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Effect and analysis of process parameters on welded joints made by MIG welding process using design of experiment method

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ABSTRACT

In industry welded joints are the most important part for making products. Welded joints are made by a various process like TIG, MIG, spot resistance welding, arc welding process etc. For the present research study, the MIG welding process is selected for analysis of the welded joints. Three process parameters are selected for this study which is feed rate, gas flow rate and gap among pieces. The design of experiment method is selected for making the experiment table. The method is BB response surface method. In this method, low centre and high levels are selected. Total of 30 experiments is generated using this DOE approach. One response parameter welding time is measured for this research study. Model equation generation using adequacy check is also conducted in this research study.

Keywords— *MIG, Process parameters, Welding time box-bhenken design, ANOVA analysis*

1. INTRODUCTION

Welding is a process of joining two or more pieces of the same or dissimilar materials which are melted together by the application of heat or pressure or both and with or without adding filler material to obtain monolithic structures.

1.1 Welding Process

The welding process is divided into two sections which are following
- Plastic Welding
- Fusion Welding

1.1.1 Plastic Welding Process: Plastic Welding Process is otherwise called Pressure Welding Process. The process in which two metal pieces are fortified together by the use of outer powers creating a temperature beneath the softening purpose of the base material without the expansion of filler material is known as Pressure Welding Process. In this process, the metal pieces encounter a plastic state because of warming furthermore, by the use of outside pressure. Along these lines, the joining of metal pieces is delivered because of the use of temperature, time and pressure combination without dissolving the base material. The metals joined utilizing this process can keep up their original properties as base metals, in light of the fact that no dissolving occurs in the base metals amid Pressure Welding Process.

1.1.2 Fusion Welding Process: Fusion Welding Process is also known as Non-Pressure Welding Process. In this process, the metals are joined by heating the material to the molten state and then cooling it to solidify. In Fusion Welding Process, no external pressure is applied. The fusion takes place only by the application of various sources. The shielding gases such as argon, helium, nitrogen etc. protect the molten metal from the surrounding atmosphere by providing proper shielding. Similarly, the filler material is also added to attain fully filled joints.

The main objective of the present research dissertation is to perform practicable research analysis on process parameters of MIG welding on EN-08 object material which is not in the heat treated condition. The effect of process parameters of MIG on response parameters is also investigated in present research work. The individual investigation of present research work is the following:
(a) Perform analysis on MIG for varying the feed rate of filler material for different levels to check the feasibility of MIG responses like hardness, joint structure, strength etc.
(b) Perform analysis on MIG for different levels of inert gas flow conditions to check the different responses
(c) Perform the analysis for changing the gap among two different test pieces, which have the same object material to find the strength of the combined object. This analysis is much more advanced and new for this research outcome.

2. EXPERIMENTAL SETUP

In the present research study, the MIG machine used for field experiments is present in figure 1. The machine is installed at college foundry shop at RIET, Jaipur.

Fig. 1: Experimental Setup of MIG welding machine

As seen in the figure, the machine setup shows the feeder system as well as the torch used for the welding process. Pilot experiments are conducted to verify the machine process parameters and the outcome of pilot experiments are shown in figure 2. The pilot experiment is conducted to find the effect of changing the process parameters like feed rate, gas flow rate and effect of a gap for welded joints.

Fig. 2: Pilot experiments analysis for MIG process

3. MATERIAL SPECIFICATION

In present work one material is selected for welding experiments, the selection of material depends on literature review and local availability of material and machine working conditions. The material is an industrial grade of steel (EN-24). EN-24 is used in general applications like household products made of sheets, automobile body making, agriculture products, construction equipment etc. Chemical and mechanical properties of EN-24 is present in table 1 and table 2 respectively.

Table 1: Chemical Composition of EN-24 (in % composition)

Material	C	Mn	Si	Cr	Ni	P	Fe
EN-24	0.35	0.60	0.25	0.85	1.8	0.035	Balance

Table 2: Mechanical Properties of EN-24 (ANSI-4340)

Material	Tensile Strength (N/mm2)	Yield Strength (N/mm2)	% Elongation	Impact (Izod J)	Hardness HB
EN-24	900	700	13	55	250

4. FACTOR AND LEVELS

Three factors are selected for the current research study and present in this section, the factors are selected on the basis of pilot experiments which is performed and present in this chapter. These parameters are present in table 3 with levels.

Table 3: factor and levels

Factor	Unit	Min (-1)	Center (0)	Max (+1)
Feed rate	Inch/sec	4	5	6
Gas Flow	psi	3	3.5	4
Gap	mm	0	1	2

The experiment table is generated using Box-Bhenken design method and the experiment table generated using MINITAB software is present in table 1 for this research study.

Table 4: Experimental results for responses selected for MIG study

Run Order	Feed Rate	Gas Flow Rate	Gap	Welding Time
1	5	3.5	1	36.03
2	5	3.5	1	32.29
3	6	3	1	37.75
4	5	3.5	1	35.76
5	5	4	0	34.09
6	5	3	2	66.94
7	5	3.5	1	35.81
8	6	3.5	0	27.47
9	6	4	1	44.15
10	4	3	1	54.56
11	4	3.5	0	46.85
12	5	3.5	1	34.9
13	4	3.5	2	77.84
14	6	4	1	47.13
15	6	3	1	41.02
16	4	3	1	54.12
17	5	4	0	45.53
18	5	3	0	35.29
19	4	3.5	0	44.35
20	6	3.5	2	70.29
21	6	3.5	0	32.03
22	5	3	0	36.31
23	5	3	2	62.84
24	5	4	2	67.42
25	4	4	1	62.38
26	4	3.5	2	70.01
27	4	4	1	57.92
28	5	3.5	1	35.76
29	6	3.5	2	69.62
30	5	4	2	65.37

5. RESULT AND DISCUSSION

The present research work is focused to improve process parameters effect, on welding quality made with MIG welding machine. In the present research work design of the experiment, the method is used for experiment table generation and the factor and levels are present in table 4 for this research work. The adequacy check for welding time is present in table 5.

As discussed in the following section the various test is conducted to analyse the regression modelling of the equation through adequacy check is performed for welding time and the results are present in table 5.

Table 5: Adequate model for Welding Time (WT)

Sequential Model Sum of Square Test						
Source	SS	df	MS	F-Value	P-value	
Linear	4541.24	3	1513.75	21.94	0.000	
Linear + Square	6035.01	6	1005.83	72.12	0.000	
Linear +2-way	4615.04	6	769.17	10.29	0.000	
Full Quad	6108.81	9	678.76	60.02	0.000	Selected
Lack of Fit Test						
Source	SS	df	MS	F-Value	P-value	
Linear	1642.87	9	182.54	20.57	0.000	
Linear + Square	149.10	6	24.85	2.80	0.044	
Linear +2-way	1569.06	6	261.51	29.47	0.000	
Full Quad	75.29	3	25.10	2.83	0.075	Selected

Error Test						
Source	**SS**	**df**	**MS**	**Contribution (%)**		
Linear	1793.74	26	68.99	28.31		
Linear + Square	299.97	23	13.40	4.74		
Linear +2-way	1719.93	23	74.78	27.15		
Full Quad	226.16	20	11.31	3.57		Selected
Model Summary Test						
Source	**St. Dev.**	**R^2**	**Adj-R^2**	**PRESS**	**Pre-R^2**	
Linear	8.30	71.69	68.42	2147	66.10	
Linear + Square	3.61	95.26	94.03	529	91.64	
Linear +2-way	8.64	72.85	65.77	2361	62.72	
Full Quad	3.36	96.43	94.82	567	91.04	Selected

As seen in table 5, the full quad mode equation is selected for further analysis means optimization of response analysis. As seen in SS test, the P value is in range of 0.05 for all options but in lack of fit test only one equation show p-value more than 0.05 which is a full quad model equation, in Error test full quad show lower contribution when compared with other model equation options.

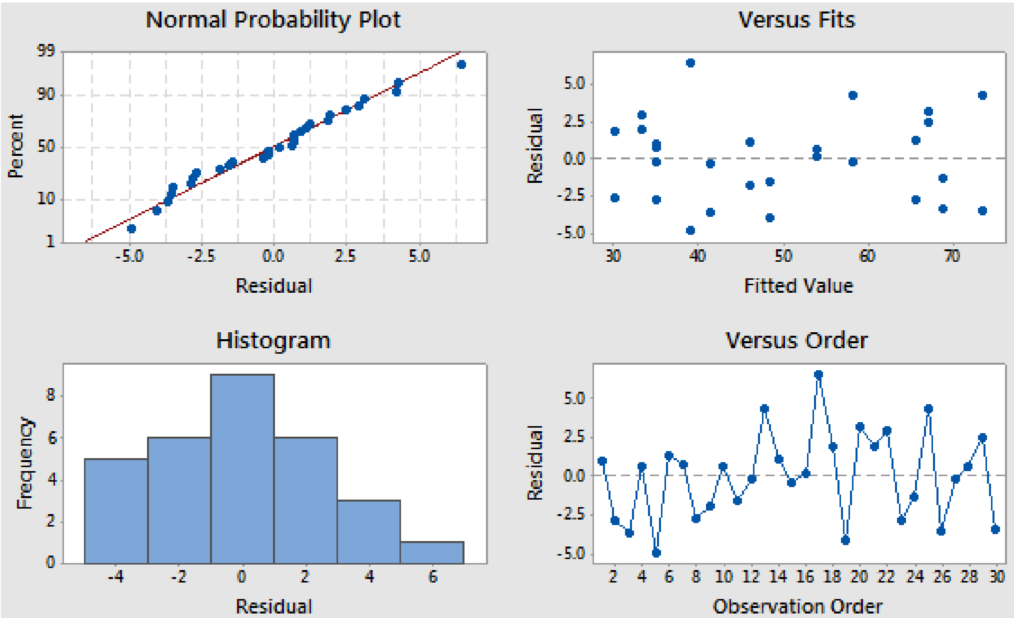

Fig. 3: Residual Plot for WT for Full Quad model

Figure 3 shows the residual plots for Full Quad model for WT, as seen in normal distribution plot, it is a clear show that residual is very low when compare with theoretical best value (zero).

5.1 Interaction plot for Welding Time (WT)

Interaction plot for welding time is shown for all three factors are shown in figure 4 to figure 6. As seen in figure 4, the first figure at the lower left side, the X-axis has feed rate and Y-axis has welding time whereas holding factor is gas flow rate. In this figure, it is shown that by changing the levels of feed rate, WT is decreased for each level of holding factor gas flow rate.

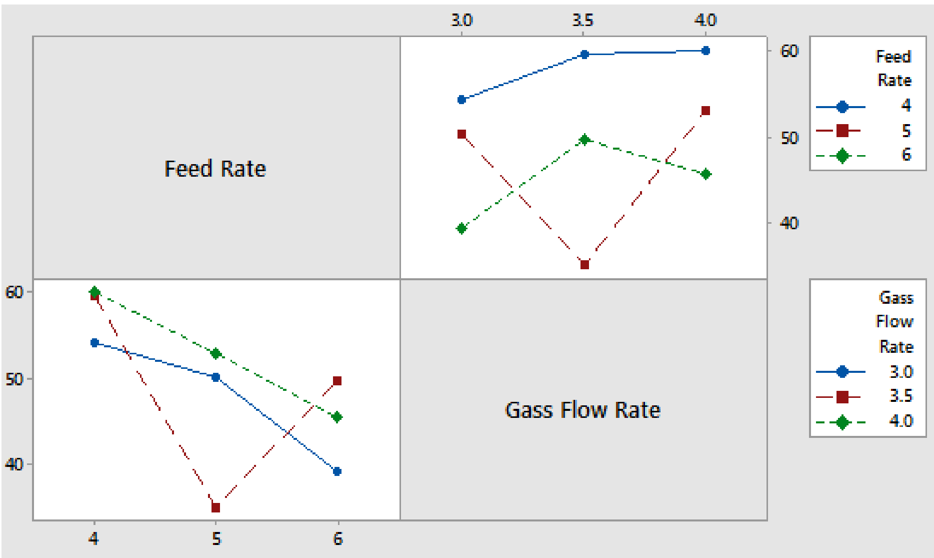

Fig. 4: Full matrix interaction plot for feed rate and gas flow rate for WT

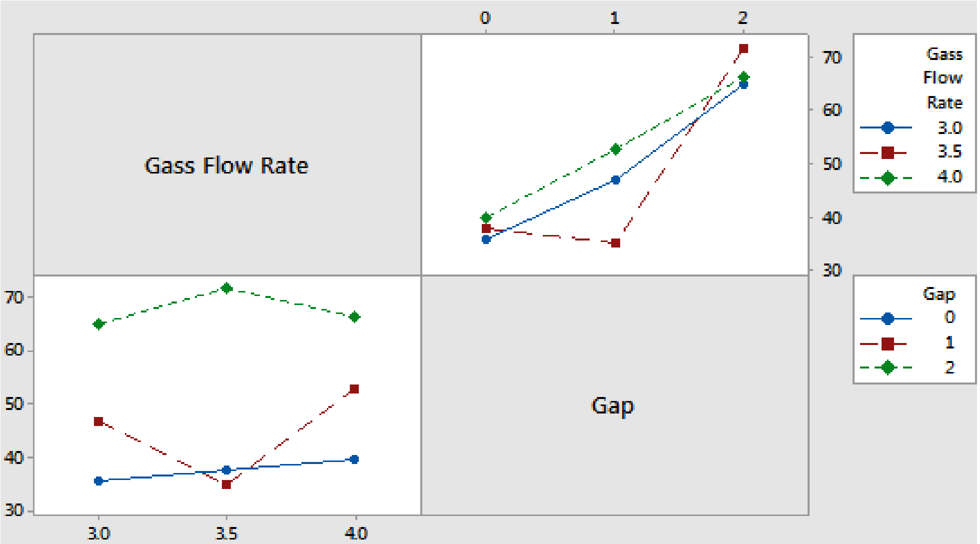

Fig. 5: Full matrix Interaction plot for Gas Flow rate and Gap for WT

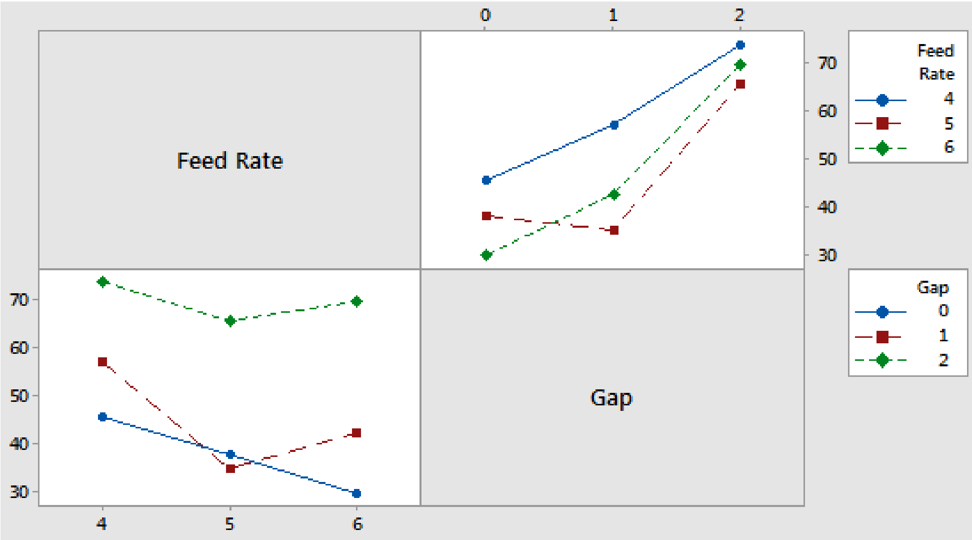

Fig. 6: Full matrix Interaction plot for Feed Rate and Gap for WT

5.2 Model equation for welding time (WT)

WT = 570.2 - 99.3 Feed Rate - 159.3 Gas Flow Rate - 16.5 Gap + 8.94 Feed Rate*Feed Rate
+ 23.41 Gas Flow Rate*Gas Flow Rate + 10.78 Gap*Gap + 0.22 Feed Rate*Gas Flow Rate + 2.97 Feed Rate*Gap
- 1.25 Gas Flow Rate*Gap

6. CONCLUSION

The main conclusion of this study is present in this section and the conclusions are following and present here

- Box-Behnken Design (BBD) is applied for three factors feed rate, gas flow rate and gap for three levels for MIG study. Total of 30 experiments is designed using this DOE technique. One response welding time is selected as output parameters for MIG research work.
- Adequacy check analysis is performed for welding time response variables using Analysis of Variance (ANOVA) tests. The final regression model equation for welding time (WT) is a full quad model equation

WT = 570.2 - 99.3 Feed Rate - 159.3 Gas Flow Rate - 16.5 Gap + 8.94 Feed Rate*Feed Rate
+ 23.41 Gas Flow Rate*Gas Flow Rate + 10.78 Gap*Gap + 0.22 Feed Rate*Gas Flow Rate + 2.97 Feed Rate*Gap
- 1.25 Gas Flow Rate*Gap

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