Optimization Of Process Parameter In Hardfacing By Shield Metal Arc Welding (SMAW)

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Abstract – *Related to wear resistant applications; in last few years HARDFACING become an issue of intense development .Shielded metal arc welding (SMAW) is most commonly used process for hardfacing. Over a year research is going on to reduce the wear either in the form of use of new wear resistant material or by improving wear resistant of existing material by addition of wear resistant alloying element. Hardfacing is an important process in which layer of wear resistant material can be deposited over base material. So it became an important tool in tribology.*

Knowing the large scale applications of mild steel the present work is carried out on mild steel by SMAW for the optimization of process parameters in hardfacing. The study is done on current; number of layers and type of electrode as a key parameters in SMAW.

Keywords – SMAW; Hardfacing; Microhardness,; Current; Layer, Electrode

I INTRODUCTION

If a hard ware resistant material is deposited over a soft and ductile material to improve the wear resistant then the process is called HARDFACING. Hardfacing is done for improving surface characteristics like corrosion resistance; wear resistance also for getting required size of the job. It is one of the most useful & economical way to improve the performance of the components under severe wear condition.

Low carbon steel (mild steel) is selected for present work because of its low cost; easily available and has variety of applications. Further in hardfacing process an alloy can be homogeneously deposited onto base material by welding.

Present work is aimed to study the Hardness of base material by varying the number of layers and current with changing the electrodes.

For studying the result Design of experiment by Taguchi is used.

II DESIGN OF EXPERIMENT

As there are three factors; a two level L8 orthogonal array is used. The input parameters and levels are given in table no. 1 below.

As per the design matrix beads on mild steel plates have been deposited to conduct eight trials of 2^3 factorial design.

Table 1: Input Parameters and Levels

Parameters	Coding	Level 1	Level 2
Welding current	I	140	170
Electrode	E	650	350
Number of layers	L	1	2

Accordingly the response parameter (hardness) is recorded. To check the significance of the model by the method of regression the analysis of variance is done by assuming the linear relationship.

III EXPERIMENTATION

For carrying out the experimentation work the selected base material is cut into 150x50x80mm^3 size of low carbon steel. Electrode used is DUROID 650 and ZEDALLOY 350 having hardness 55-58 HRC and 35-40 HRC respectively. The electrodes used for experimentation arc having good arc stability; low spatter and smooth arc characteristic.

FIG. 1 Electrode

IV PREPARATION OF BASE MATERIAL

Eight mild steel plates have been selected (150x50x8 mm^3). The mild steel specimens were taken as the base metal upon which the hardfacing material has been deposited by SMAW welding.

V CONDUCTING TRIAL RUNS

FIG.2 Specimens

Trial runs were conducted on the base plate according to different parameters selected from orthogonal array. In the present work electrode size, welding position, welding speed, electrode to base plate angle was kept constant to the maximum possibility. In the trial runs it was observed changing the electrode changes hardness, also to some extent changing current and layers also changes hardness. Number of specimens were prepared and examined. Cut specimens were taken for microhardness evaluation. Testing of samples was done.

VI TESTING

After experimentation samples were tested for the following & results are studied.

Hardness Test

Hardness test is done at Subodh labs Navi Mumbai. The hardness tests were carried out by polishing the cross sectioned samples with emri papers up to grade 2000. For micro hardness testing the specimens were prepared by using standard procedure ASTM E384-2016.

Polishing with fine grades of Emery paper up to 2000 grit size. Micro hardness tester was used to measure micro hardness at various zones in weldment. A load of 10gf to 1000gf is used. The indenter is held in place for 10 or 15 seconds. Different readings were taken along the edge length of welded specimen and average of all the readings was taken to get final value. The Vickers hardness (HV) is calculated using

$$HV=\frac{1854.4L}{d^2}$$

d= average diagonal in μm

L= load in gf

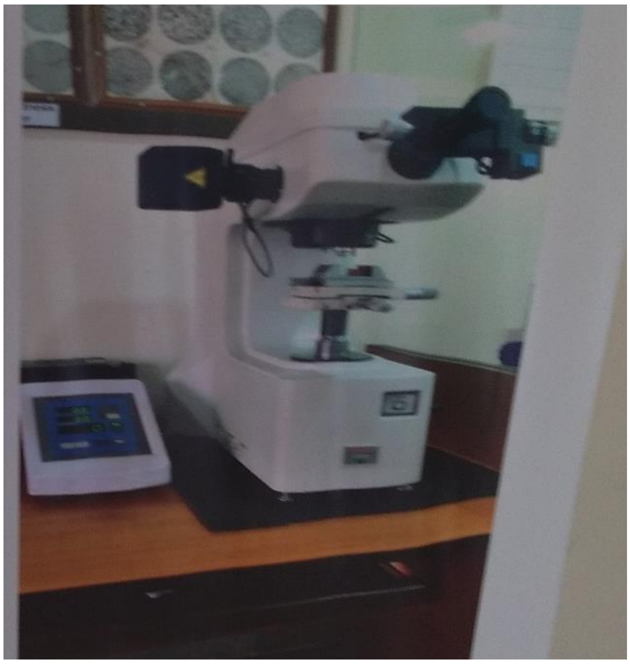

FIG. 3 Micro-Hardness Tester

VII EXPERIMENTAL RESULTS

The result of this experimentation over layers for hardfacing of low carbon steel using hardfacing electrode is discussed. The table 2 shows the L8 orthogonal array for different levels and input parameters.

Table 2: L8 orthogonal array

Sample Number	Welding Current	Electrode	Number Of Layers
1	1	1	1
2	1	1	2
3	2	1	1
4	2	1	2
5	1	2	1
6	1	2	2
7	2	2	1
8	2	2	2

The mechanical testing of welded specimens is given in table 3. The samples were categorized as 1 to 8 as per the welding conditions which are welding current, electrode and number of layers.

Table 3 Microhardness and S/N Ratio

Sample No.	Welding current (I)	Electrode (E)	No. of Layer(L)	Average Micro Hardness (HV)	S/N Ratios
1	140	650	1	751	57.512
2	140	650	2	813	58.201
3	140	350	1	303	49.628
4	140	350	2	311	49.855
5	170	650	1	503	54.031
6	170	650	2	783	57.875
7	170	350	1	299	49.513
8	170	350	2	311	49.855

VIII ANALYSIS OF MICROHARDNESS

Micro-hardness analysis here depends on three variables:

1. Welding Current
2. Welding Electrode
3. Number of Welding Layers

IX SIGNAL TO NOISE RATIO (S/N RATIO)

As mentioned earlier, hardness is the higher–the –better performance characteristic. The loss function for the higher-the-better performance characteristic can be expressed as

$$SN_L = -10 \, LOG_{10}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right]$$

Where y_i represents the experimentally observed value of the experiments, n is the repeated number of each experiment in each run. The S/N ratio from the observed value is calculated in decibel (db).

X ANALYSIS OF VARIANCE

The purpose of the ANOVA is to investigate which hardfacing process parameters significantly affect the performance characteristic.

Analysis was undertaken at a level of significance of 5%. The percentage contribution by each welding process parameters in the total sum of squared deviation can be used to evaluate the importance of process parameter change on the performance characteristics. In addition to, the F-test named after fisher can also be used to determine, which welding process parameter have a significant effect on the performance characteristics. When the F value is large usually the change of the welding parameter has a significant effect on the performance characteristics.

Table 4 shows the process parameters that were chosen. Two levels were specified for each parameter. Above table shows ANOVA for micro-hardness of hardfaced value. From table 3 the values of sum of squares, mean of squares and % contribution are found as shown in Table 4

And it can be seen that electrode and number of layer are significant factor. Also the electrode contribution is 95.23% with a residual error of 0.005%. The main effect of hardfacing is to increase the hardness, so larger is the better option is selected from Taguchi design and accordingly signal to noise ratio is generated. It was found that level-1 of electrode and level-2 of layers with level-1 of current gives the optimum values. Among all the welded specimens maximum microhardness (813HV) is observed with current 140 A with electrode 650 and layer 2. The minimum hardness observed is 299 HV with current 170A ,electrode 350 and layer 1.Electrode deposited on the base material has the most significant effect on microhardness. The highest microhardness has highest S/N ratio calculated using " MINITAB 17" software at parameter 140 A welding current, electrode 650 and 2 layers. Depending upon the input parameters ANOVA is applied to authenticate the significant or non-significant factor with percentage contribution is calculated.

Table 4 ANOVA for S/N ratios for micro-hardness

Para-meter	Current (I)	Electrode (E)	No. of layer (L)	Residual error	Total
Degree Of freedom (df)	1	1	1	4	7
Sum Of Squares (SS)	1.923	3.254	103.45	6.16	114.786
Mean squares (MS)	1.923	3.254	103.45	1.54	
F value	1.25	2.11	67.18		
P value	0.326	0.220	0.001		
% Contribution	1.77	95.23	2.995	0.005	100.00

From ANOVA following equations were obtained,

Hardness (350 electrode)=535-2.35 xcurrent+90.5xlayer

Hardness (650 electrode)=941-2.35xcurrent+90.5xlayer

XI RESULT AND ANALYSIS

Table 5 Response Table for Hardness

Level	Current	Layers	Electrode
1	53.80	52.67	49.71
2	52.82	53.95	56.91
Delta	0.98	1.28	7.19
Rank	3	2	1

Main Effects Plot For S/N ratios

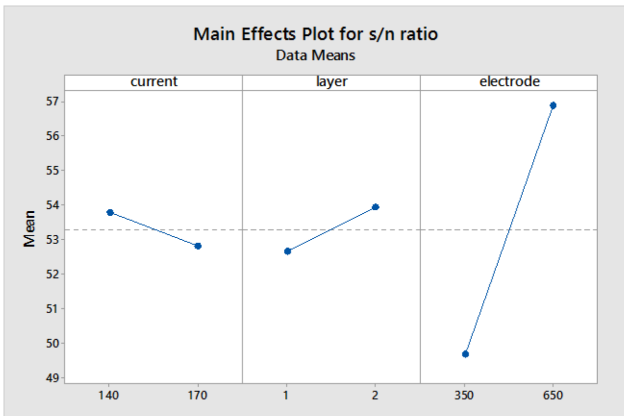

Fig. 4 Main effect plots for S/N ratios

The main effect plots for S/N ratios in figure 4. This plot shows the variation of micro-hardness (HV) with change in three parameters; welding current, electrodes, number of layers of welding. In plots, the x-axis indicates

The value of each process parameter (at two levels for welding current, electrodes and no. Of welding layers), y-axis the response value (micro-hardness). Horizontal line indicates the mean value of the response or microhardness. The main effect plots are used to determine the optimal design conditions to obtain the optimum micro-hardness (HV).

Main effect plots for micro-hardness (HV) are plotted between:

1. Micro-hardness (HV) V/s electrodes
2. Micro-hardness (HV) V/s Welding Current
3. Micro-hardness (HV) V/s no. Of layers.

The effect of each parameter on the micro hardness is plotted on the graph in form of lines in figure 4. From the main effect plots for S/N ratios, it is clear that the micro hardness decreases as the current is increased. Main effects plot for S/N ratios between electrodes, no. Of layers of welding and micro hardness show that the micro hardness increases linearly from lower to higher value with increase in no. of layers of welding and electrodes from 350 to650. From this it is observed that the electrodes and no. of layers have the most significant effect on the micro-hardness (HV).

Time Series Plot FOR Micro hardness

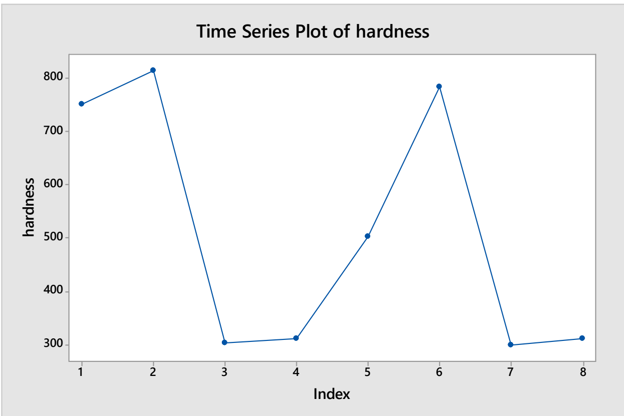

Fig. 5 Time series plot for micro-hardness

In time series plot there is a sequence of measurements of some numerical quantity made at some regular interval. Figure 6 shows time series plot of mean micro hardness. This graph shows a plot of mean micro-hardness versus number of experimental runs. Time series plots consist of time scale (number of runs) on X- axis and Data scale (micro-hardness) on the Y- axis. From figure 6, it is clear that the two extreme points on periodic Fluctuation Represents the minimum and maximum micro-hardness at 3rd and 2nd run of experiment respectively.

Main Effect Plot for Microhardness

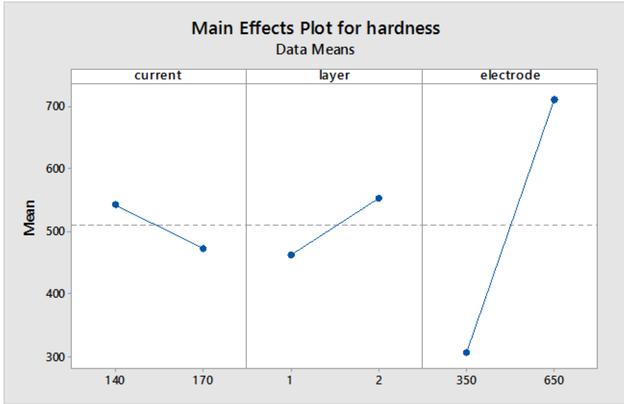

Fig. 6 Main effect plot for micro hardness

Main effect of current on hardness can be revealed from figure 7. As the value of current is increased, the value of hardness is decreased due to dilution effect. An increase in the value of hardness with change in electrode and in welding layers as is increased from 1 to 2.

Table 6 Confirmation Test Result

Parameters	Optimal Parameters	Predicted Optimal Value	Experimental Value	Error %
Hardness (HV)	I1E1L2	793.0	813	2.46

XII CONCLUSION

Present work concludes as follows:

- Effect on Micro hardness of welding current, number of layers and type of electrode is linear in characteristics.
- Micro hardness decreases with increase in welding current.
- Micro hardness increases with number of layers.
- Micro hardness increases with types of electrodes.
- Optimum result observes with the combination of factors that current and DUROID 650 electrode that is 2nd layer of welding.
- It is observed that the type of electrodes and number of layers significantly affects the hardness.

VII FUTURE SCOPE

- The toughness properties can also be tested from different point of view depending upon the Service condition of hardfaced component.
- Corrosion testing may be incorporated depending upon the specific service condition of hardfaced component.

- In future bending testing also may be incorporated with hardness and wear testing.
- Other hardfacing processes may also be investigated on similar aspects.

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