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Effect of Welding Parameters on Tensile Strength of a Mild Steel Specimen using Response Surface Method

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Abstract- In present work the effect of shielded metal arc welding (SMAW) process parameters on ultimate tensile strength (UTS) was investigated. The parameters used for the study were welding current, wire feed rate and number of welding passes. The correlations between the welding parameters and ultimate tensile strength were established by central composite rotatable design (CCRD) with quadratic model. The correlation coefficients found close to 0.9 signifies the reliability of selected model. Hence the model can be effectively used for predicting the response within the domain of the welding parameters. Analysis of variance (ANOVA) was used to predict the impact of welding parameters on the response. It can be seen that UTS mostly affected by higher order of welding current (nearly 40-60% contribution) followed by higher order of number of welding passes (nearly 30% contribution). From the experimental results, it is observed that UTS increases up to its maximum value for certain increase in all process parameters. Further increase in parameter value, decrease in UTS value was observed. An empirical relation for UTS was derived using the experimental results.

Keywords- Shielded metal arc welding (SMAW), Welding current, Wire feed rate, Number of welding passes, ultimate tensile strength (UTS), Response surface method

I. INTRODUCTION

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined are melted at the joining interface and usually a filler material is added to form a pool of molten material that solidifies to become a strong joint. Welding is used extensively in all sectors or manufacturing, from earth moving equipment to the aerospace industry. Shielded metal arc welding is a process that uses a coated consumable electrode to lay the weld. As the electrode melts, the (flux) coating disintegrates, giving off shielding gases that protect the weld area from atmospheric gases and provides molten slag which covers the filler metal as it travels from the electrode to the weld pool. Metals such as mild steel, carbon steels which are widely used in commercial applications are joined by SMAW welding process by choosing appropriate welding conditions. The variations in the welding conditions have significant effects on mechanical properties of welded joint.

II. EXPERIMENTAL DETAILS

2.1 Work piece details

In the present study, IS 2062 grade E250 steel plates were used, with dimensions 300mm × 50mm × 12mm. The chemical composition of the work piece was investigated; details of the same are given in Table 1. The carbon content is in between 0.16-0.29 %, therefore mild steel is having relatively low tensile strength. Each tensile specimen size was prepared in accordance with ASTM E08 standards as shown in Figure1. [1]

2.2 Experimental Details

SMAW process was used for welding, which uses 300 amp heat source with Copper coated steel electrode was used with 0.8 mm diameter, with uniform feed rate of 1 m / min. For avoiding warpage during and after welding of two plates C-clamps were used as shown in figure 2. A 600 Tonnage capacity of universal testing machine (UTM) was used to determine UTS. The specimen for tensile test were prepared using ASTM A370 standard. The details of the dimensions for test specimen are given in Fig. 1

Table 1. The Chemical Composition of IS 2062 Grade E250 Steel By Percentage

Carbon	Silicon	Manganese	Sulphur	Phosphorus
0.18	0.15	0.52	0.032	0.036

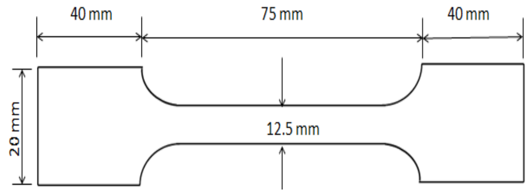


Fig. 1: Dimensions of Tensile Specimen

Fig. 2: Experimental Set Up Used In The Present Work

2.3 Design of Experiments (DOEs)

DOE approach was used to reduce total number of physical experiments and study the effect of other parameters such as welding speed, feed rate and number of welding passes [4] on ultimate tensile strength. Central composite rotatable design (CCRD) method with an alpha value of 1.68179 was used for generating experimental matrix. Table 2 shows the welding parameters and their minimum and maximum ranges. Pilot experiments were performed to finalize range of welding current. It was observed that welding operation was not feasible below 190 amps welding current, whereas above 230 amps burnt edges were observed. It is observed that SMAW process generates desired welds for selected current range. Number of welding passes varies between 1-5 & wire feed rate was selected in the range of 1-3 as selected range was compatible with the welding current.

Table 2. Welding Parameters

Input parameter	Minimum	Maximum
Welding current (amp)	190	230
Wire feed rate (mm/min)	1	3
Number of welding passes	1	5

III. MATHEMATICAL MODELS

Experiments were performed as per the parameter ranges shown in Table 3. Analysis of experimental results was performed using Design Expert software. An empirical relation between UTS and selected welding parameters was developed using quadratic model. An empirical relation developed is as given below,

$$UTS = -17236.76136 + 164.7454545*A + 202.3636364*B + 59.63636364*C + 0.3*A*B + 1*A*C - 17.5*B* - 0.400227273*A^2 - 45.59090909*B^2 - 34.64772727*C^2$$

where A = welding current, B = wire feed rate and C = number of welding passes.

Table 3. Experimental Matrix

SR. NO.	Welding current	Wire feed rate	Number of passes	UTS	SR. NO.	Welding current	Wire feed rate	Number of passes	UTS
1	200	1.5	2	306	11	210	2	1	285
2	200	2.5	2	364	12	210	2	5	346
3	200	1.5	4	393	13	210	1	3	378
4	200	2.5	4	390	14	210	2	3	457
5	220	1.5	4	391	15	210	3	3	439
6	220	2.5	4	420	16	210	2	3	435
7	220	1.5	2	290	17	210	2	3	471
8	220	2.5	2	328	18	210	2	3	444
9	190	2	3	278	19	210	2	3	457
10	230	2	3	310	20	210	2	3	445

3.1 Adequacies of the Developed Models

The adequacies of the developed equations were checked by Analysis of Variance (ANOVA) technique. R squared is a coefficient of multiple determinations, which measures variation proportion in the data points. It is always desirable that the correlation coefficient (R-square) must range from -1 to +1. The equation is considered to be significant if the value of R is very close to +1. R-squared adjusted is a measure of the amount of variation about the mean explained by the model. Predicted R-squared is a measure of how good the model predicts a response value. The Adjusted and Predicted R-squared values should be within about 0.20 of each other, to be in ''reasonable agreement.'' If they are not, there may be a problem with either the data or the model. [2] Adequate precision is a measure of the range in predicted response about its associated error, in other words a signal to noise ratio. Its desired value is 4 or more. In the present case, the values of R-squared are very close to 1; the Adjusted and Predicted R-squared values are in reasonable agreement. Adequate precision values are more than 4; therefore the equations obtained are significant. The model F-value 20.98 obtained for all the equations also implies that the model is significant. ANOVA results for the ultimate tensile strength are depicted in Table 4.

Table 4. ANOVA Results for Ultimate Tensile Strength

Factors	Ultimate tensile strength
R-Squared	0.95
Adj R-Squared	0.90
Pred R-Squared	0.66
Adeq Precision	13.63
Model F-value	20.98

In this model values of 'Prob> F' 0.0003 was less than significance level of 0.05, it indicates that the model is significant. The significance level for a given hypothesis test is a value for which a p-value less than or equal to significance level is considered statistically significant [2]. ANOVA results for F-values for welding parameter are shown in Table 5. It can be seen that UTS mostly affected by higher order of welding current (nearly 40-60% contribution) followed by higher order of number of welding passes (nearly 30% contribution). Other elements shows secondary contributions to different responses, their contribution can be seen as less prominent in comparison to contributions of welding current.

Table 5. ANOVA Results for F-values Showing % Contribution of Different Parameters on UTS

Elements	F-value	% contribution
A-A	0.251	0.11
B-B	9.37	4.11
C-C	28.83	12.66
AB	0.045	0.019
AC	2.0145	0.88
BC	1.5424	0.67
A^2	101.42	44.53
B^2	8.22	3.60
C^2	76	33.37
Total	**227.71**	**100**

IV. RESULTS AND DISCUSSION

4.1 Effect of welding parameters on ultimate tensile strength (UTS)

The effect of welding speed, wire feed rate and number of welding passes on ultimate tensile strength during welding was discussed based on developed equation. Curves showing relations for each input parameter with ultimate tensile strength. UTS increases when welding current increases from 200-220 amps, number of welding passes increases from 2 to 4 & wire feed rate increases from 1.5 to 2.5 as shown in figure 3 (a), (b) & (c).

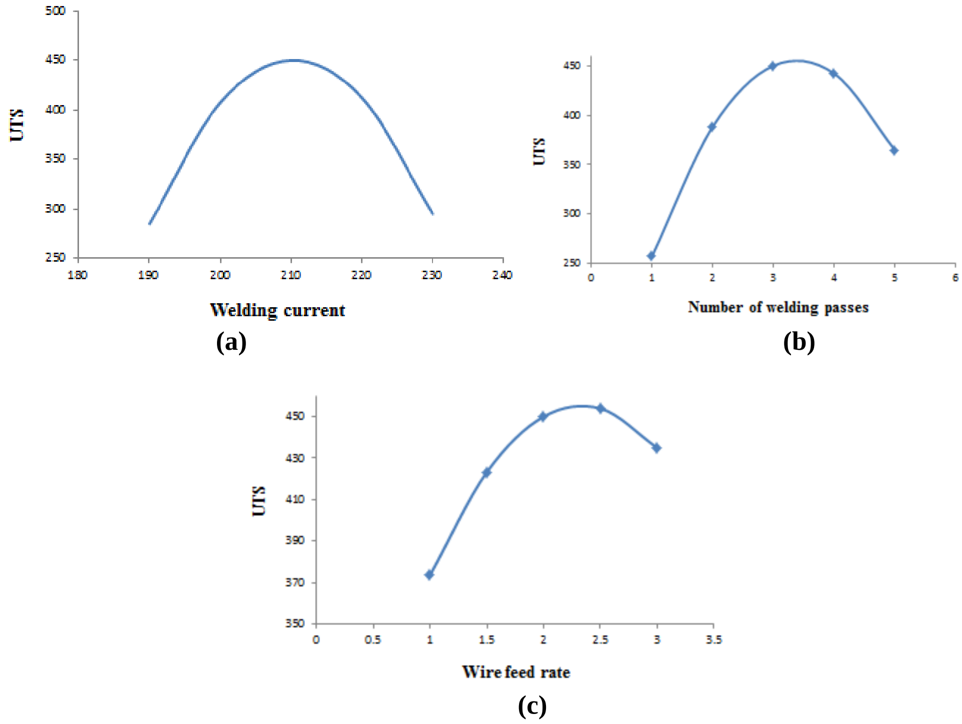
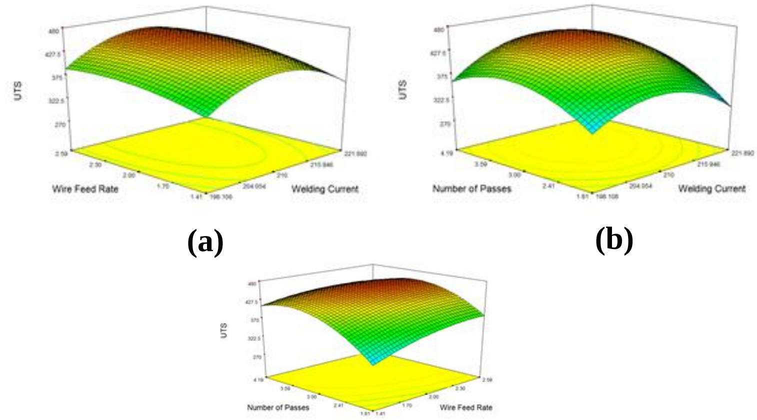


Fig. 3 : Effect on Ultimate Tensile Strength by (a) welding current, (b) wire feed and (c) number of welding passes

4.2 3-D response surface showing interaction effect

3D response plots are taken to show effect of welding parameters on ultimate tensile strength. Effect on ultimate tensile strength by (a) welding current, (b) wire feed and (c) number of welding passes are shown in figure 4. [2] It can be seen from figure 4 that ultimate tensile strength increases with the increase in number of welding passes, followed by center value of welding current 210 amps and wire feed rate of 2 m/min.



(a) **(b)**

(c)

Fig. 4 : 3D Response Plot Of Effect On Ultimate Tensile Strength by (a) Welding Feed Rate & Welding Current, (B) Number Of Welding Passes & Welding Current & (C) Number Of Welding Passes & Wire Feed Rate

CONCLUSIONS

The ultimate tensile strength was assessed for different levels of welding parameters. The correlation coefficient found close to 0.9, shows that the developed models are reliable and could be used effectively for predicting the responses within the domain of the welding parameters. Comparative evaluation of UTS was made considering the effect of different parameters through mathematical modeling using response surface methodology. Highly significant parameters were determined by performing an Analysis of Variance (ANOVA).Numbers of welding passes followed by welding current become the most influencing factors for increasing the ultimate tensile strength. It has been observed that by using optimum welding parameters as 210 amps of welding current, wire feed as 2 m/min and 3 number of welding passes one can get better ultimate tensile strength.

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