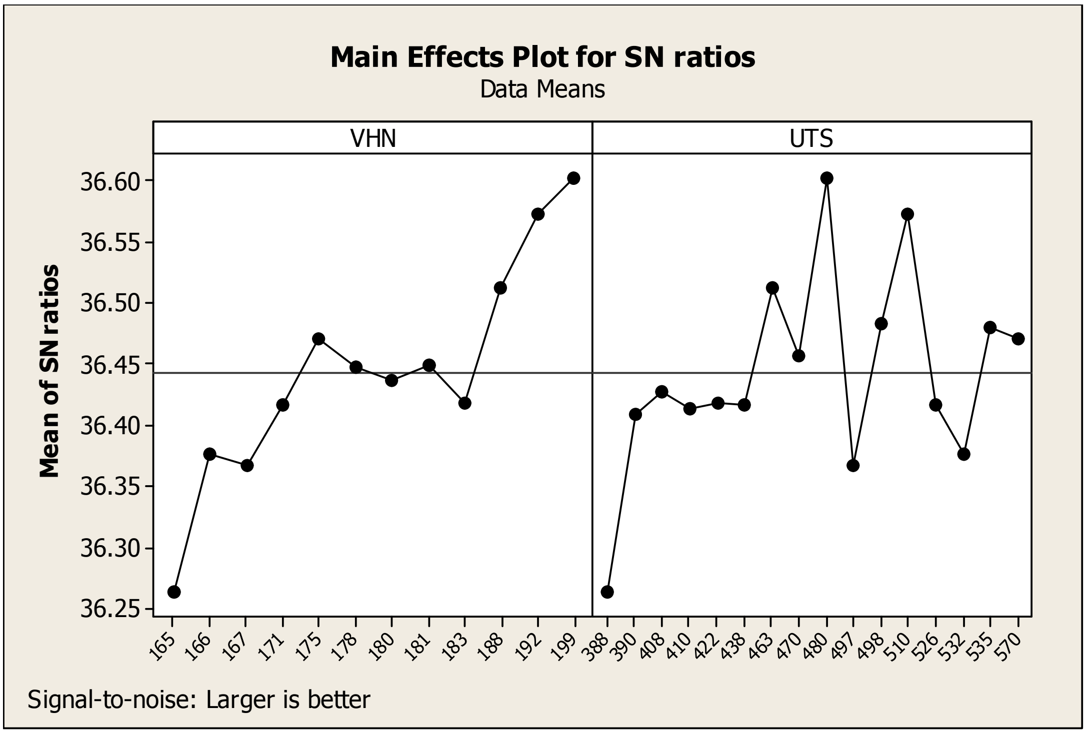

Figure 9.Main Effect Plot of Process Parameter on UTS and Hardness for Signal to Noise Ratio

The optimal process parameters have been established by analyzing response curves of S/N ratio. From Fig. 10, it is found that fourth level of arc voltage (28V), first level of gas flow rate (10 L/min) and second level of wire feed speed (350 m/min) give the optimal hardness. Hence the optimum condition of input parameters is A4B1C2.

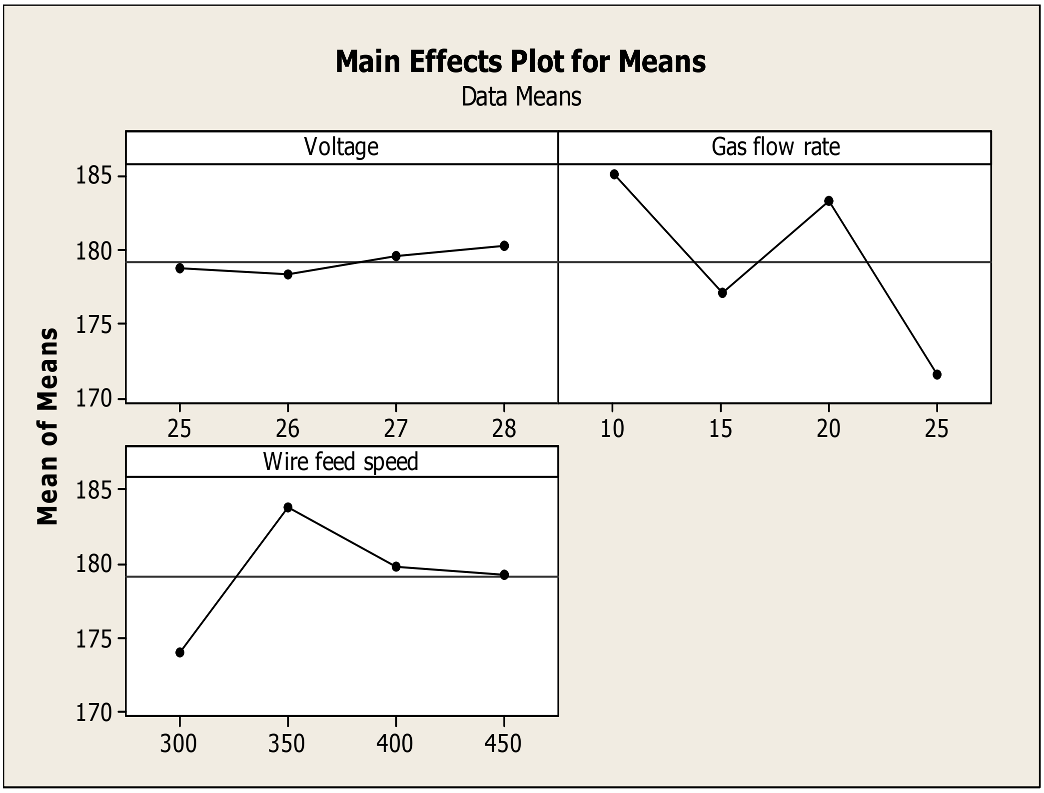

Figure 10.Effects of Process Parameters on Hardness S/N ratio

CONCLUSION

In the present research work, the following conclusions can be obtained:

1. Taguchi design of experiment method is very efficiently suitable for optimizing the welding parameters in manufacturing operations.
2. The optimum welding process parameters are found to be voltage of 28 V, gas flow rate at 10 L/hr and wire feed speed at 300 mm/min.
3. Tensile strength and hardness (weldability) of IS2062 steel is significantly influenced by current followed by welding voltage and wire feed speed.
4. The maximum hardness is obtained at an arc voltage (28V), gas flow rate (10 L/min) and wire feed speed (350 m/min).

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