International Journal of Research in Advent Technology, Vol.2, No.3, March 2014
E-ISSN: 2321-9637

Assessment of Deposition Rate in MIG Welding of Stainless Steel

Rajiv Suman[1] and Dr. Jatindar Kumar[2]
[1]*Mechanical Engineering Department, Ph.D. Scholar, G. B. Pant University of Agriculture & Technology, 263145 Pantnagar, India.*
[2]*Mechanical Engineering Department, Assistant Professor, National Institute of Technology, Kurukshetra, India.*
raje.suman@gmail.com

Abstract- This work covers the study of complete welding operation on SS304 (S30400) used as work material and more stress is given to the response variables as they are capable to respond fast with the changing input parameters and these input parameters should be compatible with new technological changes. A performance measurement framework has been developed for this study based on extensive reviews of literature on “Design of Experiment (DOE) approach and Taguchi Method”.

In this study the areas or input parameters which are responsible (significant) for major changes in response variables are identified by using Design of Experiment (DOE) approach and analyze the future effects of variation to the input parameters. Four input or control parameters namely current, voltage, wire speed and gas flow rate and response variables namely deposition rate has been used for this study.

Index Terms - MIG welding; GMAW; DOE; Taguchi approach; deposition rate; hardness.

1. INTRODUCTION

Design of Experiments (DOE) is a powerful statistical technique introduced by R. A. Fisher in England in the 1920's to study the effect of multiple variables simultaneously. In his early applications, Fisher wanted to find out how much rain, water, fertilizer, sunshine, etc. are needed to produce the best crop. Since that time, much development of the technique has taken place in the academic environment, but did help generate many applications in the production floor [Yusuf1 *et al*, (2010)].The DOE using Taguchi approach can economically satisfy the needs of problem solving and product/process design optimization projects. By learning and applying this technique, engineers, scientists, and researchers can significantly reduce the time required for experimental investigations.DOE can be highly effective when:

Optimize product and process designs, study the effects of multiple factors (i.e. - variables, parameters, ingredients, etc.) on the performance, and solve production problems by objectively laying out the investigative experiments (Overall application goals).

Study Influence of individual factors on the performance and determine which factor has more influence, which ones have less [Ibrahim *et al, (2011)*]. It can also find out which factor should have tighter tolerance and which tolerance should be relaxed. The information from the experiment will tell how to allocate quality assurance resources based on the objective data. It will indicate whether a supplier's part causes problems or not (ANOVA data), and how to combine different factors in their proper settings to get the best results (Specific Objectives).

2. PROBLEM FORMULATION

The literature review reflects that in the welding operation, the input parameters such as current, voltage, wire speed, gas flow rate affects the physical characteristics of weld bead like hardness and deposition rate to a significant extant [Katherasan *et al,* (2012)].

Some research work has been reported in this regard for various work materials such as High-Chromium-High-Carbon die steel, polycarbonate and ABS (acrylonitrile-butadienestyrene) blend, RDE-40 aluminium alloy, aluminium alloy A319, SS316 L, stainless steel and carbon steel, Inconel 718, AISI1040 steels etc. However there is critical need for exploring these issues in welding of SS304 (S30400) for which almost no work has been reported.

3. INPUT (CONTROL) PARAMETERS

Current, voltage, wire speed and gas flow rate are selected as control parameters. These four parameters are selected because of their ease of control and due to the limitations of available experimental setup. Parameters used for the actual experiment are given below:-

TABLE: 1-Control Parameters

CONTROL FACTORS	SYMBOL
Current	Factor A
Voltage	Factor B
Wire speed	Factor C
Gas flow	Factor D

3.1: Level of Various Control Factor: - The short range of control factors will have minor effect on response parameters that is why a considerable range of control parameters had been chosen. In this experimental study, each control factor used having two levels. Details of each control factor level are as under:-

TABLE: 2- Levels of Control Factors

CONTROL FACTORS	Levels	
	1st level	2nd level
Current	150 amp	250 amp
Voltage	20 V	30 V
Wire speed	30 rpm	40 rpm
Gas flow	10 Kg/cm2	15 Kg/cm2

3.2: Response Variables: - In the present study two response variables has been selected (deposition rate). The details of these response variables are given below:-

TABLE: 3- Response Variables

S.N.	Response variable	Unit	Response type
1	Deposition Rate	Kg/hr	Continuous

3.3: Representation of Factor Levels: - The notation used for the factors having their specific meaning, as given below.

TABLE: 4- Factor Levels

Factors	Level-1	Level-2
Current	A1	A2
Voltage	B1	B2
Wire speed	C1	C2
Gas Flow Rate	D1	D2

TABLE: 5- Values of Input Parameters

A For Current Where; • A1=150amp • A2=250amp	**B For Voltage Where;** • B1=20V • B2=30V
C For wire speed Where; • C1=35cm/sec • C2=50 cm/sec	**D For Gas Flow Rate Where;** • D1=10Kg/cm² • D2=15Kg/cm²

TABLE: 6- Standard L8 Orthogonal Array

EXP. NO.	FACTORS			
	A	B	C	D
1	1	1	1	1
2	1	1	2	2

3	1	2	1	2
4	1	2	2	1
5	2	1	2	1
6	2	1	1	2
7	2	2	2	2
8	2	2	1	1

TABLE: 7- Parameters Setting For Each Run

Experiment no. 1	**Experiment no. 2**	**Experiment no. 3**	**Experiment no. 4**
A1=150amp	A1=150amp	A1=150amp	A1=150amp
B1=20V	B1=20V	B2=30V	B2=30V
C1=35cm/sec	C2=50 cm/sec	C1=35cm/sec	C2=50 cm/sec
D1=10Kg/cm^2	D2=15Kg/cm^2	D2=15Kg/cm^2	D1=10Kg/cm^2
Experiment no. 5	**Experiment no. 6**	**Experiment no. 7**	**Experiment no. 8**
A2=250amp	A2=250amp	A2=250amp	A2=250amp
B1=20V	B1=20V	B2=30V	B2=30V
C2=50 cm/sec	C1=35cm/sec	C2=50 cm/sec	C1=35cm/sec
D1=10Kg/cm^2	D2=15Kg/cm^2	D2=15Kg/cm^2	D1=10Kg/cm^2

TABLE: 8- Control Log for Experimentation

Exp. No.	**Current (A) Amp**	**Voltage (B) V**	**Wire Speed (C) cm/sec**	**Gas Flow (D) Kg/cm^2**
1	150	20	35	10
2	150	20	50	15
3	150	30	35	15
4	150	30	50	10
5	250	20	50	10
6	250	20	35	15
7	250	30	50	15
8	250	30	35	10

4. CONDUCTING THE EXPERIMENT

Once the factors are assigned to a particular column of the selected orthogonal array, the test strategy has been set and physical preparation for performing the test is initiated. Some decisions need to be made concerning the order of test.

Randomizing the order of performing the test of various trails should include some form of Randomization. The randomized trail order protects the experiment from any unknown and uncontrolled factors that may vary during the experiment and may influence the result.

Analysis of Experimental Results

A number of methods have been suggested by the Taguchi for analyzing the data, in the present study following methods are used:-

- Plot of average response
- ANOVA for raw data

The plot of average response at each level of a parameter indicates the trend. It is a pictorial representation of the effect of parameters on the response. The S/N ratio treated as response of experiments, which is measure of the variation within a trail when noise factors are present. A standard ANOVA is conducted on raw data which identified the significant parameters.

Conformation Experiments

The conformation experiments are the final step in verifying the conclusion from the previous of experimentation. The optimum conditions are set for the significant factors and levels and server tests are made under constant conditions. The conformation experiments are a crucial step and should not be omitted.

4.1: Deposition Rate Calculation

Deposition rates are calculated by doing actual welding tests, and the following shows the formula for measuring deposition rates.

Deposition Rate= (*Wt. of test plate after welding - Wt of test plate before welding*) / (*Measured period of time*)

TABLE: 9- Deposition Rate

Experiment no. 1	Experiment no. 2	Experiment no. 3	Experiment no. 4
1) 1.5000 2) 1.5240	1) 2.5000 2) 1.7230	1) 1.2500 2) 1.3650	1) 2.6500 2) 1.9983
Experiment no. 5	**Experiment no. 6**	**Experiment no. 7**	**Experiment no. 8**
1) 2.5540 2) 2.6231	1) 2.1100 2) 2.0654	1) 2.9560 2) 2.8546	1) 1.7265 2) 2.1631

5. RESULTS

The analysis of result obtained has been performed according to the standard procedure recommended by Taguchi.

5.1: S/N Ratio: - The S/N ratio is obtained by using Taguchi approach. Here the term SIGNAL represents the desirable value (mean) and NOISE represents the undesirable value. Thus S/N ratio represents the amount of variation present in the performance characteristics.

For the Deposition Rate the Larger is Better S/N ratio corresponding to different experimental runs has been tabulated in the table no. – 10 along the mean value of deposition rate.

5.2: Main Effect Due To Parameters: - The main effect can be studied by the level average response analysis of mean data and S/N ratio. The analysis is done by averaging the mean and/or S/N data at each level of each parameter and plotting the value in graph. The level average response from the mean data helps in analyzing the trend of performance characteristics with respect to variation of the factors under study. The main effect of raw data and those of S/N ratio for response variables have been shown in figures – 1.

Analysis Of Variance (ANOVA):- The ANOVA (general linear model) for mean has been performed to identify the significant parameters to quantify their effect on performance characteristics. The ANOVA test for raw data is given in table no. – 5.5 and 5.6.

TABLE: 10- Test Data for Deposition Rate

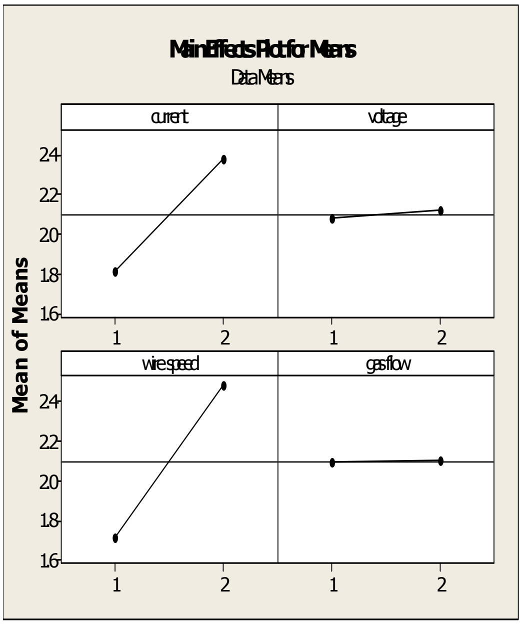
Exp. No.	Deposition Rate		Deposition Rate Mean Value	Deposition Rate S/N Ratio
	1st Run	2nd Run		
1	1.5000	1.5240	1.51200	3.59022
2	2.5000	1.7230	2.11150	6.04810
3	1.2500	1.3650	1.30750	2.30363
4	2.6500	1.9983	2.32415	7.06831
5	2.5540	2.6231	2.58855	8.25881
6	2.1100	2.0654	2.08770	6.39188
7	2.9560	2.8546	2.90530	9.25985
8	1.7265	2.1631	1.94480	5.61299
Average			2.0976875	6.06672375
Max.	2.9560	2.8546	2.90530	9.25985
Min.	1.2500	1.3650	1.30750	2.30363

TABLE: 11- Factor Effect on Average Response

Factor Effect	Levels	Deposition Rate
Current	A1	1.814
	A2	2.382
Voltage	B1	2.075
	B2	2.120
Wire Speed	C1	1.713
	C2	2.482
Gas Flow Rate	D1	2.092
	D2	2.103

TABLE: 12- Factor Effect on S/N Ratio

Factor Effect	Levels	Deposition Rate
Current	A1	4.753
	A2	7.381
Voltage	B1	6.072
	B2	6.061
Wire Speed	C1	4.475
	C2	7.659
Gas Flow	D1	6.133
	D2	6.001



Optimal combination A2 B2 C2 D2

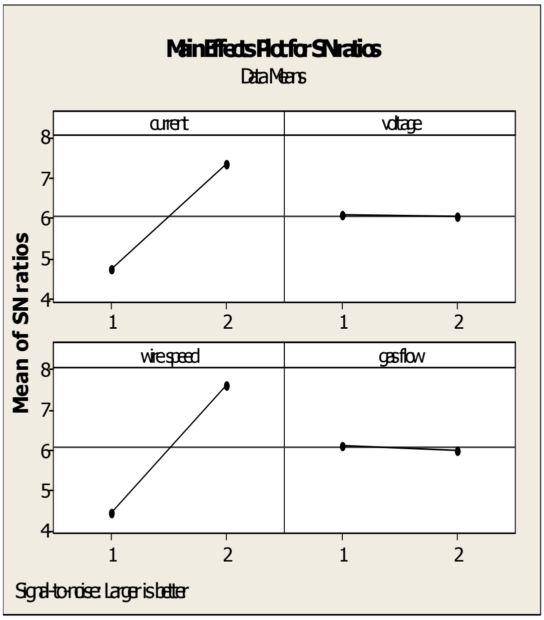


Figure 1: Effect of Process Parameters on Deposition Rate - Raw Data and S/N Ratio

TABLE: 5.6- ANOVA Test Summery for Deposition Rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current	1	1.28959	1.28959	1.28959	17.09	0.002
Voltage	1	0.00828	0.00828	0.00828	00.11	0.747
wire speed	1	2.36775	2.36775	2.36775	31.38	0.000
gas flow	1	0.00045	0.00045	0.00045	00.01	0.940
Error	11	0.83000	0.83000	0.07545		
Total	15	4.49608				

S = 0.274691 R-Sq = 81.54% R-Sq(adj) = 74.83%

Order of significance 1:Wire Speed; 2: Current;

6. DISCUSSION

After performing experiment and analyzing the results, the discussion for the effect of different input parameters on response variables is described below:

6.1: Effect on Deposition Rate: - It can be seen for the figure 1 that the wire speed and current affects the Deposition Rate very significantly. The different input parameters used in the experimentation can be ranked in order of increasing effect as gas flow, voltage, current and wire speed.

It is clear from the figure-1 that wire speed and current affects deposition rate significantly. The slope of current and wire speed indicates that increase in wire speed results in increase of current and it is also practical that for higher wire feeding there should be higher current to melt the wire coming out continuously at higher speed. So basically for the deposition rate heat is required to melt the wire hence according to H=I2RT (H- Heat, I- Current) current and heat are directly proportional to wire speed. Similarly voltage and current are also related to each other according to V=IR. So we can say that each control factor is related to each other partially or directly influencing the deposition rate.

6.2: Optimal Parameters Setting: - The analyses of variance test results showed that the A2 B2 C2 D2 is the optimal parameters setting for the deposition rate. In this study we concluded that the optimal input parameters setting for the current is 250 amp, voltage is 30 V, wire speed is 50 cm/sec and gas flow is 15 Kg/cm^2 while welding the stainless steel 304 on the MIG welding machine as far as the deposition rate is concerned.

7. CONCLUSION

Based on the experiments conducted the following conclusions have been drawn:

- Wire Speed and Current both affects the deposition rate significantly while welding the stainless steel 304 on MIG welding machine. Theoretically for the deposition rate current should be high for higher heat (H=I2RT) to melt the wire electrode which is continuously fed.
- With regard to the average response, wire speed and current are more significant for deposition rate as compare to voltage and gas flow.
- For the S\N ratio response of deposition rate, wire speed has been found to have highest contribution followed by current. If wire speed is not proper as compare to the current then it affects the deposition rate.
- Current too high and wire speed is low - Improper deposition of weld metal (thin bead).
- Current is low and high wire speed – wire does not melt properly.
- The analyses of results showed that the A2 B2 C2 D2 is the optimal input parameters setting for the deposition rate when welding the stainless steel 304 on MIG welding machine. Where the values of optimal settings are-

A2= 250 amp B2=30 V

C2= 50 cm/sec D2= 15 Kg/cm2

Current, B- Voltage, C- Wire Speed, D- Gas Flow

The optimized value of deposition rate is 2.98 Kg/hr respectively. The optimized value for deposition rate has been validate through the confirmation experiments.

REFERENCES

[1] D.Katherasan, Madana Sashikant, S.Sandeep Bhat, P.Sathiya [2012], “Flux Cored Arc Welding Parameter Optimization of AISI 316L

(N) Austenitic Stainless Steel", World Academy of Science, Engineering and Technology 61 2012.

[2] Gusri Akhyar Ibrahim, Che Hassan Che Haron, Jaharah Abdul Ghani, Ahmad YasirMoh. Said, andMoh. Zaid Abu Yazid [2011], "Performance of PVD-Coated Carbide ToolsWhen Turning Inconel 718 in DryMachining", Hindawi Publishing Corporation Advances in Mechanical Engineering Volume 2011, Article ID 790975, 7 pages doi:10.1155/2011/790975.

[3] Khairi Yusuf1, Y. Nukman, T. M. Yusof1, S. Z. Dawal, H. Qin Yang, T. M. I. Mahlia and K. F. Tamrin [2010], "Effect of cutting parameters on the surface roughness of titanium alloys using end milling process", Scientific Research and Essays Vol. 5(11), pp. 1284-1293, 4 June, 2010.