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To study the wear characteristics of W-Co Hardfaced AISI 1020 steel using Paste Technique

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Abstract: *Hardfacing is a part of surfacing technique that is a process of depositing a layer or layers of some special alloy material on the substrate that are subjected to wear and severe loading conditions. AISI 1020 steel has been selected as the substrate material because of its low wear resistance and wide industrial application. In the present work a detailed study has been carried out to study the effects of different composition of cobalt and tungsten mixture applied with paste technique and different heat input variables. A paste of cobalt and tungsten metal powder was prepared by using sodium silicate as binder. After the application of paste on substrate material a layer of AWS E6013 SMAW electrode was deposited with SMAW process Optimization of parameters was done using factorial design and Taguchi methods and it was observed that with 11% cobalt and 10% tungsten at 100A current gives the best combination of quality i.e. minimum wear rate, maximum microhardness. It was found that with the increase in cobalt concentration in the mixture wear resistance and microhardness was increased up to very significant level*

Keywords- *AISI 1020 Steel, Hardfacing, Paste technique, Wear, Microhardness.*

1. INTRODUCTION

Layers of various materials are deposited over base or substrate either to improve surface characteristics like corrosion resistance, wear resistance, etc or to get the required size or dimension. If a hard material is deposited over soft ductile material to improve wear resistance then the process is called hardfacing[3].

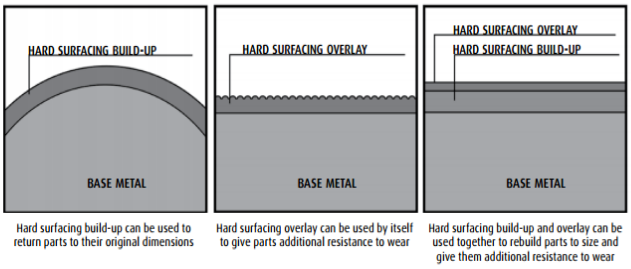

Figure 1.1: Hardfacing application

Conventional hardfacing materials are generally classified as nickel-based alloys, cobalt-based alloys, copper-based alloys, tungsten carbide composites etc [10]. WC-CO composite are the best choice for the enhancement of wear characteristics of any material. In the present work on wear study AISI 1020 steel has been chosen as substrate for improvement of its wear characteristics by hardfacing process using paste technique. The use of welding in the world of technology is extensive. It has a phenomenal rise since 1930; this growth has been faster than the general industrial growth. Practical applications of welding include automobile cars, aircrafts, ships, nuclear power plants, refineries, electronic equipment, machinery, household appliances, etc [1]. For hardfacing propose welding process is the best approach. Welding process used are SAW, FCAW, SMAW etc. Generally the hardfacing is done by using hardfaced tubular electrode but that process has limitation of
composition variation and high cost. Based on the results reported in the literature, the present study focuses its attention on paste technique for the hardfacing propose using SMAW process. Mateos et al. [2] analyzed the changes in the tribological properties of WC–Co coatings deposited by plasma spraying before and after laser surface melting using CO_2 source. The objective of this technique is to fuse, totally or partially, the coating layer. A paste of W-Co [9] was used for this process. Two parameters have been selected for the work one is composition of tungsten and cobalt mixture and second is welding current. Variation in welding current controls the heat input. With the application of taguchi methodology using MINITAB software parameters are optimized and effect of different parameters have been depicted with the help of different graphs.

2. EXPERIMENTAL

2.1 Base Metal used

AISI 1020 steel has been chosen as the substrate materials because it has a wide application in the fabrication industry. Three length of 180mm×50mm×10mm were taken for paste application. The general composition of AISI 1020 steel is given in table 2.1.

Table 2.1 – The chemical composition of base metal

C%	Si%	Mn%	P%	S%	Fe%
0.28	0.147	0.407	0.032	0.029	Rest

Table 2.2 – Physical properties of base metal

Hardness (VHN)	111
Ultimate Tensile Strength (GPa)	394.72
Bulk Modulus (GPa)	140
Shear Modulus (GPa)	80
Poisons Ratio	0.29
Wear Rate (g/min)	0.1092

2.2 Metal Powder Used

A combination of cobalt metal powder (99.5% purity) and tungsten metal powder (99.5% purity) have been taken for hardfacing the base metal. Three different combinations of metal powder have been taken for depositing the layer on the substrate [9].

Table 2.3 – Combination of metal powder

	Level 1 (A)	Level 2 (B)	Level 3 (C)
Cobalt (Co)	5%	8%	11%
Tungsten (W)	10%	10%	10%

Percentage composition of cobalt powder and tungsten powder was calculated by measuring electrode weight and accordingly percentage of both metal powders was selected.

2.3 Determination of percentage composition

Electrode weight was measured and accordingly cobalt metal powder and tungsten metal powder were added to calculate percentage composition. Weight of sodium silicate was neglected because most of it was evaporated during baking process. Following percentage composition of cobalt and tungsten were selected as shown in table 2.4

Table 2.4 – Calculation of weight percentage of composition

Level	Electro-de weight (gms)	Cobalt Wt (gms)	Tungsten Wt (gms)
A	27	$\frac{X}{27+X} \times 100 = 5$ Then X=1.42	$\frac{X}{27+X} \times 100 = 10$ Then X=3
B	27	$\frac{X}{27+X} \times 100 = 8$ Then X=2.34	$\frac{X}{27+X} \times 100 = 10$ Then X=3
C	27	$\frac{X}{27+X} \times 100 = 11$ Then X=3.33	$\frac{X}{27+X} \times 100 = 10$ Then X=3

2.4 Electrode Used

The electrode used for experimentation work is E-6013. It is an all position welding electrode used for welding structural steels. It results in medium penetration for lower dilution levels with least spatter. Smooth and easy to operate in all position including vertical down. Electrode chemical composition is given below in table 2.5

Table 2.5 – The chemical composition of electrode

C%	Si%	Mn%	P%	S%	Fe%
0.10	0.25	0.35	0.03	0.03	Rest

2.5 Welding Process Used For Hardfacing

Shielded Metal Arc Welding (SMAW), also known as Manual Metal Arc Welding or informally as stick welding has been used for the hardfacing due to its easy operation and low cost. In order to vary the heat input three different levels of current i.e. 100A, 120A, and 140A were selected on the basis of literature survey.

2.6 Application of paste on plate

Paste was applied on different lengths for different current values on the edge of 10mm thickness and along the length with the help of custom made die. For the stability of arc during welding baking was done to remove moisture from the plate [5]. For this, the plates were placed in muffle furnace for baking at 35^0c for three hours. The plate is then thoroughly cleaned.

Figure 2.1: Paste coated plate

Figure 2.2: Welded plate

2.7 Wear test

Wear test was performed on coated plates using conventional pin-on-disk apparatus wear and friction monitor machine. To perform wear test nine cylindrical pins of diameter 8mm and length 30mm were prepared. The wheel rotation speed was set at 500 rpm and a weight of 5 kg was applied. Wear track diameter was kept as 60mm. The sample weight loss was checked at an interval of 5 minutes. The final weight loss was measured of each sample on weighing machine with least count 0.0001 gm. Loss in weight was correlated to indicate the wear rate of each sample [6].

2.8 Microhardness test

A sample of 10×10 mm was cut to determine the microhardness. For microhardness test, specimen were prepared using standard procedure like polishing using successively fine grades of emery papers up to 500 grit size. It removes coarse and fine oxide layer as well as scratches from the surface that id to be analyzed. A load of 500grams and a dwell time of 20 seconds were set for determining the microharness in VHN. Different readings were taken at interval of 1 mm along the cross section of hardfaced plate.

3. RESULTS AND DISCUSSIONS

3.1 Analysis of wear test

The weight loss of pins was measured and results obtained were analysed on MINITAB 17 software.

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Table 3.1 Wear rate

Welding Current(A)	%age Composition	Wear Rate (grams/5min)
100	A	0.0089
100	B	0.0071
100	C	0.0034
120	A	0.0098
120	B	0.0083
120	C	0.0080
140	A	0.0132
140	B	0.0101
140	C	0.0085

3.1.1 Main Effects Plot for S/N Ratio

The main effects plots for S/N ratio are shown in figure 3.1. This plot shows the variation of wear rate with corresponding variation in two parameters viz welding current (A) and percentage composition (%) of cobalt and tungsten mixture. Horizontal line indicates the mean value of the response on wear rate. The main effects plots are used to determine the optimum design conditions to obtain the minimum wear rate. Main effects plots for wear rate are plotted between

1. Wear rate Vs Welding current.
2. Wear rate Vs percentage composition of cobalt and tungsten mixture.

The effect of each parameter on wear rate is plotted on graph in the form of lines. In S/N ratio results, that value is taken as optimum which is numerically maximum because it has to minimize the noise value over the signal response.

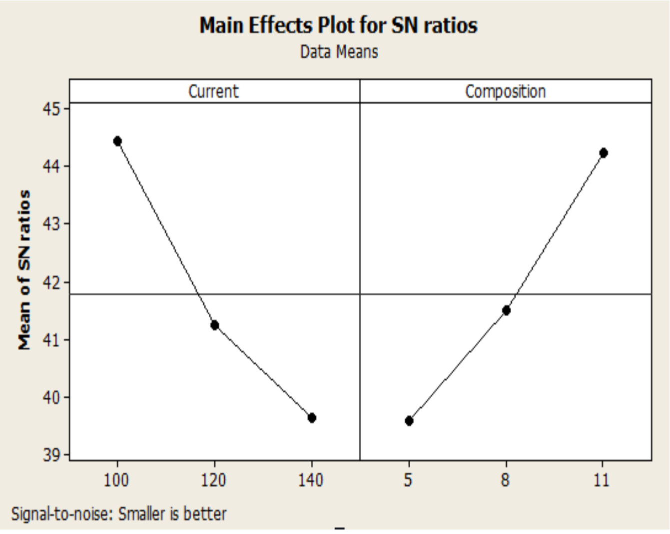

Figure 3.1: Main effect plot for S/N ratio for Wear rate

From the figure 3.1 it can be clearly seen that the wear rate increases as the current is increased however it decreases with the increase in percentage composition of mixture of cobalt and tungsten.

3.1.2 Time series plot for wear loss

In time series plots there is a sequence of measurements of some numerical quantity made at some regular interval. Figure 3.2 shows time series plot of mean wear rate. This graph shows a plot of mean wear rate versus no of experimental runs. Time series plot consist of time scale (No of runs) on x-axis and data scale (wear rate) on the y-axis. From figure 3.2 we can observe that the two extreme points on periodic fluctuation represents the minimum and maximum wear rate at 3rd and 7th run of experiment respectively.

Figure 3.2: Time series plot for wear loss

3.2 Analysis of microhardness test

Microhardness of each specimen was examined and results obtained are as below:

Table 3.2 Microhardness test results

Welding Current(A)	Wt % age Composition	Microhardness (VHN)
100	A	350
100	B	433
100	C	506
120	A	353
120	B	386
120	C	443
140	A	296
140	B	360
140	C	405

3.2.1 Time series plot for microhardness

In time series plots there is a sequence of measurements of some numerical quantity made at some regular interval. Figure 3.3 shows time series plot of mean microhardness. This graph shows a plot of mean microhardness versus no of experimental runs. Time series plot consist of time scale (No of runs) on x-axis and data scale (Microhardness) on the y-axis. From figure 3.3 we can observe that the two extreme

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points on periodic fluctuation represents the maximum and minimum microhardness at 3rd and 7th run of experiment respectively.

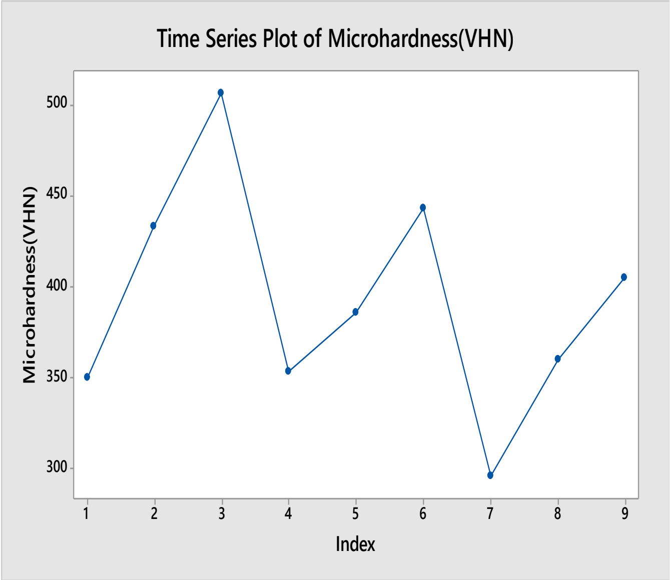

Figure 3.3: Time series plot for microhardness

4. CONCLUSION

In the present work coatings of W-Co were deposited over substrate AISI 1020 steel by using paste technique. The microhardness and wear behavior of W-Co coated specimen were studied.

- Wear loss is minimum (0.0034 grams) at 100A current with 11% Cobalt and 10% Tungsten and maximum (0.0132) at 150A current with 5% cobalt and 10% Tungsten.
- Best result for the Microhardness achieved is 506 VHN which is 3.6 times the base metal (140 VHN) .This result has achieved with 11% Cobalt and 10% Tungsten at 100A Current value.
- Microhardness test results have shown a decline in the value with Increase in the level of current from 100A to 140A this is because of increase in dilution, however it has increased with the increase of composition of Cobalt and this is because of dissolution of tungsten carbide in to cobalt matrix.

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