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Optimization of TIG Welding Parameters on SS Materials using Regression Analysis

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Abstract— Quality and productivity play a major role in today's manufacturing market. Productivity can be increased by having sound knowledge of all the optimization techniques for machining. For TIG Welding on SS materials the experiments have been planned using Design of experimentation and followed by regression analysis. A L4 orthogonal array was chosen for experimental layout, to analyze the effect of each parameter on the welding characteristics Weld Current (I amps), Gas flow rate (FR L/min) and Root Gap (G mm))and to predict the optimal choice for each weld parameter such as weld current, Gas flow rate and root gap. Analyzed the effect of these parameters on Distortion (D) and Tensile Strength (TS).

Key words: Regression analysis, Weld current, Root gap, Tensile strength

I. INTRODUCTION

Gas tungsten arc welding (GTAW) is an electric arc welding process that produces an arc between a non-consumable electrode and the work to be welded. The weld is shielded from the atmosphere by a shielding gas that forms an envelope around the weld area. The size of the filler metal wire depends on the thickness of the base metal, which usually dictates the welding current. The methods of operation for GTAW can be manual or automatic

Welding procedure variables control the welding process and the quality of the welds produced. Joint configuration is determined by the design of the weldment, the metallurgical analysis, and by the process and procedure required by the weldment. Welding variables are selected after the base metal, filler metal, and joint configuration has been selected. The fixed welding variables include the type of filler metal, electrode type and size, the type of current, and the type of shielding gas. The adjustable variables control the shape of the weld by affecting things such as bead height, bead width, penetration, and weld integrity. The primary adjustable variables for GTAW are welding current, arc length, and travel speed. In TIG welding, an arc is formed between a non-consumable tungsten electrode and the metal being welded. Gas is fed through the torch to shield the electrode and molten weld pool. If filler wire is used, it is added to the weld pool separately In welding, bead geometry is very important characteristic [1]. Mechanical properties of welding joint are influenced by the composition of base metal and also on weld bead geometry [2]. Taguchi method is a powerful statistical tool that yields optimized values of process parameters for the design response characteristics. Meticulous experimental design using Orthogonal array coupled with standard or S/N analysis of results using Taguchi techniques gives optimum levels of parameters with minimum amount of experimentation.

II. REGRESSION ANALYSIS

Regression testing is a type of software testing that seeks to uncover new software bugs, or regressions, in existing functional and non-functional areas of a system after changes such as enhancements, patches or configuration changes, have been made to them.

The purpose of regression testing is to ensure that changes such as those mentioned above have not introduced new faults.[2] One of the main reasons for regression testing is to determine whether a change in one part of the software affects other parts of the software.[3]

Common methods of regression testing include rerunning previously completed tests and checking whether program behavior has changed and whether previously fixed faults have re-emerged. Regression testing can be performed to test a system efficiently by systematically selecting the appropriate minimum set of tests needed to adequately cover a particular change.
Since the true form of the data-generating process is generally not known, regression analysis often depends to some extent on making assumptions about this process. These assumptions are sometimes testable if a sufficient quantity of data is available. Regression models for prediction are often useful even when the assumptions are moderately violated, although they may not perform optimally. However, in many applications, especially with small effects or questions of causality based on observational data, regression methods can give misleading results.

In a narrower sense, regression may refer specifically to the estimation of continuous response variables, as opposed to the discrete response variables used in classification. The case of a continuous output variable may be more specifically referred to as metric regression to distinguish it from related problems reduces to solving a set of N equations with N unknowns (the elements of β), which has a unique solution as long as the X are linearly independent.

If f is nonlinear, a solution may not exist, or many solutions may exist. The most common situation is where N > k data points are observed. In this case, there is enough information in the data to estimate a unique value for β that best fits the data in some sense, and the regression model when applied to the data can be viewed as an over determined system in β.

Under certain statistical assumptions, the regression analysis uses the surplus of information to provide statistical information about the unknown parameters β and predicted values of the dependent variable Y.

III. EXPERIMENTATION

A. Work Piece Material:

In the present Experimentation AISI type 316l stainless steel is used having many advantages such as low thermal conductivity, high resistance of corrosion and high stability at elevated temperatures and also it is used in numerous industries, including electronics, medical instruments, home appliances, automotive and specialized tube industry. It has excellent forming and welding characteristics. The properties of a typical stainless steel sheet are given in table-1.

Carbon	0.03 max.
Manganese	2.00 max.
Phosphorus	0.045 max.
Sulfur	0.03 max.
Silicon	0.75 max.
Chromium	16.00 - 18.00
Nickel	10.00 - 14.00
Molybdenum	2.00 - 3.00
Nitrogen	0.10 max

Table 1: Material Composition of SS316l

Tensile strength	Yield strength	Density	Melting point	Thermal conductivity	Elongation
515 Mpa	290 Mpa	7.99 g/cm^3	1400-1450^{o}c	21.4 W/m^o K at 500^{o}c	20 %

Table 2: Properties of AISI 316l Steel

B. Experimental Set-Up:

When selecting TIG welding machine, you should know how much power and sophistication are needed for the job. It is also necessary to ascertain the volume of such jobs currently on hand and the projected business for TIG welding. The next question is - does one need AC or DC power source. Professionals say that aluminum and magnesium are two metals that are best welded using the AC output from the power source. Steels and stainless steels are most often welded with DC output. To weld a variety of metals, use a combination AC/DC machine.

If the power source is either moved around the shop, or taken from one site to another, then a portable welder is needed. There are two basic ways to accomplish portability – inverters and engine-driven welders. Inverters are now available that weigh around 13 kg and come with handles for easy shifting around. Engine-driven machines are used when a welder has no access to primary power for welding. Engine-driven power sources are needed for field maintenance, pipe welding, or construction work.

C. The Process Parameters Considered In The Present Investigation Are:

1) Welding current
2) Gas flow rate
3) Root gap

1) Welding Current:

Welding current is the most influential parameter because, it affects bead shape, controls the rate at which electrode is melted and therefore also controls the deposition rate, heat affected zone, the depth of penetration and the amount of base metal melted. Penetration and reinforcement increase with the increase in welding current [3].

If the current is too high at a given welding speed, the depth of fusion or penetration will also be too high, so that the resulting weld may tend to melt through the metal being joined. High current also leads to waste of electrodes in the form of excessive reinforcement and produces digging arc and undercut. This excessive welding increases weld shrinkage and causes greater distortion [5].

The current used will be determined by the choice of electrode, electrode diameter, material type and thickness. Current has the significant effect on penetration. Three levels of current are chosen in the present work and level values are given in Table 2.

Polarity:
Polarity is generally determined by operation and electrode type
E.g. DC +ve, DC –ve or AC

Parameter	Notation	Units	Levels of factors	
			L_1	L_2
Welding current	I	Amp	80	90

Table 3: Level values of Welding Current

2) Gas Flow Rate:

Pure Argon is normally used as a TIG shielding gas and is suitable for both steel and aluminium welding. The shielding gas must be completely inert. [6] Flow rate will generally be 6 to 7L/min. The rate might be increased slightly to compensate for drafty conditions. TIG uses a lot of shielding gas so it pays to set up the gas flow accurately. A flow meter attached to the regulator will give a more accurate flow reading than the gauge on the regulator.

Parameter	Notation	Units	Levels of factors	
			L_1	L_2
Gas flow rate	FR	l/min	8	10

Table 4: Level values of Gas flow rate

3) Root Gap:

Butt welds are the welds where two pieces of metal are joined at surfaces; they are at 90 degree angles to the surface of at least one of the other pieces. These types of welds require only some preparation and are used with thin sheet metals that can be welded with a single pass. Common issues that can weaken a butt weld are the entrapment of slag, excessive porosity or cracking [6]. The root gap levels selected are shown in Table 5.

S.No	Name of the response characteristic	Quality characteristic
1	Distortion	'Smaller the better'
2	Tensile strength	' Bigger the better'

Table 5: Response characteristics and their quality characteristic

D. Deciding The Orthogonal Array:

Taguchi method helps in arriving at systematic analysis of the experimental results to derive a meaningful conclusion with minimum amount of experimentation. Taguchi Orthogonal array is quite useful to have meticulous experimental design [7]. In the present investigation three factors are considered at three levels which yield to total degrees of freedom of '6'. So a L9 array with total degrees of freedom of '8' is chosen for experimentation [7]. This L9 array can accommodate the entire 3-level factor considered is given in Table 5 which shows L9 array.

Trial no	Welding parameter levels		
	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

Table 6: L4 (23) Orthogonal Array

E. Experimentation:

SS plate of 5mm thickness is chosen as work piece material. Butt weld joint is made with these 5 mm thick SS plates by maintaining parameter values as mentioned in Table 5. Experimental trial combinations are carried out at random to minimize the effect of noise factors.

IV. RESULTS AND DISCUSSION

The experiment was carried on SS 316L grade material with Design of Experimentation (DOE). The output factors are absorbed using dial guage and the universal testing machine. The table.6 the input parameters that are taken for experimentation and results. Fig: 1 shows the values of the tensile strength and in fig: 2 shows the distortion values of the experiments.

Exp.No	Current (amps)	Root gap (mm)	Gas flow (l/min)	Tensile Strength(Mpa)	Distortion (mm)
1.	80	1	8	204	0.7
2.	90	2	10	197	1.5
3.	80	1	10	225	0.9
4.	90	2	8	214	0.7

Table 7: Results of the experimentation

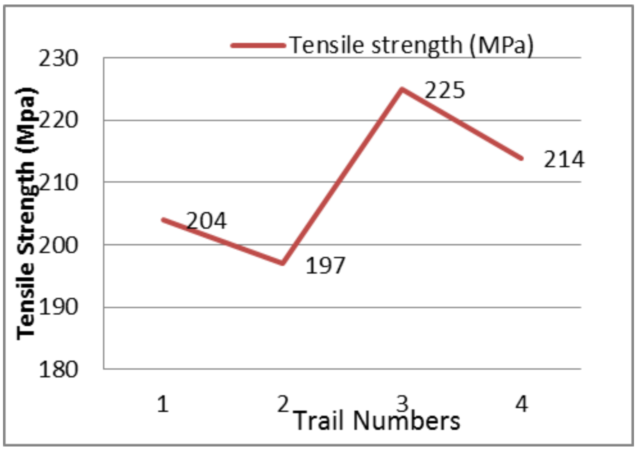

Fig. 1: Tensile strength vs experimental trails

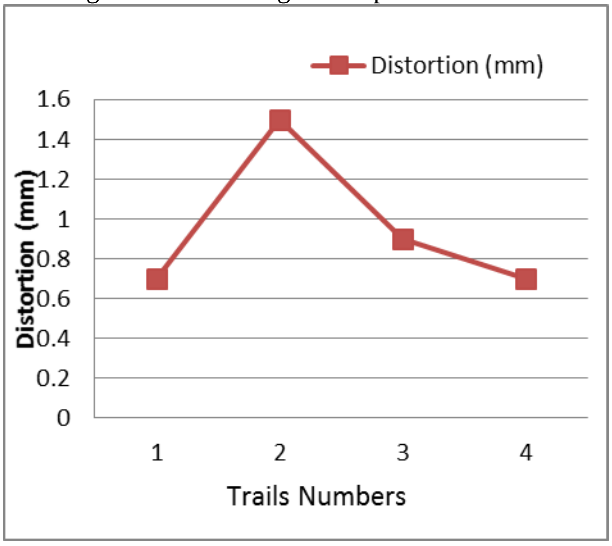

Fig. 2: Distortion vs experimental trails

Exp.no	Current (amps)	Root gap (mm)	Gas flow (l/min)	Tensile Strength(Mpa)	Distortion (mm)
3.	80	1	10	225	0.9
4.	90	2	8	214	0.7

Table 8: Optimum experimental values

The reduced values of distortion lead to reduced costs. The present study involves design of experiments to develop the process knowledge base and a linear regression analysis technique to account for the major contribution of the selected factors on the response of quality process evaluators. The gas flow rate is found to be a major contributing factor. The interactions of current and gas flow rate are the most influencing factor with respect to tensile strength. The interactions of voltage and gas flow rate and the gas flowrate alone influence the bead width. The interactions of current and voltage greatly influences the tensile strength of the material. The confirmation tests demonstrated a closer agreement of prediction with experimental results as evident from the results that the error is within 10%. It proves the effectiveness of the selected regression analysis to be capable of better predictions for tensile strength and distortion.

V. Conclusions

After conducting the experiments and analyzing the experimental results the following conclusions are made.

- Welding process parameters such as welding current, root gap and gas flow rate selected as studying factors. The process parameters are chosen using DOE.
- In the current investigation the effect of process parameters on Tensile strength and distortion are studied.
- DOE method is used to do numerical simulation of experiments, and experiments are carried out find out tensile strength and distortion values.
- Regression analysis is used to obtain the optimum values and the experimental values are compared with these values.
- The error percentage between experimental and regression values for tensile strength is found to be under 4%.
- The error percentage between experimental and regression values for tensile strength is found to be under 11%.

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