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Optimizing Arc Welding Process Parameters Using Taguchi Technique

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Abstract— Welding is a basic manufacturing process for making components or assemblies in industries. Recent welding economics research has focused on developing the reliable machinery database to ensure optimum design. There are many welding parameters whose selection contributes to the welded product as they all affect the strength and quality to a larger extent. Some of them are material, welding rod, diameter of electrode, weld design Root face, and Root gap. In this research, welding input process parameters have been optimize for greater weld strength in Electric arc welding. Metal like mild steel (1018), carbon steel (1020) and alloy steel (4130) are presented as a study material and welding rod and voltage of current are the other two parameter for the T-joint welding.. After this theses welds are tested for bending strength on universal testing machine. The Taguchi methodology is adopted to analyze the effect of each welding process parameter on the weld strength, and the optimal process parameters are obtained to achieve greater weld strength. The study includes selection of parameters, utilizing an orthogonal array, conducting experimental runs, data analysis, determining the optimum combination. Finally the experimental verification has been done. Experimental results are provided to illustrate the proposed approach. Finally we derived a mathematical model for breaking load for bending with the help of MATLAB software. After the whole work comparative analysis of results from different theories has been done in which we found that all results are approximately similar. Hence author concluded that the values of parameters can be selected for other vital experiment on the basis of mathematical model generated bythis research.

Key words: Mild Steel, Carbon Steel, Alloy Steel, Welding Parameters, Electric Arc Welding, Taguchi Method

I. INTRODUCTION

Electrical arc welding is the procedure used to join two metal parts, taking advantage of the heat developed by the electric arc that forms between an electrode (metal filler) and the material to be welded. The welding arc may be powered by an alternating current generator machine (welder

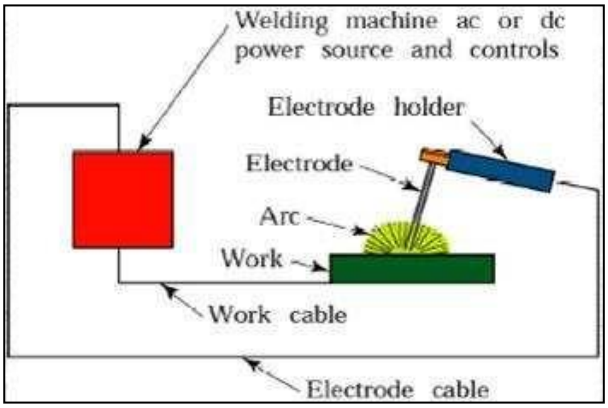

Fig. 1: AC or DC welding machine

Fig. 2: Experimental setup of electric arc welding

I. LITERATURE REVIEW

Nabendu Ghosh et.al. presented the parametric optimization of gas metal arc welding process by using grey based taguchi method on AISI 409 ferrite stainless steel. In the present work, X-ray radiographic test has been conducted in order to detect surface and sub-surface defects of weld specimens made of Ferrite stainless steel. Results of visual inspection and X-ray radio-graphic tests are compared, someconsistency are founds. The best result is obtained for the sample no.9. [1]

Aleem Pasha et.al. have worked on optimization of process parameters of arc welded joint by taguchi. Process parameters were optimized by Taguchi design of experiments. Regression equation has been stated by regression analysis for tensile strength & impact strength to predict the tensile & impact strength for various process parameters. . According to result mechanical behavior of the MMA welded joint for mild steel was studied by the Taguchi design of experiment and observed that the MMA weld joint exhibited comparable strength with the base material. [2]

Prof. S.D. Ambedkar et.al. have described the Parametric Optimization of Gas metal arc welding process by using Taguchi method on stainless steel AISI 410. The present study is to investigate the influence of welding parameters on the penetration. The optimization for Gas metal arc welding process parameters (GMAW) of Martensitic Stainless steel work piece AISI 410 using Taguchi method is done. Sixteen experimental runs (L16) based on an orthogonal array Taguchi method were performed. This work presents the effect of welding parameters like welding speed, welding current and wire diameter on penetration. The ANOVA and signal to noise ratio (S/N ratio) is applied to identify the most significant factor and predicted optimal parameter setting. An L16 orthogonal array was adopted to conduct the experiment suggested by MINITAB14 Statistical software. [3]

Vibhor Padhare et.al. have determined The Significant Factors Affecting The Bending Strength Of Weld Joint Prepared By Gas Metal Arc Welding. In this study weld joints of low carbon steel, medium carbon steel and die steels are prepared by Gas Metal Arc Welding (GMAW) process with varying process parameters of welding current, welding voltage and welding speed. The bending strength of the weld joints are measured using universal testing machine. The effects of various welding parameters is analyzed using Design of Experiment on ReliaSoft DOE++ software to determine the significant factors affecting the bending strength of the weld joint. Among the chosen different process parameters welding voltage is found to be the most significant factor affecting the bending strength of the weld joints. [4]

Deepak Kumar et.al optimized the Process Parameters of Gas Metal Arc Welding By Taguchi's Experiment Design Method. In this work, experiments were carried out on 1018 mild steel plates using gas metal arc welding (GMAW) process. L9 orthogonal array of Taguchi`s experimental design was used for optimization of welding current, voltage and gas flow rate on welded joints. L9 Orthogonal Array was selected to study the relationships between the tensile strength and the three controllable input welding parameters. Voltage is the significant factor for tensile strength but current and gas flow rate are the non-significant parameters in GMAW. [5]

Radosław Winiczenko discussed the Effect of friction welding parameters on the tensile strength and micro-structural properties of dissimilar AISI 1020-ASTM A536 joints. A hybrid response surface methodology (RSM) and genetic algorithm (GA)-based technique were successfully developed to model, simulate, and optimize the welding parameters. The results of the metallographic study show clearly that the friction welding process was accompanied by a diffusion of carbon atoms from ductile iron to steel. [6]

Ankita Singh et.al. have used the Taguchi's Method coupled with fuzzy based desirability function approach for the Optimization of bead geometry of submerged arc weld. Fuzzy inference system has been adapted to avoid uncertainly, imprecision and vagueness in experimentation as well as in data analysis by traditional Taguchi based optimization approach. . The proposed procedure is simple and effective in developing a robust, versatile and flexible welding process. Optimization of MPCIs of the process can easily be achieved through proper system model simulation in order to fulfill customers demand. Accuracy in prediction of the model analysis can be susequently increased by increasing number of membership function in the fuzzy system. [7]

Dharmendra Singh Jadoun et.al. have discussed the Optimization Of Welding Parameter For Arc Welding Of Mild Steel Plate (Grade-40). In this work The Taguchi method is adopted to analyze the effect of each welding process parameter on the weld strength, and the optimal process parameters are obtained to achieve greater weld strength. The tensile strength of the mild steel welded plates is measured in the Universal Testing Machine (UTM). Taguchi analysis for optimization of ultimate tensile strength is applied and found to be satisfactory. [8] M. Aghakhani et.al. investigated Parametric Optimization of Gas Metal Arc Welding Process by Taguchi Method on Weld Dilution. Finally a mathematical model based on regression analysis for predicting the weld dilution was obtained. Results from this research work show that wire feed rate (W),arc voltage (V) have increasing effect while nozzle-to-plate distance (N) and welding speed (S) have decreasing effect on the dilution whereas gas Flow rate alone has almost no effect on dilution. [9]

Binoy Krishna Biswas et.al. presented Optimization of Process Parameters for Flux Cored Arc Welding of Boiler Quality Steel Using Response Surface Methodology and Grey-Based Taguchi Methods. metal plates of boiler quality (BQ) steel have been welded by FCAW at varied levels of input parameters. Use of grey- based Taguchi method for multi-response optimization of the FCAW process in butt welding of BQ steel is reported. According to presented work Response surface and contour plots are developed. These are helpful to interpret combined effects of any two parameters on the response(s) while the third parameter is held at some constant level. [10]

II. LITERATURE SUMMERY

According to the survey of till presented research work it is found that in most of the cases TIG, MIG, GAS METAL ARC WELDING, SUBMERGED ARC WELDING, FRICTION STIR WELDING etc. are done on different materials. But from all of that welding techniques, electric arc welding has greater welding strength. For further checking the parameters selected are satisfactory or not Taguchi Methodology is adopted.

III. TAGUCHI METHODOLOGY

Taguchi is a methodology which gives the optimum combination of independent parameter which has a significant role to change the value of dependent parameter. The prime objective of the method is to design best quality product at least cost of manufacturer. This method was generated by Dr. Genichi Taguchi of Japan .This method has designed to investigate how various parameters significantly affect the mean and variance of parameter pertaining to main characteristic and quality of process

.The orthogonal arrays is the prime tool which arrays to organize the parameters affecting the process and the levels at which they should be varies. Taguchi method tests pairs of combinations in place of all possible combinations .This provide the necessary data to identify the significance of factors affecting product quality with a minimum recourses and time. The arrays are selected on the basis of degree of freedom of parameter which depends on the no of parameter and their level. The data from the arrays can be analyzed by visual analysis.

A. Taguchi Technique

This technique is completely based on statistical concepts and. Many renowned firms have achieved great success by applying this method. Taguchi method adopted experimentally to investigate influence of parameters such as material stress, thickness and diameter of pipe on the induced stress in chassis. The Taguchi process helps to select or to determine the optimum combination for material stress, thickness of pipe and diameter of pipe and effect of these parameters on induced compressive stress on chassis during time of collision. Many researchers developed many mathematical models to optimize these parameters to get minimum induced stress in various processes.

B. Philosophy of the Taguchi Method

1) Quality of product depends on the process by which it has been produced. One can improve the quality by optimising the parameter affects the process.
2) Best quality can be achieved by minimizing uncontrollable environmental factor which leads to deviation from a target.
3) The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system wide.

C. Procedure and Steps of Taguchi parameters design

1) Step-1: Selection of the quality characteristic:

There are three types of quality characteristics in the Taguchi methodology, such as smaller-the-better, larger the-better, and nominal-the-best. For example, smaller-the-better is considered when measuring fuel consumption of fuel in automobile or roughness in surface finish. The goal of this research was to find the effect of parameters and achieve minimum compressive stress induced during collision

2) Step–2: Selection of noise factors and control factors:

In this step, the controllable factors are material (M), Voltage (V) and diameter of electrode (D) which was selected because these are the factors which affect the induced tensile stress. Since these factors are controllable so they are considered as controllable factors in the study.
Uncontrollable factor may be the ambiance temperature and Humidity

3) Step–3: Selection of Orthogonal Array:

There are 9 basic types of standard Orthogonal Arrays (OA) in the Taguchi parameter design. Selection of arrays depends on the degree of freedom of selected parameter. Degree of freedom of all three parameter is 6. An L9 Orthogonal Array is selected for this work. The layout of this L9 OA is as mentioned in Table 1

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 1: L_9 Orthogonal Array

4) Step–4: Conducting the experiments:

Table illustrates the experimental settings in this study for maximum tensile stress. The parameters used in this experiment are material (three different materials), electrode diameter and voltage.

5) Step–5: Predicting Optimum Performance:

Using the aforementioned data, one could predict the optimum combination of material, electrode diameter and voltage for maximum tensile stress. With this prediction, one could conclude that which combination will creates the better result.

6) Step-6: Establishing the design by using a confirmation experiment:

The confirmation experiment helps to verify our prediction particularly when small fractional factorial experiments are utilized. The purpose of the confirmation experiment in this study was to validate the optimum tensile stress of butt joint.

IV. EXPERIMENTAL SETUP

A. Selection of frame

As the literature suggested, the experimental setup is constructed for the various factors and their levels are chosen, which affect the quality of product

The factor that considerably contributes to the variation in Quality is selected.

B. Electrode Diameter

The first parameter is electrode diameter and it has three levels low, medium, high.
D_1 = 4 mm, D_2= 5 mm and D_3 = 6 mm

C. Material

Material is the main aspect of chassis design. In these experiment three different materials is taken which is as follows.
M_1 = AISI 1018 Mild/Low Carbon Steel (Yield stress=370 MPa)
M_2 =AISI 1020 Low Carbon/Low Tensile Steel (Yield stress=450 MPa)
M_3 = AISI 4130 Alloy Steel (Yield stress=460 MP)

D. Voltage

The third parameter is voltage at which welding is done and it has also three levels low, medium, high.
V1=150V, V2=160V and V3=170V

S. No.	Symbol	Levels		
		Low	Medium	High
1.	D	4	5	6
2.	M	AISI 1018	AISI 1020	AISI 4130
3.	V	150	160	170

Table 2: Process parameters and their levels

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Expt No.	Electrode Diameter (mm)	Yield Tensile Stress(MPa)	Voltage (V)	Breaking Load (KN)
1	4	370	150	36.8
2	4	450	160	34.0
3	4	460	170	50.8
4	5	370	160	46.8
5	5	450	170	31.2
6	5	460	150	40.6
7	6	370	170	50.8
8	6	450	150	37.2
9	6	460	160	34.4

I. RESULT OF MATLAB

From the MATLAB result the equation formed is
Breaking Load Breaking Load
$=22.6079(\text{E dia})^{0.0141}*(\text{Yield stress})^{-0.7291}*(\text{Voltage})^{0.9761}$

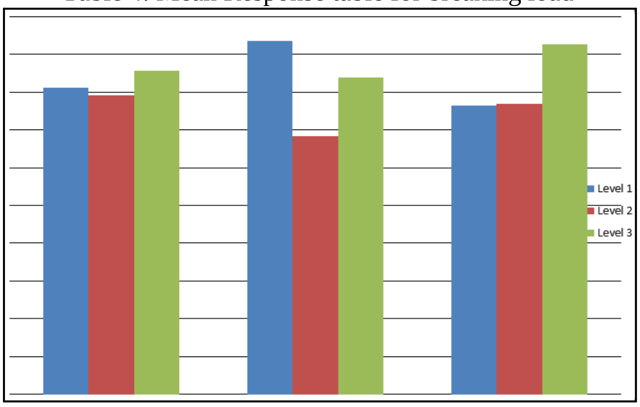
II. DISCUSSION

A. *Comparision Results of Butt Joint*

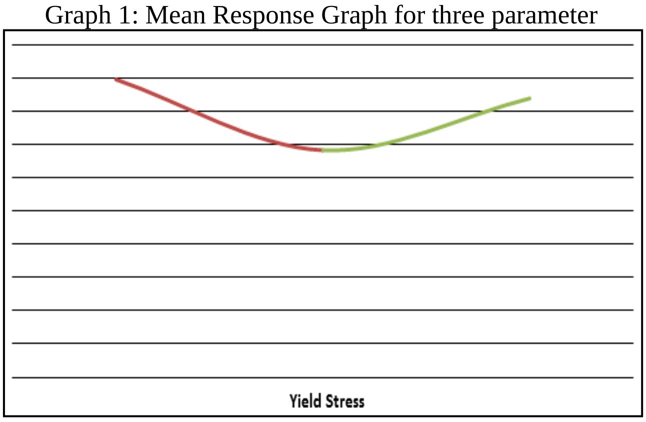
The final comparison of the confirmation for breaking load with values obtained from Taguchi parametric design & actual tensile testing of Butt-joint is in the table

Symbol	Controllable Factors	Breaking Load (KN)		
		L	M	H
D	Electrode Diameter	40.53	39.53	42.8
M	Material	46.8	34.13	41.93
V	Voltage	38.2	38.4	46.26

Table 4: Mean Response table for breaking load



Graph 1: Mean Response Graph for three parameter

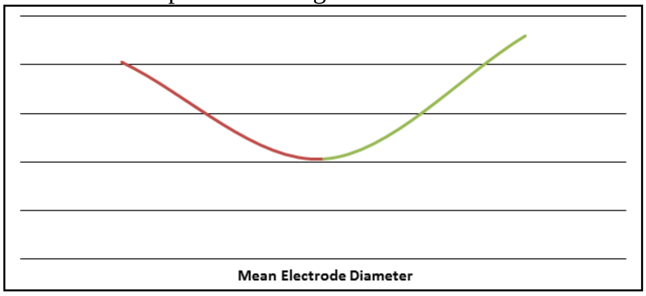


V. EXPERIMENTAL RESULTS

A. *Result of Tensile on UTM*

Table 3: Result of Tensile test on UTM of Butt-joint

Graph 2: Breaking Load v/s Yield Stress



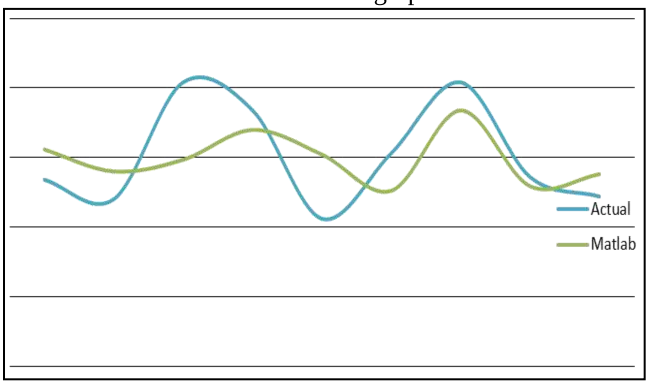
Graph 3: Breaking Load v/s Mean Electrode Diameter

Graph 4: Mean Breaking Load v/s Voltage

Exp No.	Elect. Dia. (mm)	Yield Tensile Stress (MP)	Voltage (V)	Breaking Load (KN) Actual	Breaking Load (KN) Mat lab
1	4	370	150	36.8	41.148
2	4	450	160	34.0	37.99
3	4	460	170	50.8	39.67
4	5	370	160	46.8	43.962
5	5	450	170	31.2	40.438
6	5	460	150	40.6	35.219
7	6	370	170	50.8	46.762
8	6	450	150	37.2	35.880
9	6	460	160	34.4	37.606

Table 5: Comparison Between ACTUAL and MATLAB Results

Graph 5: Comparison between ACTUAL and MATLAB results on graph



I. CONCLUSION

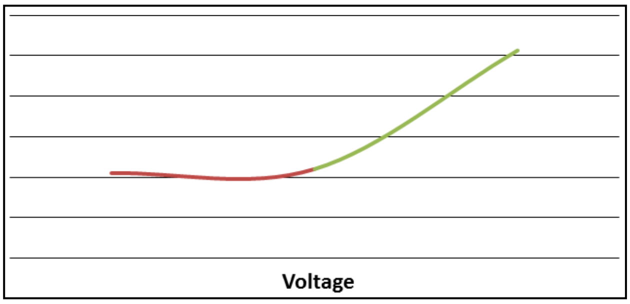
The thesis has discussed an application of Taguchi method for optimizing the design parameters and indicates that the Taguchi design of experiment is an effective way of determining the optimal combination of parameter.

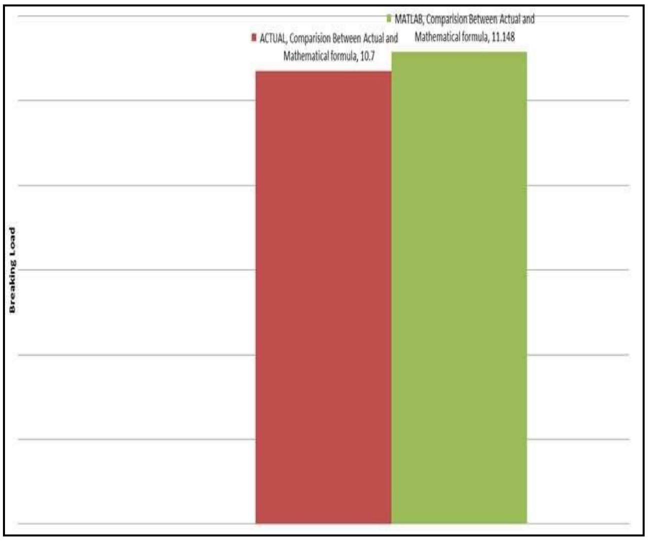
The outcome of the calculation and formulation for the optimization by Taguchi method, are summarized.

Results	Actual Breaking Load (KN)	Breaking Load by (Mathematical formula)
Level	$D_1+M_1+V_3$	$D_1+M_1+V_3$
Breaking Load (KN)	10.7	11.1480

Table 6: Optimum breaking load by ACTUAL and

MATLAB





Graph 6: Comparison between ACTUAL and MATLAB results

From response table and graph observational findings are illustrated that level 1 for electrode diameter level 1 for material and level 3 for voltage are the optimum situation in terms of mean value.The result obtained from the confirmation experiments reveals that the Taguchi method has provided the good prediction for the response value By the application of Mathematical regression modeling researcher has find out the empirical formula, which shows the relation between these three factors i.e. electrode diameter , material and voltage. By the use of this formula can be find out the value of Breaking load at the time bending at any given combination between given range.

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