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GMAW Process Parameter Utilisation Analysis using ANOVA and Taguchi Relations

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ABSTRACT ***- The present paper deals with the utilisation of welding parameters; Preheat temperature, welding current and Gas flow rate using Analysis of Variance (ANOVA) technique. It also deals with the Taguchi relations for optimised tensile strength and Rockwell hardness of the weld joint.. Gas Metal Arc Welding is carried out to create the weld joint between EN8 and Stainless Steel. Preheat temperature, Gas flow rate and Welding current are the parameters to be optimised. All the parameters are taken at 3 level and thus using degree of freedom, 9 set of experiments are carried out. Signal-to-noise ratio of each set of experiment is calculated and thus the optimised set of experiment in both cases, tensile strength and hardness of the joint, is evaluated. The final results exhibit a difference of 6% and 10% respectively for tensile strength and hardness from the measured values. ANOVA technique shows the highest contribution of around 74% in creating a highly strengthened weld.***

Keywords:- Gas flow rate, Grey Relational Analysis, Preheat temperature, Parameters optimization, Process Taguchi method, Welding current.

INTRODUCTION

Welding is a process used to permanently join the different materials like metals, alloys or plastics, together at their contacting surfaces by application of heat and pressure. During welding process, the work-pieces which have to be joined are melted and after solidification of this melted metal a permanent joint can be achieved. Sometimes a filler material is added to form a weld pool of molten material in between the two or more work pieces which after solidification gives a strong bond between the work pieces. Weld ability of a material depends on various factors like the metallurgical changes that occur during welding, changes in hardness in weld zone due to rapid solidification, extent of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the joint position.

I. OPTIMIZATION METHOD

A. *Taguchi Method*: A Taguchi method has now a days become a powerful optimization techniques for improving productivity during research and development, so that a high quality of the product can be produced at low cost and also quickly. Taguchi method is one of the best method which offers the effective selection process parameters minimum no.of experiments. Thus the combination of design of experiment with the optimal welding parameters to provide a best result is achieved in Taguchi Technique. With the help of Taguchi method it possible to find out which parameter is less influence and which is more influence. Taguchi technique use a special set or design called “Orthogonal array”, to investigate the entire process parameter with a small number of experiments only. Dr. Taguchi S/N ratio, which are log function of desired output, serve as a objective functions for optimization, help in data analysis and prediction of optimum results. Taguchi method use the S/N ratio to identify the control factors to optimization process first one is to find out those control factor that reduce variability and second is to find out those control parameters which have a small or no effect on the signal-to-noise ratio and which move the mean to target. The S/N ratio under different noise condition measures how the response varies relative to the nominal or target value. Depending on the goal of your experiment, you can choose from different signal-to-noise ratios. Minitab offers S/N ratios, for static design.

There are three Signal-to-Noise ratio of common interest for optimization:

Smaller-The-Better:

n= -10 Log_{10} [mean of squares of measured data]

Larger-The-Better:

n= -10 Log_{10} [mean of square of the reciprocal of measured data]

Nominal-The-Best:

n= 10 Log_{10} (square of mean/variance)

B. *Analysis Of Variance (ANOVA):* The purpose of ANOVA is to investigate which welding parameters significantly affect the performance characteristic. This is accomplished always by separating the total variability of the grey relational grades, which is measured by the sum of the squared deviations from the total mean of the grey relational grade, into contributions by each welding parameter and the error. First, when the total sum of the squared deviations SST from the total mean of the grey relational grade.

II. LITERATURE REVIEW

A. **Dheeraj Singh, Vedansh Chaturvedi, Jyoti Vimal [4]** this research paper discuss the optimum welding parameters for Gas tungsten arc welding. Taguchi method with an L16 orthogonal array (4-level and 4-factor) based on 16 experiment run were performed. Parameters namely used is current, gas flow rate, welding speed & gun angle is taken as a process parameters. The objective function have been chosen in relation to parameter of TIG welding bead geometry i.e. area of penetration, tensile load, , bead width, bead height, and penetration for quality target.

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Parameters/Factors		level		
		1	2	3
A	***Welding Current (Amp)***	100	112	124
B	***Gas Flow Rate (cu. mm/min)***	10	15	20
C	***Preheat Temperature (°C)***	275	285	300

Table 1. Welding Parameters

Table 1 shows the parameters to be optimised viz. welding current, preheat temperature and gas flow rate while Table 2 exhibits the designed set of experiments as per the degree of freedom calculated.

Experiment were perform on a specimen of1.2mm 304 stainless steel plate (30 x 250 mm). The paper presented the optimization of the TIG welding process of stainless steel work piece by the grey relational theory. The optimal process parameters that have been identified the best combination of process variables for S.S are current at 40 A, gas flow rate at 5 l/min, welding speed 12m/min and gun angle at a 80 ^{o}. After the predicted optimal parameter setting with the help of (ANOVA) the most significant factor also found in this case gun angle is having max % contribution.

B. **Deepak Malik, Sachin Kumar, Mandeep Saini [3]** investigate that the angular distortion is a major problem in butt weld plates. Restriction of this distortion by restraint may lead to higher residual stress. In initially angular distortion in (–ve) direction is provided to reduce the angular distortion if the magnitude of distortion is predictable. For optimizing the weld parameter control ANOVA is applied. In these paper the transverse direction of TIG, welding process was evaluated using following as main input parameter welding current, filler rod diameter, length of plate and time gap between passes. Experiment was carried out with SS 302 & MS samples of varying length, 50mm width and 6mm thick. The stainless steel and mild steel plates were prepared with V grove design and butt weld type. With single pass filler metal, the distortion is measured with dial gauge fitted to a height gauge. 70 to 100 Amps was used as a current variation. A carbon steel filler rod of 1.5 to 2.5 used as a filler metal in these cases

In this L9 orthogonal array was selected for design of experiments towards the distortion optimization caused by welding. MATLAB 16 software is used to developed a source code to do optimization. Direct and interaction effect of the process parameters were analyzed & presented in graphical form. At the end conclusion was explain that the highest effect on angular distortion is found of diameter of electrode. The least effect on angular distortion is found of time between successive passes.

III. EXPREIMENTATION

During the welding operation, parameters to be optimised are: Welding Current, Gas flow rate, Preheat temperature

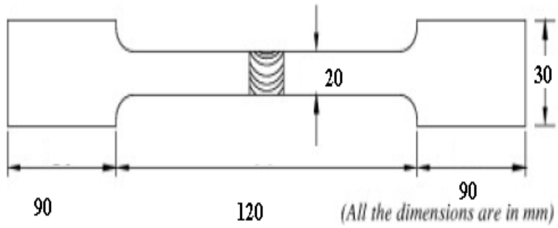

Fig. 1 Specimen

Material used in welding operation

A. **<u>EN8</u>:** EN8 is an unalloyed medium carbon steel which is used in applications where better properties than mild steel are required.

B. **<u>Stainless Steel</u>:** It is a family of iron-based alloys that contain a minimum of approximately 11% chromium, a composition that prevents the iron from rusting, as well as providing heat-resistant properties.

Exp. no.	*Welding current (Amp)*	*Gas flow rate (mm^3/min)*	*Preheat temperature (°C)*
1	100	10	275
2	100	15	285
3	100	20	300
4	112	10	285
5	112	15	300
6	112	20	275
7	124	10	300
8	124	15	275
9	124	20	285

Table 2. Design of Experiments of welding parameters

Source	*DF*	*Adj SS*	*Adj MS*	*F-Value*	*P-Value*	*Percentage*
Preheat temperature	2	0.066822	0.033411	97.00	0.041	74.22%
Gas flow rate	2	0.011022	0.005511	16.00	0.019	12.22%
Welding current	2	0.012289	0.006144	17.84	0.023	13.33%
Error	2	0.000689	0.000344			
Total	8	0.090822				

Table 3. ANOVA Grey Relation Grade (For Parameter Utilisation)

IV. RESULTS AND DISCUSSION

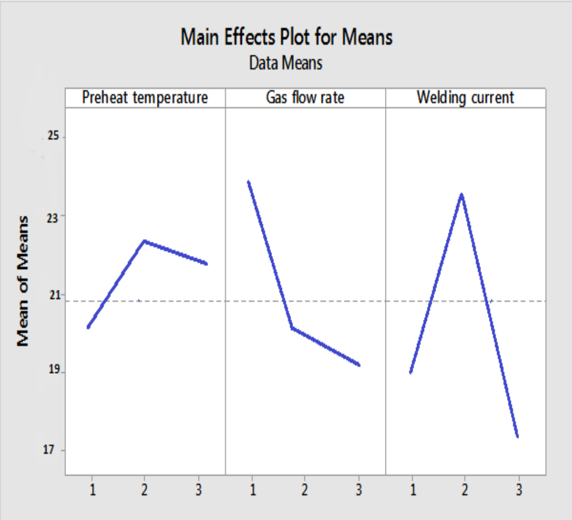

Fig. 2. Statistical Result of Tensile strength

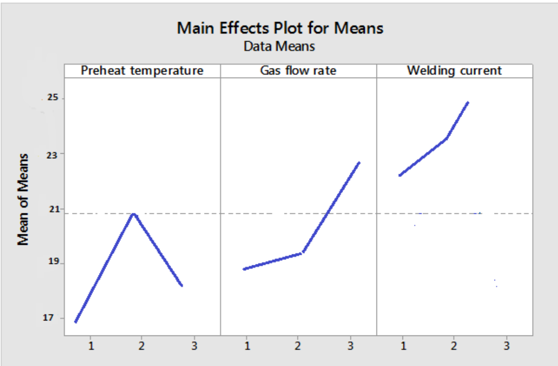

Fig. 3. Statistical Result of hardness

Fig.2 and Fig. 3 display the results graphically and it is clearly evident that for tensile strength the set of experiment A2B1C2 is the optimised experiment and for Rockwell hardness A2 B3 C3 is the optimised experiment.

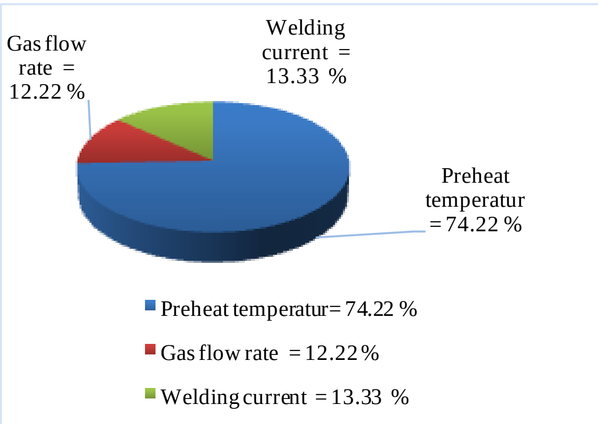

Fig.4. Graphical representation of utilization results

V. CONCLUSION

Tensile Strength			
Optimized Experiment	***Predicted Value***	***Observed Value***	***Percentage Deviation***
A2B1C2	88.78 MPa	94.65 MPa	6.20%
Rockwell Hardness			
Optimized Experiment	***Predicted Value***	***Observed Value***	***Percentage Deviation***
A2B3C3	75.56 HRC	84.07 HRC	10.12%

Table 4 Results of tensile strength and Rockwell hardness

The following conclusions have been noted by applying statistical approaches in the experimental investigations of Stainless steel and EN8 welded joint by GMAW.

Taguchi's based Grey relational analysis is suitable to analyze this problem as described in this work.

- The predicted v/s observed values are within the tolerance limits.
- It is found that the parameter design of Taguchi and ANOVA based relational analysis provides a simple, systematic and efficient methodology for the optimization of the GMA welding parameters.
- ANOVA results display the utilization factor with the utilization of preheat temperature about 74% in gaining the tensile strength and hardness of the weld.

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