Parametric Optimization on MIG Welded EN8 Material Joints by using Taguchi Method

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Abstract—Welding is a manufacturing process, which is carried out for joining of metals. By MIG Welding it is possible to weld in all positions. Optimization of the parameter will be carried out by Taguchi method. We will use EN-8 material which is more use in Automobile parts. EN8 plate with dimensions 250mm x 125mm x 6mm with V- Groove 650.Where the input parameters are welding current, Wire feed and gas flow rate and output parameters are tensile strength and Hardness.

Key words: MIG Welding, Orthogonal array Method, ANOVA, S/N Ration.

I. INTRODUCTION

Welding is recognized all over the world today, as a remarkably versatile means of metal fabrication. Welding is the process of metallurgical joining of metals by the application of heat or pressure or both. Welding, in combination with allied processes like thermal cutting, brazing and metal spraying has provided ample freedom to the modern designer to develop metallic products in which optimum mechanical properties, lightness and aesthetics are harmoniously blended. A large number of welding and allied processes have come into industrial use in last 30 years. Variations and extensions of these processes are being developed and put to practical use from time to time. Thus the metal joining technology is in a constant state of flux. The unbalance radial electromagnetic force was firstly obtained by measuring the real time input electrical impedance of GMAW. This force serves as an attaching force because it pushes the droplet aside of the welding wire and sticks on the tip of welding wire as a result of surface tension force. In spray transfer mode, lower unbalance radial electromagnetic force was observed when argon shielding gas was used [1]. The wide range and variety of these processes enables to the modern engineer to join almost all commercial metals and alloys in many different shapes and sizes and in thicknesses ranging from a fraction of millimetre to over 500 mm.

II. LITERATURE REVIEW

A. The effect of Gas Metal Arc Welding (GMAW) processes on different welding parameters [2]

Izzatul Aini Ibrahim et al (2012): Gas Metal Arc Welding (GMAW) process is leading in the development in arc welding process which is higher productivity and good in quality. In this study, the effects of different parameters on welding penetration, microstructural and hardness measurement in mild steel that having the 6mm thickness of the base metal by using the robotic gas metal arc welding are investigated. The variables that choose in this study are arc voltage, welding current and welding speed. The arc voltage and welding current were chosen as 22, 26 and 30 V and 90, 150 and 210 A respectively. The welding speed was chosen as 20, 40 and 60 cm/min. The penetration, microstructure and hardness were measured for each specimen after the welding process and the effect it was studied.

As a result, it obvious that increasing the parameter value of welding current increased the value of depth of penetration. Other than that, arc voltage and welding speed is another factor that influenced the value of depth of penetration. The microstructure had shown the different grain boundaries of each parameter that affected of the welding parameters. The grain boundaries of microstructure changes from bigger size to smallest size when the variable welding parameters changed.

B. A study on V-groove GMAW for various welding positions [3].

D.W. Cho et al (2012-13): This study performed three-dimensional transient numerical simulations using the volume of fluid method in a gas metal arc V-groove welding process with and without root gap for flat, overhead, and vertical welding positions. The elliptically symmetric arc models for arc heat flux, electromagnetic force and arc pressure were used to describe the more accurate molten pool behaviours. The numerical models not only formed a stable weld bead but also simulated the dynamic molten pool behaviours such as overflow which was not described before. This study analysed these molten pool flow patterns for various welding positions and validated the numerical models used by comparing the simulation results with experimental ones.

1) Without the root gap, it is difficult to form a fully penetrated weld bead in the flat and overhead positions, while humping and melt-through beads are formed in the vertical-upward position under the same welding condition.
2) With a 1-mm root gap, the molten pool overflow patterns can be described for various welding positions under the given welding conditions. The overflow patterns in some welding positions do not induce the weld defects, while a weld bead with incomplete penetration can be formed in the vertical downward position. Thus, it is necessary to avoid the overflow patterns in such a case by increasing the welding speed.

C. Parametric optimization of weld strength of Metal Inert Gas Welding [4]

Chandresh N. Patel et al (2013): He has studied Design of Experiment method (Full factorial method) for this work and by the use of the experimental data has optimized by gray relational analysis (GRA) optimization technique. In which input parameters for MIG welding are welding current, wire diameter and wire feed rate and the output parameter is hardness.

We were used AISI 1020 or C20 material for welding. It is a plain carbon steel and also known as "soft" or mild steel. Small scale trial welding experiments, in the light of field joint of the plate have been planned to perform on 5 mm plate thicknesses of low alloy steel AISI 1020 or C20 and double V-groove joint is used. For Experimental design we were used full factorial method ($L=m^n$) to find out number of readings. To find out the percentage contribution of each input parameter for obtaining optimal conditions, we were used analysis of variance (ANOVA) method. We take a gray relational analysis (GRA) optimization technique for optimization of different values. A gray relational grade obtained from the gray relational analysis is used to optimize the process parameters. By analysing the gray relational grade we find the optimum parameters.

Based on the result obtained, it can be concluded as follows:

- By use of ANOVA analysis the percentage contribution of MIG welding for welding current is 94.01 %, wire diameter of 0.402 % and wire feed rate of 0.016 % and the error is about 5.56 %. This error is due to human ineffectiveness and machine vibration. From the ANOVA it is concluded that the welding current is the most significant parameter for MIG welding. Increase in welding current, the value of hardness is increased in MIG welding.
- By use of the GRA optimization technique the optimal parameter combination is meeting at its parameter value 100 Amp welding current, 1.2 mm wire diameter and 3 m/min wire feed rate for MIG welding.

III. DESIGN OF EXPERIMENT (DOE)

Taguchi Method is used to arrange the experiments. The Taguchi technique has become a powerful tool for improving productivity during research and development work, so that higher quality products can be produced rapidly and at minimum cost. Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has introduced a method based on "ORTHOGONAL ARRAY" methods which give much reduced "variance" for the experiment with "optimum settings" of control parameters. So the marriage of Design of Experiments with optimization of control parameters to get best results is achieved in the Taguchi Method "Orthogonal Arrays" provide group of well balanced (least) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), they are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results [5].

1) Signal-to-noise ratio

1) Larger the better:

$$SN_l = -10\log\left(\frac{\sum_{i=1}^{n}\frac{1}{{y_i}^2}}{n}\right)$$

2) Smaller the better:

$$SN_s = -10\log\left(\frac{\sum_{i=1}^{n}{y_i}^2}{n}\right)$$

3) Nominal the better:

$$SN_N = 10\log\left(\frac{y^{-2}}{s^2}\right)$$

Where, η - Signal to Noise(S/N) Ratio,
Yi - it's observed value of the response,
n - no. of observations in a trial,
y - Average of observed values (responses) [7].

Work Material: The work material used in the present work is En - 8, the dimensions of the work piece length 250mm, width 125mm, thickness is 6mm. Shielding Gas: 20 %CO2, 80 % Argon.

Chemical Composition Of EN-8 Material	
Carbon	0.36-0.44 %
Silicon	0.10-0.40%
Manganese	0.60-1.00%
Sulphur	0.050 max.
Phosphorus	0.050 max.

Table. 1: EN8 Material Composition

080M40 (EN-8) – mechanical properties	
Yield Stress	465 N/mm^2
0.2% Proof Stress	450 N/mm^2
Elongation	16% Min
Hardness	201-255 Brinell

Table. 2: Properties of Material

Chemical composition of wire electrode	
Carbon	0.06-0.15%
Silicon	0.80-1.15%
Manganese	0.08-0.15%
Phosphorus	≤ 0.025%
Silicon	≤ 0.035%
Copper	≤ 0.50%

Table. 3: Chemical Composition of wire electrode ER70S-6

B. ANALYSIS OF S/N RATIO

In the Taguchi Method the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value (standard Deviation) for the output properties. Therefore, the S/N ratio to the desirable value of the S. D. S/N ratio used to calculate the quality characteristic variable from the desired value. The S/N ratio S is defined as

S = - 10 log (Mean of sum square of reciprocal of measured Data)

To get the optimal welding performance, higher the better quality characteristic for penetration must be taken. Regardless of the category of the quality, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio.

C. ANALYSIS OF VARIANCE

The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. This is to be accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, in contributions by each of the design parameters and the error. First, the total sum of squared deviations SST from the total mean S/N ratio can be calculated.

IV. EXPERIMENTAL PLAN AND DETAILS

The experimental design was according to an L'9 array based on Taguchi method, while using the Taguchi orthogonal array would markedly reduce the number of experiments. A set of experiments designed using the Taguchi method was conducted to investigate the relation between the process parameters and response factor. Minitab 16 software is used for optimization and graphical analysis for obtaining data.

Parameters	Level 1	Level 2	Level 3
Welding Current(Amp)	120	125	130
Wire feed (m/min)	2.4	2.8	3.2
Gas flow rate (l/min)	12	14	16

Table. 4: Mig welding parameters and their levels

Run	Welding current Amp	Wire feed m/min	Gas flow rate l/min	Tensile strength	Hardness
1	120	2.4	12	590	70
2	120	2.8	14	603	88
3	120	3.2	16	594	74
4	125	2.4	14	592	84
5	125	2.8	16	622	88
6	125	3.2	12	522	80
7	130	2.4	16	440	84
8	130	2.8	12	511	74
9	130	3.2	14	540	78

Table. 5: Design of Experiments

Exp.	Tensile strength		Hardness	
Run	S/N	MEAN	S/N	MEAN
1	55.41704	590	36.90196	70
2	55.60635	603	38.84965	88
3	55.47573	594	37.38463	74
4	55.44643	592	38.48559	84
5	55.87581	622	38.88965	88
6	54.35341	522	38.0618	80
7	52.86905	440	38.48559	84
8	54.16842	511	37.38463	74
9	54.64788	540	37.84189	78

Table. 6: Mean and S/N ratio for Tensile strength and hardness

Level	Welding Current	Wire Feed	Gas Flow Rate
1	595.7	540.7	541.0
2	578.7	578.7	578.3
3	497.0	552.0	552.0
Delta	98.7	38.0	37.3
Rank	1	2	3

Table. 7: Response table for Mean of Tensile strength

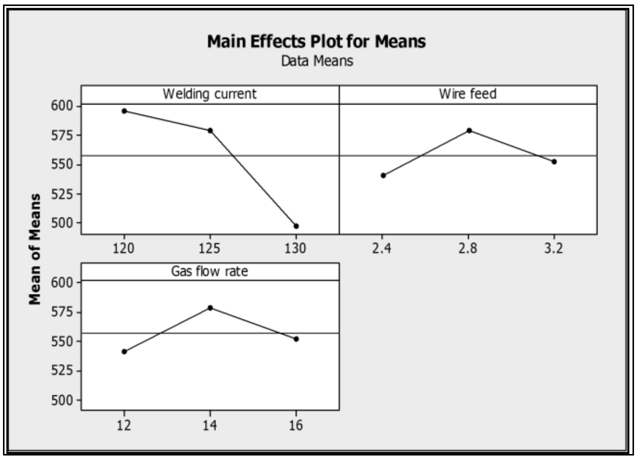

Fig. 1: Main effect plot for a mean of tensile strength

Level	Welding Current	Wire Feed	Gas Flow Rate
1	37.73	37.96	37.45
2	38.48	38.39	38.41
3	37.9	37076	38.25
Delta	0.75	0.63	0.96
Rank	2	3	1

Table. 8: Response table of S/N Ratio for Tensile strength

Level	Welding current	Wire feed	Gas flow rate
1	77.33	79.33	74.67
2	84.00	83.33	83.33
3	78.67	77.33	82.00
Delta	6.67	6.00	8.67
Rank	2	3	1

Table. 9: Response table of mean for Hardness

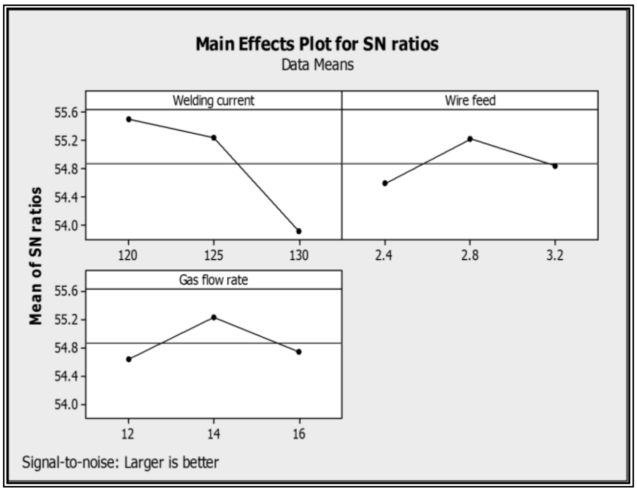

Fig. 2: Main effect plot for S/N Ration of tensile Strength

Level	Welding current	Wire Feed	Gas Flow Rate
1	37.73	37.96	37.45
2	38.48	38.39	38.41
3	37.90	37.76	38.25
Delta	0.75	0.63	0.96
Rank	2	3	1

Table. 10: Response table of S/N Ratio for Hardness

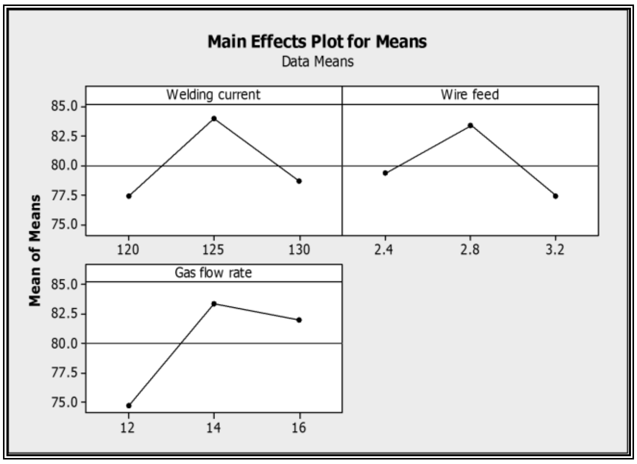

Fig. 3: Main effect plot for Mean of Hardness

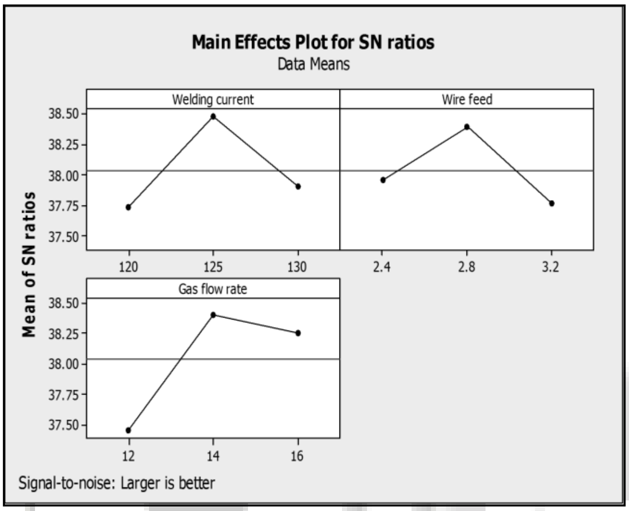

Fig. 4: Main effect plot for S/N Ration of Hradness

V. CONCLUSION

1) By use of ANOVA it can conclude that Current is the most significant parameter.
2) The gas flow rate is found to have an effect on hardness. Increase in welding current as increase the hardness.
3) In this experiment the value of the S/N ratio of tensile strength 55.87 which indicate optimal input parameter current 125 A, wire feed 2.5 m/min and gas flow rate is 16 l/min.
4) In this experiment the value of the S/N ratio of tensile strength 38.33 which indicate optimal input parameter current 125 A, wire feed 2.5 m/min and gas flow rate is 16 l/min.

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