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OPTIMIZATION OF SS316L WELDMENTS USING SMAW BY VARYING FILLER ELECTRODE

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Abstract - *Shielded metal arc welding (SMAW) is an AW process that uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding. This work aims at optimization and analysis of SS316L weldments using SMAW, SS316L is selected over other grades because of its lower carbon content and its weldability properties. The welding parameters are being assessed by means of Taguchi's mixed level design (L16 orthogonal array) with varying welding current, welding angle and filler electrode with the predictions achieved the sample is welded. Welding currents were chosen as 80A, 90A, 100A and 110A, welding angles were chosen as 15°, 25°, 35° and 45°, the filler electrodes were chosen as E316Land E308L. Analyzed the tensile strength of the specimens welded based on the design and optimization is done, and using that optimized parameter welding is again done and microstructural analysis was carried out.*

Key Words*: *Shielded Metal Arc Welding, Stainless Steel 316L, Taguchi method, Tensile Strength.

1. INTRODUCTION

Welding is a process of joining two or more pieces of the same or dissimilar materials to achieve complete coalescence. This is the only method of developing monolithic structures and it is often accomplished by the use of heat and or pressure. Although in its present form it has been used since about the beginning of 20th century but it is fast replacing other joining processes like riveting and bolting. At times it may be used as an alternative to casting. SMAW is one of the methods of fusion welding; here actual melting of the metal is involved in forming the bond[1]. Fusion welding requires an intense source of heat for the melting of heat both parent metal and filler electrode.

Presently welding is used extensively for fabrication of vastly different components including critical structures like boilers and different pressure vessels, ships, off-shore, structures, bridges, storage tanks and spheres, pipelines, railway coaches, anchor chains, missile and rocket parts, nuclear reactors, fertilizers and chemical plants etc. Welding is also used in heavy plate fabrication industries, pipe and tube fabrication, jointing drill bits to their shanks, automobile axle to brake drums, lead wire connections to transistors and diodes, sealing of containers of explosives like nitroglycerine, welding of cluster gears etc[2].

1.1 Stainless steel 316L

Stainless steels or corrosion resistant steels are those alloy steels that have a Cr content of at least 12.5%. These steels do not rust and strongly resist attack by a great many liquid, gases and chemicals unless the Cr has reacted with C and leads to Chromium Carbide precipitation. This reaction is known as sensitization. So to avoid or reduce this reaction it is preferred to increase the Cr percentage or reduce the carbon percentage. Because of that, here the material selected is SS 316L, where the L represents low carbon.

SS 316L is a austenitic stainless steel which usually contains a combined total of Cr, Ni, and MN content of 24% or higher with Cr content more than 16% and Ni content more than 7%[3]. The Cr gives the oxidation and corrosion resistance while the Ni and Mn stabilize the austenite phase sufficiently to retain most or all of it when the steel is cooled rapidly to room temperature.

1.2 Tensile testing

Tensile tests are carried out to determine the ultimate tensile strength and yield point under static loading of base metal, weld metal and welded metal. Percentage elongation (ductility of joint), over and under matching, reduction of area as well as proof stress for hard steels. For determining the tensile strength of base metal the usual procedure of finding the tensile strength is used and to determine the tensile strength of weld metal alone or welded joint the samples are prepared. Here transverse butt weld test is used for tensile testing.

2. OPTIMIZATION OF THE PROCESS PARAMETERS USING TAGUCHI METHOD

There are different types of optimization process like full factorial, Response surface, Taguchi etc. And in the case of full factorial design as the number of factors and their level increases the number of runs increases exponentially therefore it increases the experimentation cost along with the time also. So we prefer Taguchi's orthogonal array method for the optimization of the parameter due to the reason that it is simple and also accurate technique and it can be used effectively to identify problems that are happening in a manufacturing process quickly from the existing data. The software called Minitab is used for the construction of array. It gives the mean performance value close to the required values, thus improves the quality of the product. So using such an arrangement we can perform completely randomized experiments [4]. Taguchi's method of optimization for process parameter permits evaluation of the individual parameter which is independent of the other parameter and also their interactions on the identified quality characteristic which is the ultimate tensile strength.

3. EXPERIMENTAL PROCEDURE

To investigate the characteristics of weldments, the weld beads were obtained by welding two stainless steel 316L flat plates of dimension 100mm×20m×5mm in the butt position using the filler electrodes E316L and E308Lof 3.15mm diameter. The chemical compositions of base metal used SS316L, electrodes used E308L and E316L is shown in the table 1. The Taguchi's design for mixed levels and the three parameters which is here employed is shown in the table 2.The welded samples are machined according to ASTM A370 standards to take the tensile tests. Compared to other design processes like factorial design where, as the number of experiments increases exponentially with that of the factors and levels also increases. On the other hand Taguchi design doesn't gives any complicated results or the number of experiments will not increase that much as factors and levels increases compared to other design processes and still with a number of experiments we can able to get optimum result using this[5]. Therefore Taguchi design of L16 orthogonal array is selected for 3 levels and 3 factors for the both the electrodes as shown in the Table 3. Here the transformer used for welding is Ador Welding Transformer which is shown in the figure 1. The specification of the Ador welding transformer is given in the table 4.

Table -1: Chemical composition of SS316L, E316Land E308L

Elements (wt %)	SS316L	E316L	E308L
C	0.03	0.03	0.03
Cr	16-18	18	21
Ni	10-14	12	9.20
Mo	2-3	2.8	0.75
N	.10	.10	.10
Mn	2	1.9	1.6
Fe	Balance	Balance	Balance

Table -2: Parameters and factors

Levels	Current (A)	Travel angle (°)	Electrode
1	60	15	E316L-16
2	80	25	E308L-16
3	100	35	-
4	120	45	-

Table -3: Experimental data

Sl.No	Current (A)	Travel angle (°)	Electrode
1	60	15	308L
2	60	25	308L
3	60	35	316L
4	60	45	316L
5	80	15	308L
6	80	25	308L
7	80	35	316L
8	80	45	316L
9	100	15	316L
10	100	25	316L
11	100	35	308L
12	100	45	308L
13	120	15	316L
14	120	25	316L
15	120	35	308L
16	120	45	308L

Fig -1: Ador Welding transformer

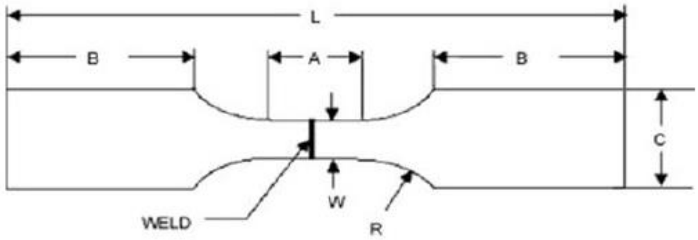
Table -4: The specifications Ador transformer for the welding is given below:

Phase	3phase, 50 cycles/sec
Current	50 A to 400 A
Open circuit voltage	80 volts
Efficiency	0.85%
Power factor	0.4
Energy consumption	4kWh/kg of Metal deposit
Welding speed	1 min/200mm

4. RESULTS AND DISCUSSIONS

4.1Tensile Test

The welding operation was performed on the test-pieces with respect to the parameters incurred by the Taguchi's orthogonal array, which is represented in Table 3. The tensile test was conducted with the help of UTM on the samples and the data was recorded for further tests.



Name	Dimensions (mm)
L	200
A	57
W	12.5
R	12.5
B	50
C	20

Fig -2: ASTM Testing specimen

The ASTM (American Society for Testing and Materials) standard tensile testing specimen for tensile testing on as per norms of ASTM A370 on welding work piece. Mainly there are two types of standard dimensions one for plate and another for rod type specimen. Now the profile is used for welding of plate type specimen. So the selection of standard tensile testing specimen is plate type standard specimen for welding [6].

Fig -3: Specimen (Before testing)

Fig -4: Specimen (After testing)

Here the specimen before testing and after testing is shown in the figure 3 and figure 4 respectively. And the values obtained from the test are shown in the table 5.

Table -5: Tensile Strength

Sl.No	Tensile strength (MPa)
1	496.36
2	509.89
3	527.21
4	516.74
5	511.19
6	493.88
7	509.47
8	514.66
9	536.72
10	553.08
11	541.95
12	526.18
13	529.07
14	493.86
15	487.65
16	511.44

4.2 Contour Plots

In a contour plot, the two variables are represented in the X and Y axis whereas the third variable will be represented as the shaded region which is called as the Contour.

Here for the sake of simplicity in using MINITAB software, the electrodes 308L and 316L are represented as 1 and 2 respectively.

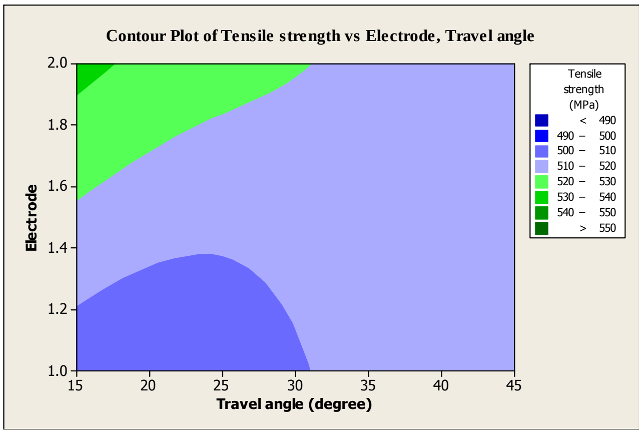


Fig -5: Contour plot of tensile strength (MPa) vs electrode and travel angle(°)

Figure 5 shows a contour plot of tensile strength vs electrode and travel angle in degrees. The figure shows that for a tensile strength greater than 550 MPa we need to have an travel angle at a range of 15 to 18° approximately and the electrode should be E316L which is indicated in the top left corner of the figure.

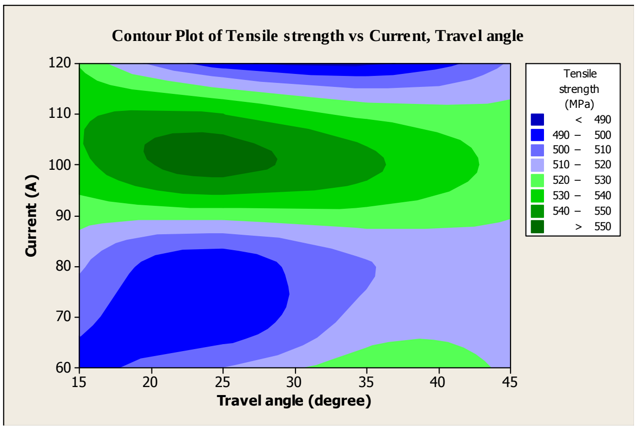


Fig -6: Contour plot of tensile strength (MPa)vs current (A) and travel angle(°)

Figure 6 shows the Contour plot of Tensile strength (MPa) vs Current in Amperes, travel angle in degrees. The maximum value of tensile strength is achieved when the current is in the range of 98 to 105A, and the electrode should be 19 to 25° which is calculated approximately from the graph.

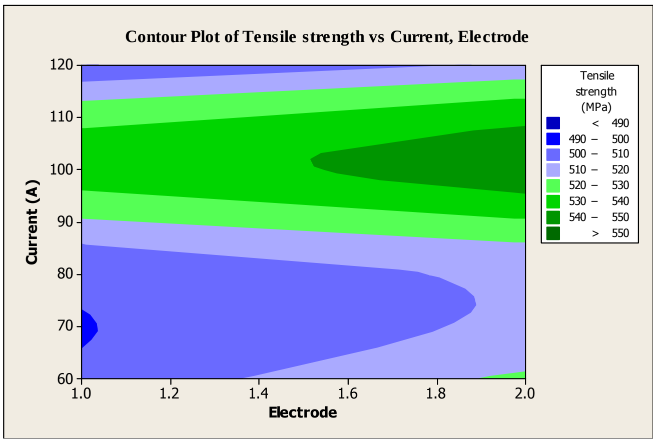


Fig -7: Contour plot of tensile strength (MPa) vs current (A) and electrode

Figure 7 shows the Contour plot of Tensile strength vs electrode, current in Amperes. The maximum value of tensile strength is reached when the current is 98 to 105A approximately and the electrode should be E316L which is observed from the Figure 5.

4.3 Probability Plots

Use of probability plots helps to determine whether a particular distribution fits your data or to compare different sample distributions. It calculates the cumulative distribution function (cdf) and confidence intervals based on parameters estimated from your data. We can also provide historical parameters using the distribution options. The parameter estimates the historical parameters which are displayed in an output table along with an Anderson-Darling goodness of fit statistic and associated p-value and the number of observations.

If the distribution fits your data:

• The plotted points will roughly form a straight line;

• The plotted points will fall close to the fitted distribution line.

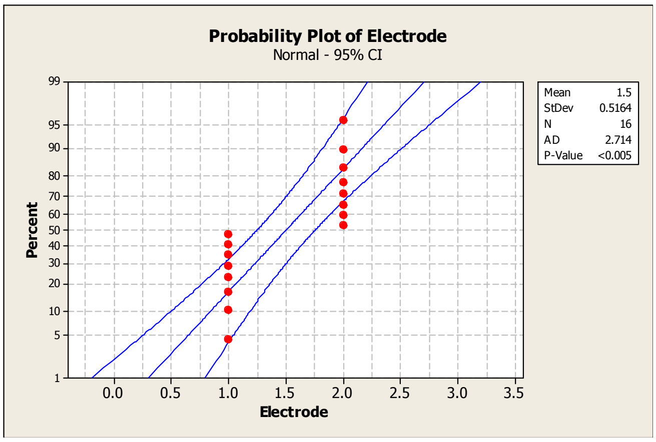


Fig -8: Probability Plot of electrode

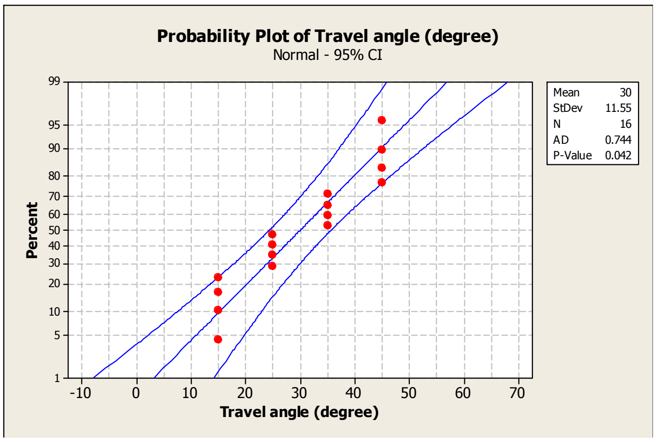


Fig -9: Probability Plot of travel angle (°)

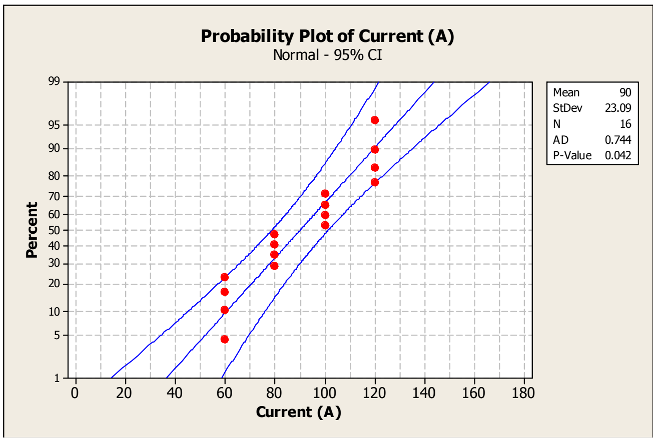


Fig -10: Probability Plot of current (A)

The Figures 8, 9 and 10 shows the probability plots which were obtained using the statistical software Minitab showed that the plotted points roughly formed a straight line and the plotted points have fallen close to the fitted distribution line which indicates that the distribution has fitted the data which is given as input.

4.4 Main effect Plot for means

Average response for each combination of control factor levels in the design. When performing a statistical analysis, one of the simplest graphical tools at our disposal is a main effects plot. This plot shows the average outcome for each value of each variable, combining the effects of the other variables as if all the variables are independent.

Figure 11 shows the main effect of plot for means where the optimum parameters will be based on the highest peak at each parameter. From the figure, the optimum parameter is determined. The optimized parameter according to the graph shows the electrode should be E316L, the travel angle should be 15° approximately and the current should be at a value of 100 amperes.

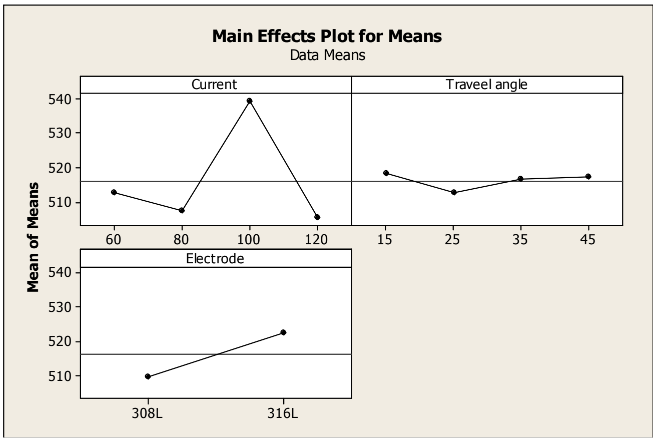


Fig -11: Main effect Plot for means - Tensile strength (MPa)

4.5 Microstructure study

The microstructure study is made in order to view the material properties after the welding operation being performed on the sample. The equipment used is metallurgical Microscope-METSCOPE-1 and the magnification of 100x. The microstructure was taken only for the sample which is welded using the optimized parameter and the microstructure of the three main zones that is Weld zone, Heat affected zone and the base metal is shown in Figure 12, Figure 13 and Figure 14 respectively. The micro structure of Weld Zone shows dendrite structure with fine grains, Heat Affected Zone shows coarse grains of austenitic structure and Base Metal shows coarse grains of austenitic structure.

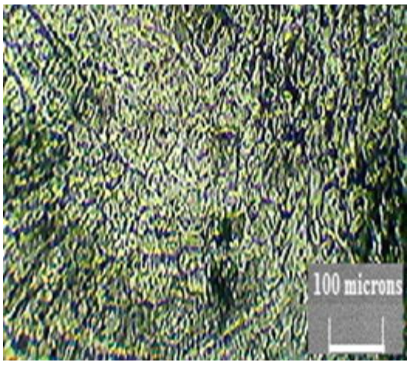


Fig -12: Weld zone

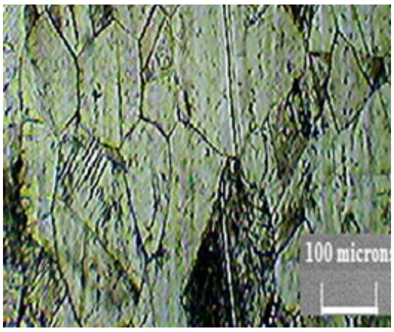


Fig -13: Base metal

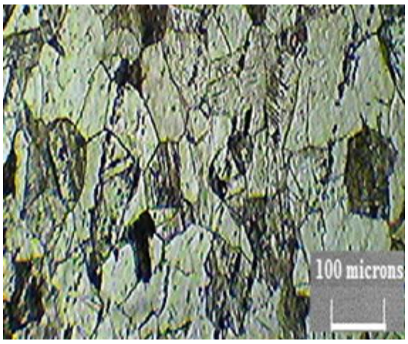


Fig -14: Heat affected zone

5. CONCLUSION

- The SS 316L shows good weldability for both the electrodes E308L and E316L.
- Current has the major impact on tensile strength and travel angle has the least impact on tensile strength.
- The optimum range includes current of 100 amperes, welding electrode of E316L, and travel angle of 15 degrees.
- The micro structure of optimized parameter weld specimen shows that, Weld Zone has fine grains of dendrite structure, Heat Affected Zone has coarse grains of austenitic structure and Base Metal has coarse grains of austenitic structure.

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