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A Study on Microstructure and Abrasive Wear Behavior of Fe-Cr-C Based Hard facing Alloys Deposited by SMAW Processes

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Abstract: ***Hard facing is one of the most useful and economical ways to improve the performance of components submitted to severe wear conditions. A study was made to compare the microstructure and abrasion resistance of hard facing alloys reinforced with primary chromium carbides. The prime requirement of a metal is to have good resistance to wear, corrosion and high temperature. The resistance of hardfacing alloy depends on many factors such as the type, shape, and distribution of hard phases, as well as the toughness and strain hardening behavior of the matrix. A study was also carried out to investigate the relationship between abrasive wear resistance and microstructure of Fe-Cr-C hardfacing alloy. Two different commercial hardfacing electrodes were employed to investigate the effect of the microstructure. Results indicate that as hardness increases, the loss of wear decreases. Electrode-I has less wear as compared to electrode-II as the percentage of chromium, carbon and silicon is more in electrode-I. However the composition of chromium, carbon & silicon in the weld deposit made with type-I electrode is higher than that of weld deposit made with type-II electrode. The abrasion tests were carried out in a dry sand-rubber wheel abrasion machine according to the procedure A of ASTM G65 standard. Experimental investigation revealed that, the factors such as, arc current, welding speed, arc voltage, electrode stick-out and pre-heat temperature, predominantly influence the weld quality.***

Index Terms: **Alloys, Hard facing, Microstructure, Wear resistance, welding.**

I. INTRODUCTION

Hard facing is one of the most economical and most widely used methods of improving surface characteristics. A wide variety of hardfacing alloys are commercially available for protection against wear and selecting the best suited for a particular application is very essential. The composition of the deposit will depend upon the base metal composition and dilution. Base metal composition is very significant in determining the preheating temperature. Carbon and low-alloy steels with carbon content of less than one percent can be easily hardfaced whereas high-carbon steel may require a special buffer layer. Selection of an alloy also depends on the nature of the service creating the need for hardfacing. Various surface alloys are available in different forms such as, bare welding rods, electrodes, and coiled wires and also in the form of powders [1]. Fe-Cr-C alloys are used in severe conditions where there is extreme erosion and therefore abrasion resistance is necessary. Their exceptional abrasive and erosive wear resistance results primarily from their high volume fraction of hard carbides, though the toughness of the matrix also contributes to the wear resistance[7],[10],[11]. The investigations of Fe-Cr-C alloy microstructures have shown that these types of materials have hypoeutectic, eutectic, and hypereutectic structures [2]. The hardfacing alloys obtained using high-energy density sources such as electron beam welding; plasma arc and laser have been widely applied to enhance the wear and corrosion resistance of material surface [3],[12]. In this study two different hardfacing alloys were used for overlaying. These are basically iron based alloys having varying amount of chromium, carbon and other alloying elements as they are more suitable for low stress abrasive wear condition [4],[5],[6]. Several welding techniques such as oxyacetylene gas welding (OAW), gas metal arc welding (GMAW), shielded metal arc welding (SMAW) can be used for hardfacing. The most important differences among these techniques lie in the welding efficiency, the weld plate dilution and the manufacturing cost of welding consumables. SMAW, for example, is commonly used due to the low cost of electrodes and easier application. The present investigation aims to study two commercial electrodes.

II. EXPERIMENTATION

The selection of base metal is very essential in deciding what alloy to use for hardfacing deposit. Since welding procedure differs according to the base metal. The base metal selected for this study is mild steel which composes the main elements of carbon, silicon, manganese, sulphar, and phosphorous [8],[9]. The chemical

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composition is shown in Table 1. Two different commercial hardfacing alloys were used for overlaying. These alloys were selected due to its low cost and easy availability in the local market and suitability for the service condition (low stress abrasion). They are basically iron – based alloys having varying amount of chromium, carbon, silicon and other alloying elements as they are more suitable for shielded metal arc welding process. Chemical compositions of two electrodes are presented in Table 2.

Table 1 Chemical composition of base metal (In weight percentages)

C	Si	Mn	S	p	Fe
0.18	0.32	1.47	0.013	0.029	Bal

Table 2 Chemical composition of hardfacing alloy (In weight percentages)

Electrode	C	Si	Mn	S	p	Cr	Mo	Ni	V	Fe
Hardfacing 1	0.33	0.28	1.15	0.014	0.025	2.22	-	-	-	Bal
Hardfacing 2	0.1	0.38	1.51	0.024	0.03	2.15	0.745	1.09	0.103	Bal

III. METHODOLOGY

The experiment was carried out in three stages to investigate the effect of current, travel speed and voltage on hardfacing electrodes, and the corresponding hardness was determined.

- In first stage, voltage (V) and travel speed (S) were kept constant and current (A) was increased.
- In second stage, voltage (V) and current (A) were kept constant and travel speed (S) was increased.
- In third stage, current (A) and travel speed (S) were kept constant and voltage (V) was increased

The selected standard size of the test specimen is shown in figure 1.The results of hardfacing obtained by varying current, travel speed and voltage along with their hardness and the corresponding relationship between them are shown in figures 3, 4 and 5 respectively. From graphs, it is concluded that as current, voltage & travel speed increases the hardness of surface & the layer next to the surface decreases. Figure 3 shows that, as current increases the hardness of the bead & HAZ decreases. Figure 4 shows, hardness decreases with increase in travel speed. Figure 5 shows as voltage increases the hardness of the bead & HAZ decreases.

Fig 1: Standard test specimen (75×26×6 mm)

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A. Stages of Experiment

Table 3 Varying current

Electrode	**Current (Amp)**	**Voltage(V)**	**Travel Speed(cm/min)**	**Hardness (HV 0.5)**
Hardfacing 1	200	25	23.1	380
	250	25	23.1	318
	300	25	23.1	317
Hardfacing 2	180	25	23.1	370
	200	25	23.1	416
	250	25	23.1	330

Table 4 Varying travel speed

Electrode	**Travel Speed(cm/min)**	**Voltage(V)**	**Current (Amp)**	**Hardness (HV 0.5)**
Hardfacing 1	15.0	25	200	417
	21.4	25	200	418
	50.0	25	200	356
Hardfacing 2	16.67	25	200	377
	25.0	25	200	388
	50.0	25	200	406

Table 5 Varying voltage

Electrode	**Voltage(V)**	**Current(Amp)**	**Travel Speed (cm/min)**	**Hardness (HV 0.5)**
Hardfacing 1	15	215	37.5	537
	25	215	37.5	390
Hardfacing 2	15	215	37.5	401
	25	215	37.5	357

IV. RESULTS AND DISCUSSION

A. Hardness Test

The specimens were cut to a size of 100x30x12mm for hardness testing and were polished using standard metallographic procedure. Micro hardness surveys were made on these specimens using Vickers hardness tester along the direction of thickness from the top surface towards the base metal after every 0.5mm. These surface values are plotted in the form of a graph shown in Figure 2. The hardness survey of heat affected zone (HAZ) samples for every 0.5mm depth was made. The results indicate that the hardness values are more on the weld surface & decrease towards the base metal & remain constant on the base metal.

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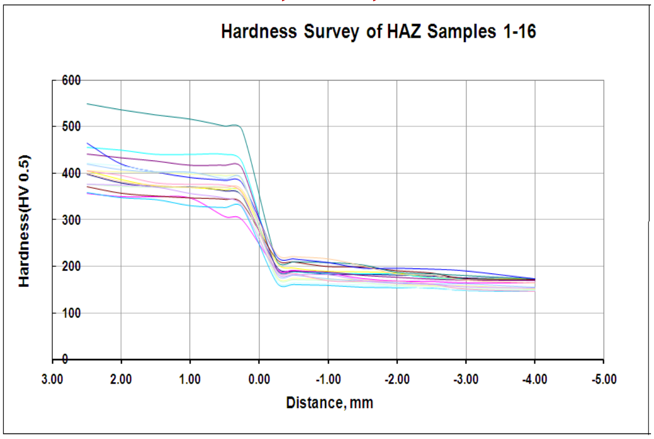

Fig. 2 Hardness Survey of HAZ

B. Dry Sand Abrasive Wear Test

Sample of 75x26x6mm size were used for analysis. Specimens were ground using surface grinder to make the surface flat. Dry sand abrasive wear test was carried out as per ASTM G65 standards. In this test, samples were held against a rotating rubber wheel under the constant flow of abrasives in between the sample and the rubber wheel under predetermined load. The wear testing machine is shown in figure 6 and the test conditions are given here under:

- Speed: 200±5rpm
- Sample run duration: 30 minutes
- Abrasive: loose silica sand having particle size 200 to 250 µm

Silica sand of size between 200 to 250µm was used as abrasive. Load is kept constant at 130.5N for all the specimens. The wear rate was calculated as weight loss in gms. The wear losses for all the specimens are shown in Table 6. Results revealed that higher amount of chromium, carbon, silicon and finer structure resulted in higher hardness where as lower hardness values were recorded in weld deposit with less amount of Cr, C & Si & coarser structure. From wear testing data under various conditions of the parameters, it can be stated that weld deposits made with type I electrode are more wear resistant than the weld deposits made with type II electrode. As hardness is more the wear loss of hardfacing specimens is less consequently the hard surface is to resists the abrasion resistance.

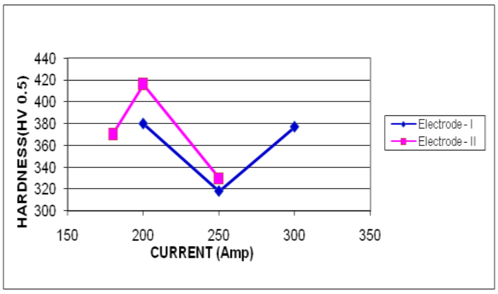

Fig 3: Hardness v/s Current

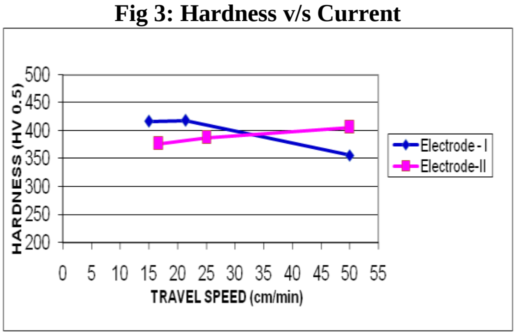

Fig 4: Hardness v/s Speed

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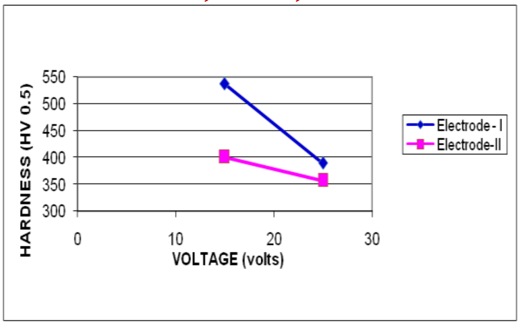

Fig 5: Hardness v/s Voltage

Fig 6: Dry sand abrasive wear testing machine

Table 6. Wear loss values corresponding to hardness

Sample Number	Load (N)	Weight loss (g)	Hardness (HV 0.5)
1	130.5	1.6075	377
2	130.5	1.3345	318
3	130.5	0.9861	380
4	130.5	0.638	417
5	130.5	0.6007	418
6	130.5	0.8454	356
7	130.5	1.0923	537
8	130.5	0.5934	390
9	130.5	0.9051	330
10	130.5	0.9698	416
11	130.5	0.9746	370
12	130.5	0.9205	406
13	130.5	1.1571	388
14	130.5	1.0576	377
15	130.5	0.9852	357
16	130.5	0.9506	401

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V. CONCLUSIONS

Experimental investigation revealed that, weld metal chemistry & hardness have significant influence on wear property. Wear resistance increases with increase in percentage of chromium & carbon content in weld deposits and the hardness mainly depends on process parameters such as welding current, arc voltage & speed of arc travel. The analysis carried out on hardness survey of HAZ samples for every 0.5mm depth indicates that the hardness values are more on the weld surface & decrease towards the base metal & remains constant on the base metal. Results of wear test indicate that as hardness increases, the loss of wear decreases. Electrode-I has less wear as compared to electrode-II as the percentage of chromium, carbon and silicon is more in electrode-I. However the composition of chromium, carbon & silicon in the weld deposit made with type-I electrode is higher than that of weld deposit made with type-II electrode.

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