Investigation of wear characteristics of Fe-Cr-C hardfacing alloy on AISI-304 steel

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***Abstract*—Wear plays a pre-dominant role in effecting tribological properties and service life factor of machinery components and tools. Every machine parts and tools have to undergo different stages of wear like Fatigue, Abrasive and Adhesion etc. To improve the surface and tribological properties hardfacing is used widely. Hardfacing is one of the oldest techniques used in surface engineering process to improve the surface properties of materials. Fe-Cr-C composed hardfacing alloys are used widely in severe abrasive conditions as these are superior in abrasive resistance. The aim of present study deals with characterization of wear tribological properties of Fe-Cr-C composition based hardfacing alloy on AISI 304 steel in form of mono and multilayers by SMAW process. The wear tests were carried out on Pin-On-Disc Tribometer and worn structures were examined under optical microscope. Phase and structural characterization were done by X-Ray diffraction.**

***Index Terms*—first term, second term, third term, fourth term, fifth term, sixth term**

I. Introduction

Surface engineering is one of the most efficient processes using widely to improve surface properties of materials to retain them in critical condition [1]. In surface engineering process, hardfacing is the oldest technique used to repair worn parts and protect from Abrasive, Adhesive, Chemical attacks by adding a protecting layer without changing material properties [7]. Since past five decades most of the researches were carried out to generate data which can raise industrial revolution in fields of protection shield layers of materials.

Fe-Cr-C hardfacing alloy with Ni addition are common hardfacing alloys used widely as these are superior in abrasive resistance in severe abrasion conditions [10]. The present study is concerned with wear characterizations of Fe-Cr-C based hardfacing alloy on AISI 304 steel applied in form of mono and multilayers. Many investigations were carried one role of mono and multilayers on resistance towards wear have contributed lot of benefits to industries in improving tribological properties of materials[6].

Superior abrasive wear resistance can be obtained by multilayering process leads to hardening of material due to formation of high volume fraction of carbides. Wear of material not depends on abrasive material but also depends on other parameters such as oxidation rate, thermal fatigue and heat impacts [7].

II. Experimental Procedure

A. Specimen Preparation

AISI 304 steel of 8 × 34 mm and 8 × 38 mm dimensioned cylindrical rod are taken for hardfacing. These specimens were subjected to surface treatment at 660^0 degrees. Before hardfacing process surface of pins were cleaned with ethyl alcohol. Fe-Cr-C based hardfacing alloy deposited in form of multilayer and monolayer depositions.

TABLE I.
CHEMICAL COMPOSITION OF PIN AND HARDFACING ELECTRODE.

Material	% C	% Cr	%Mn	%Ni	%Si	% S	% P	%Fe
Cylindrical Pin	0.08	20.0	2.0	10.0	1.0	0.03	0.04	Rem
Hardfacing electrode	0.40	10.50	1.80	19.0	0.45	-	-	Rem

Fe-Cr-C based hardfacing alloy is deposited in form of mono and multilayer by using a flux coated shielded metal arc welding (SMAW) having a diameter of 4mm electrode. The chemical compositions of pin and hardfacing electrode are reported in table 1. The welding parameters and design details of pins are reported in table 2 and table 3.

TABLE II.
SHIELDED METAL WELDING PARAMETER

Parameters	value
Length of electrode	8mm
Diameter of electrode	450mm
Voltage	30 volts
Current	140 amps

TABLE III.
DESIGNING DETAILS AND LAYERS ON PINS ARE REPORTED IN TABLE

Specimen	Length (mm)	Diameter (mm)	No of layers deposited
Tribo pair 1	40	8	1
Tribo pair 2	40	8	3

B. Hardness and Surface roughness

The hardness of the prepared specimen before hardfacing and after hardfacing with mono and multilayered are measured by using Rockwell hardness tester.

The Fig.1 shows the details of harness results. The surface roughness of specimens after hardfacing is measured by using Surftest SJ–301 surface roughness tester and surface roughness maintained 0.03 µm.

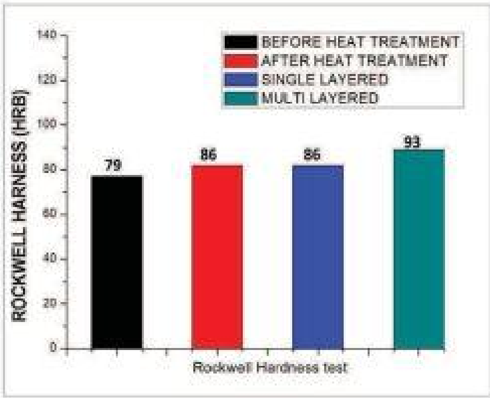

Figure 1. Hardness of specimens.

C. Wear Test

The sliding wear tests are carried out for both tribo pairs at constant parameters by using Ducom's Pin on Disc TR-20 machine in controlled room temperature under applied contact load of 30N with speed 300 rpm as per ASTM G-99A. The two tribo pairs are made contact with surface of SS alloy steel disc and revolved with track diameter of 25mm and each 2000 revolutions. Wear is not only depends on load but also dependent on the sliding speed. If sliding speed is more then, more distance is covered by the sample and static wear will be more. The wear will higher for higher sliding speed.

$$\text{Sliding speed of disc (m/sec)} = \frac{\pi D N}{60000} \quad (1)$$

$$\text{Total distance travelled (m)} = \frac{\pi D N T}{60000} \quad (2)$$

Where D = Diameter of track, N= speed of disc, T= Time travelled.

The mass loss of pin is calculated as the difference of their weights before the wear test and after the wear test. The volume loss of the pin is calculated by conversion of mass loss through equation 3.

Volume loss of pin, mm^3 =

$$\frac{Mass\ Loss}{Density} \times 1000 \quad (3)$$

$$\text{Wear rate } W_a\ (mm^3/Nm) = \frac{\Delta G}{dMS} \quad (4)$$

Where is weight loss, M is load applied, d is density and S is frictional distance travelled.

$$\text{Wear resistance } W_r = \frac{1}{Wa} \quad (5)$$

D. Results

The Figure 2 and Figure 3 show the resistance of single and multilayer hardfacings towards wear attack. These are heat treated and hardfaced specimens, showing a good resistance towards wear. As compared to single layer the multilayer hardfacing having good binding strength and lead to increase in resistance towards sliding and abrasive wear. The figure 2 shows the sudden raise of peaks due to high wear rate because the worn out particle due to sliding wear formed as abrasive particles and lead to high wear rate due lesser binding strength of single layer depositions.

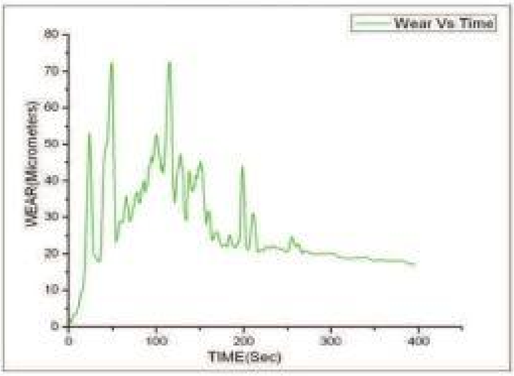

Figure 2. Wear Vs Sliding Time of Single Layer Hardfacing

Compared to mono layer the multilayer deposition of 10.5% Cr-19% Ni hardfacing shown a good resistance to wear and less amount of wear rate as shown in Figure 2.

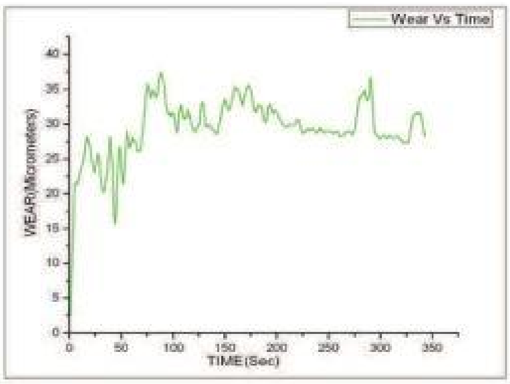

Figure 3. Wear Vs Sliding Time of Multilayer Hardfacing.

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The mass loss, volume loss and wear rate are higher for mono and wear resistance is very poor when compared to multilayer hardfacing depositions. This is due to brittleness of specimens and poor binding strength. It may be offered due to operations done on grinding and lathe machined caused the surface harder and brittle.

The results of sliding wear and corresponding mass and volume loss of pin are mentioned in table 4.

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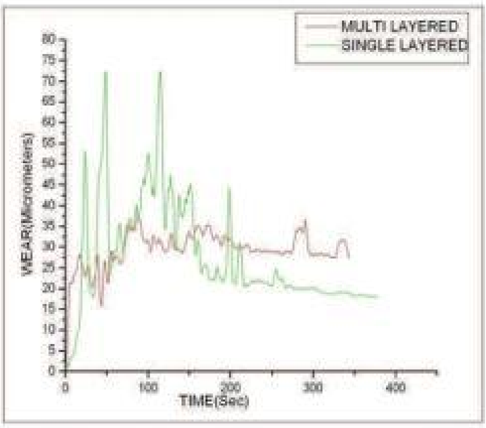

Figure 4. Comparison of Wear Vs Sliding Time of Multilayer over Single Layer Harfacings.

TABLE 4.
WEAR CHARACTERISTICS OF PINS.

Mass loss (g)	Volume loss (mm3)	Wear rate (mm3/Nm)	Wear resistance (Nm/mm3)	Wear resistance (Nm/mm3)
Single layer	0.14	17.78	3.8×10-3	263.15
Multi layer	0.06	7.54	1.6×10-3	625.00

10.5% Cr-19% Ni hardfacings showed excellent wear resistance. This resistance is offered due to higher binding strength offered between bare specimen and hardfacing alloys as the bare specimen has subjected to heat treatment to improve its properties.

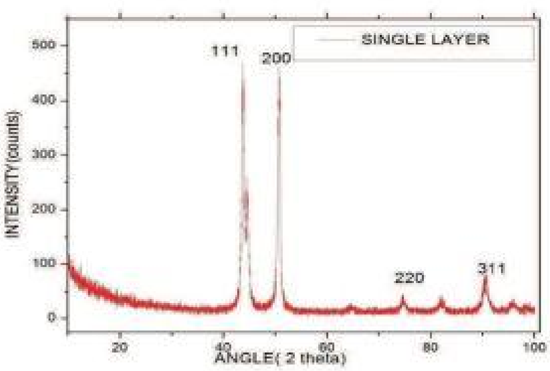

Figure 5. XRD Plots of Single Layer Hardfacing

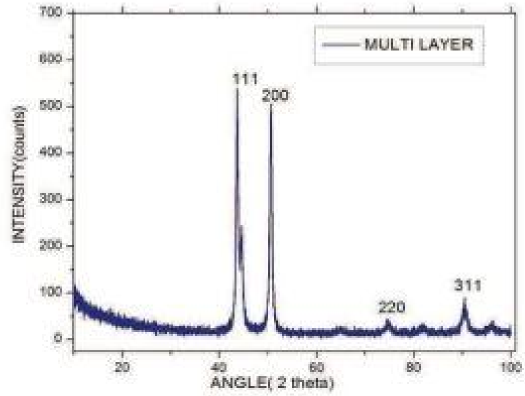

Figure 6. XRD Plots of 10.5% Cr-19% Ni Multilayer Hardfacing

Figure 5 and 6 shows XRD plots of Single and multilayer hardfacing layers hardfacings are having Face centered cubic structure with Austenitic phase. It states that there was no phase change after wear test.

E. Worn surfaces

Due to the slip actions and frictional force between the specimens and discs, mass transfer from specimens exists. The mass transfer can be observed during each test and due to this mass transfer the specimens were predominantly had a layer composed of wear debris and oxides test

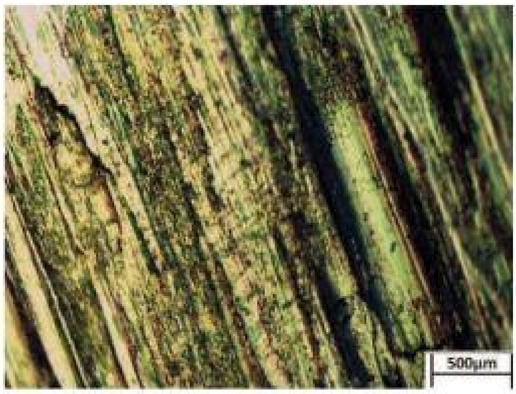

Figure 7. Worn Surface of 10.5% Cr - 19% Ni Single Layer Hardfacing after Wear Test.

Figure 7 and Figure 8 shows worn surfaces of both single and multi layered surfaces hardfacings. Figure 7 shows ploughing strips are very shallow on the surface as compared to multilayer hardfaced worn surfaces and little amount of oxide layer and void formation observed in single layer deposition.

The worn surfaces shows the formations of welded regions due abrasive particles and severe adhere wear has taken place and also severe wear transition occurred in single layer deposition. The particles which are formed while test are acting as abrasive in nature are mainly responsible for this ploughing nature and abrasive wear. The morphology of worn surfaces reports the severe

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formation of wear debris is mainly occurred on single layer as compared on multi layer and major loss of volume and wear rate is also occurred on single layer surface.

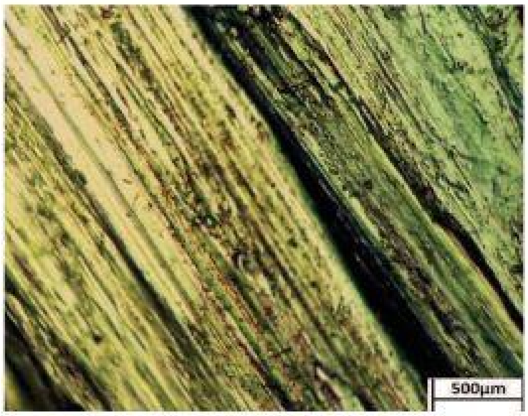

Figure 8. Worn Surface of 10.5% Cr - 19% Ni Multilayer Hardfacing after Wear Test

One of the common features absorbed in the both worn surfaces is formations of ridges running parallel to the sliding direction. The damaged spots in the form of craters can be seen in single layer depositions are decreased in multilayer depositions. The multilayer hardfaced deposition showed mild wear transition and no severe cracks was formed. The loosed wear debris formations were observed in previous hardfacing but here no such criteria were observed.

III. Conclusions

Multilayer hardfacing reduces rate of pin holes, cracks formations and also reduces internal stress in interface layers and leads to increase in volume of carbides which strongly influences the hardness of the material.

Multilayering can reduce the internal void formations and external surface defects and results in greater binding strength and hardness as the carbon content is increased with high fraction of carbide formations results in excellent resistance to external load and wear.

Increase in carbon content increase the hardness but also increases the brittleness of the material but on other way it can form more carbides which resists towards abrasive wear

In some cases the finishing operations are also responsible for hardening of surface layers.

The morphology of worn surfaces on Multilayer showed only plough nature on the surface and good wear resistance compared to single layer. As in single layer showed uneven cracks formation, voids and severe plough.XRD results stated that all hardfacing are in austenitic phase and after wear test no phase transformation was observed.

Broken flake particles from specimens acted as abrasive particles increased the wear rate due lesser birding strength. Cr-Ni based hardfaced alloy showed good binding strength, good wear resistance and fewer amounts of oxide layer formations on the surfaces of specimens as compared with all hardfacings. A buffer layer is preferred for these hardfacings

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