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Optimization of Welding Parameters by Regression Modelling and Taguchi Parametric Optimization Technique

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Abstract - There are many welding parameters. In welding process, the major factors whose selection contributes to the welded product as they all affect the strength and quality to a larger extent are weld design (edge preparation), Root face, and Root gap. The purpose of this paper is to efficiently determine the optimum welding operation parameters for achieving the highest ultimate strength in range of parameters. In order to meet the purpose in terms of both efficiency and effectiveness, this study will utilize the Taguchi parameters design methodology. The study includes selection of parameters, utilizing an orthogonal array, conducting experimental runs, data analysis, determining the optimum combination, finally the experimental verification and comparison by regression modelling.

Keywords: Welding, Taguchi, Regression modelling

I. INTRODUCTION

Welding preferred over other joining process like riveting, casting and nut bolting because it is faster, quieter and many more advantageous over other joining techniques. Now a day, welding is extensively used in fabrications of automobiles, aircrafts, ships, electronic equipment, machinery, and home applications etc. as an alternative of casting or as a replacement of riveted or bolted joints. There are two main types of arc-welding processes. They are shielded metal arc welding and gas shielded arc welding.

The main advantages of shielded metal arc welding are that high-quality welds are made rapidly at a low cost. Shielded Metal Arc Welding, also known as manual metal arc welding, stick welding, or electric arc welding, is the most widely used of the various arc welding processes. Welding is performed with the heat of an electric arc that is maintained between the end of a coated metal electrode and the work piece (See Figure below).

Figure 1. Electric arc welding process

II. TAGUCHI METHOD

Taguchi method is the process of engineering optimization in a three step approach namely system design, parameter design and tolerance design. In the system design, a basic functional prototype design will be produced by applying scientific and engineering knowledge. In parameter design, independent process parameter values will be optimized and where as in tolerance design, tolerances will be determined and analyzed for optimal values set by parameter design. Taguchi method is a powerful design of experiments (DOE) tool for optimization of engineering processes.

Figure 2. Steps of Taguchi Method

III. EXPERIMENTAL SETUP

A. Work piece material

Low carbon mild steel sheet having chemical composition of following element.

TABLE I. Chemical composition of work piece.

Elements	C	Si	Mn	P	S
Weight %	0.06	0.09	0.37	0.063	0.065

The sheet sample in dimension of 100 mm in length, 50 mm in width, and 6 mm in thickness was used for electric arc welding in order to determine weld strength. The electrode used was 3.25mm of mild steel

B. Method

The following input and output parameters are:

Input parameters selected are V-butt angle, Root face, Root gap. The output parameter predicting strength of weld joint is Ultimate strength. The all sample is welded by keeping other parameters constant.

C. Plan of Experiment

The experiment was planned using Taguchi's orthogonal array in the design of experiments, which help in reducing the number of experiments. The L_9 orthogonal array. The welding parameters identified were v-butt angle, root face, root gap. Control parameters and their level indicated in table.

TABLE II. Control factor and their level

Level	V-butt angle(A) In (degree)	Root face(B) in mm	Root gap (C) in mm
1	40	1	1
2	50	2	1.5
3	60	3	2

TABLE III. Orthogonal L9 array of taguchi

Experiment	P1	P2	P3
1	1	1	1
2	1	2	2

3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

TABLE IV. Consulate design of parameters and their response.

Experiment No.	Combination of input parameters	Output response in N/ mm ²
1	111	18.966
2	122	19.047
3	133	19.620
4	212	22.890
5	223	23.707
6	231	24.688
7	313	25.506
8	321	25.587
9	332	22.890

Average of ultimate strength= 22.544 N/ mm²

IV. ANALYSIS OF SIGNAL TO NOISE RATIO

In the Taguchi approach, the term signal represents the desired value (mean) for the output characteristics and term noise represent the undesirable value (standard deviation) for the output characteristics. Therefore S/N ratio is the ratio of mean to the standard deviation. Taguchi uses the S/N ratio to measure the quality characteristics deriving from desired value. The S/N ratio is defined as given equation.

For Higher the better

It is when the occurrences of some undesirable product characteristics is to be maximized. It is given by

$$S/N = -10 \log ((\sum 1/ y_i^2)/N) \dots \dots \dots \text{--- "Eq.1"}$$

All the three level of every factor are equally represented in the nine experiments. S/N ratio and ultimate strength for each parameter at each level. Ultimate strength for each of the Parameters at each level is calculated. These also called as main effects.

TABLE V. S/N ratio for ultimate strength

Experiment No.	S/N ratio
----------------	-----------

1	25.559
2	25.596
3	25.853
4	27.192
5	27.497
6	27.849
7	28.132
8	28.160
9	27.192

Average of S/N Ratio = 27.003 db

V. Analysis of mean for ultimate Strength and S/N ratio

TABLE VI. Mean response of ultimate strength.

Parameter/Level	Level 1	Level 2	Level 3
V-butt angle	19.211	23.761	24.661
Root face	22.454	22.780	22.399
Root gap	23.080	21.609	22.944

TABLE VII. Mean response for S/N ratio

Parameter/Level	Level 1	Level 2	Level 3
V-butt angle	25.669	27.512	27.828
Root face	26.961	27.084	26.964
Root gap	27.189	26.660	27.160

The optimum level for a factor is the level that gives the highest value of parameter in each level in the experimental region denoted by bold letter. The estimated main effects can be used for this purpose.

VI. MAIN EFFECTS

Main effects plots for the experiments have been given below.

A. Response Graphs for Mean of ultimate strength

- 1) Level 3 for V-butt angle, $A_3 = 24.661 \text{ N/mm}^2$ indicated as the optimum situation in terms of ultimate strength values.
- 2) Level 2 for Root face, $B_2 = 22.780 \text{ N/mm}^2$ indicated as the optimum situation in terms of ultimate strength values.

- 3) Level 1 for Root gap, $C_1 = 23.080 \text{ N/mm}^2$ indicated as the optimum situation in terms of ultimate strength values.

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Figure 3. Response graph for mean of ultimate strength

B. Graphs for S/N ratio of ultimate strength

- 1) Level 3 for V-butt angle $A_3 = 27.828 \text{ db}$ indicated as the optimum situation in terms of S/N values.
- 2) Level 2 for Root face $B_2 = 27.084 \text{ db}$ indicated as the optimum situation in terms of S/N values.
- 3) Level 1 for Root gap $C_1 = 27.189 \text{ db}$ indicated as the optimum situation in terms of S/N values.

Figure 4. Response graph for mean of S/N ratio

VII. RESULTS

The maximum ultimate strength for:
 V-butt angle is in the Level 3= A_3 =Higher (60 degree).
 Root face is in Level 2 = B_2 =Medium (2 mm)
 Root gap is in Level1= C_1 = Lower (1 mm)

A. Conformation of Experiment

While considering three factor the experiments were conducted and result is that the combination of Higher V-butt angle (level 3), Medium Root face (level 2) and Root gap (leve l) then the ultimate strength is maximum.

TABLE VIII. conformation of experiment

Ultimate strength (Y) in N/ mm ²	S/N ratio in (db)
25.587	28.160

B. Mathematical regression Modelling

For the combination of parameters, ultimate strength value is tabulated. Empirical formula has find out by using regression modeling.

Modelling of parameters

To generalize the results the modelling of input parameter and output parameter is done using REGRESSION MODELLING and MATLAB software R2011b.

$$C_0 = 0.6751$$

$$C_1 = 0.6252$$

$$C_2 = 0.0028$$

$$C_3 = -0.0148$$

$$C_0 = \text{Antilog}(0.6751), C_1 = 0.6252, C_2 = 0.0028, C_3 = -0.0148$$

$$Y = 1.964 (\text{V-butt angle})^{0.6252} * (\text{Root face})^{0.0028} * (\text{Root gap})^{-0.0148}$$

$$Y = 1.964(60)^{0.0203} * (2)^{0.0845} * (1)^{0.1500}$$

$$Y = 25.425 \text{ N/ mm}^2$$

C. Predicted Result (By Taguchi Method) Predicted

ultimate strength =

$$A_3 + B_2 + C_1 - 2 * Y$$

$$= 24.661 + 22.780 + 23.080 - 2 * 22.544$$

$$= 25.433 \text{ N/ mm}^2$$

$$\text{Predicted S/N Ratio} = sA_3 + sB_2 + sC_1 - 2 * m$$

$$= 27.828 + 27.084 + 27.189 - 2 * 27.003$$

$$= 28.095 \text{ db}$$

VIII. Comparison of Results

There is comparison between Actual experimental result and Predicted result of Taguchi Design experiment and Regression modelling.

Figure 5. Comparison of results for Strength

Figure 6. Comparison of results for S/N Ratio

IX. SUMMARY

In the present work the relation between ultimate strength and various process parameters namely V-butt angle, Root face, Root gap has been developed.

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