# An Experimental Investigation on the Effect of Microstructure on Wear Characteristics of Fe-Cr-C Hardfacing Alloys

K. M. Kenchi Reddy, C. T. Jayadeva

***Abstract*: Hardfacing is a low cost method of depositing wear resistant surfaces on metal components to extend service life. The prime requirement of a metal is to have good resistance to wear, corrosion and high temperature. A study has been 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. The abrasion tests were carried out in a dry sand–rubber wheel abrasion machine according to the procedure of ASTM G65 standard. The factors such as, arc current, arc voltage, welding speed, electrode stick-out and preheat temperature, predominantly influence the weld quality.**

*Index terms*: **Alloys, Hardfacing, Microstructure, Wear resistance, Welding**

## I. INTRODUCTION

THE prime requirement of a metal is to have a good resistance to wear, corrosion and high temperature. Hardfacing is a low cost method of depositing wear resistant surfaces on metal components to extend service life. 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, 7]. It serves satisfactorily in certain conditions depending upon its composition, microstructure of the deposited layer and its hardness.

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].

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Hardfacing is one of the most economical and most widely used methods of improving surface characteristics. 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]. Results revealed that weld metal chemistry & hardness have significant influence on wear property.

## II. EXPERIMENT

### *A. Base metal*

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]. The chemical composition is shown in Table I.

TABLE I
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 |

### *B. Hardfacing alloy*

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 [2, 8, 10]. Chemical compositions of two electrodes are presented in Table II.

### *C. Welding Conditions*

The standard size test specimens of 16 nos. with the dimensions of 250×100×12 mm were selected for the experiment. The following precautions are taken before hardfacing.

- The electrodes are perfectly dried in the furnace and baked at 250$^{o}$ C one hour before the use
- Area of the weld is properly cleaned
- Preheated the hardfacing area to a minimum of 200$^{o}$ C

TABLE II
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 |

*D. Machine Specifications*

Name: TORNADO MIG 630 Arc welding machine
Current: 100-630 Amps
Input Voltage: 415 volts± 10% / 50-60 HZ / 3 Phase
Machine Capacity: 50 KVA

## 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.

(1) In first stage, voltage (V) and travel speed (S) were kept constant and current (A) was increased.
(2) In second stage, voltage (V) and current (A) were kept constant and travel speed (S) was increased.
(3) 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 2, 3 and 4 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 2 shows that, as current increases the hardness of the bead & HAZ decreases. Figure 3 shows, hardness decreases with increase in travel speed. Figure 4 shows as voltage increases the hardness of the bead & HAZ decreases.


Figure. 1 Standard test specimen of size 75×26×6 mm

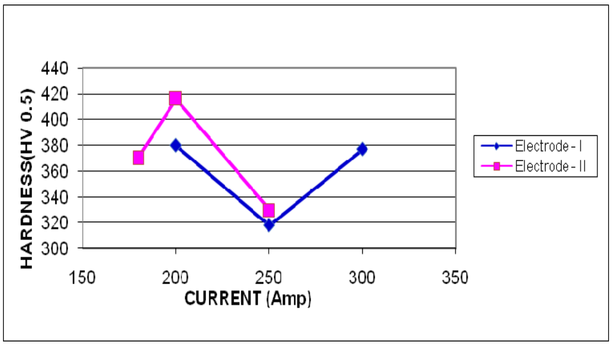


Figure. 2 Hardness v/s current keeping voltage (25volts) and travel speed (23.1 cm/min)

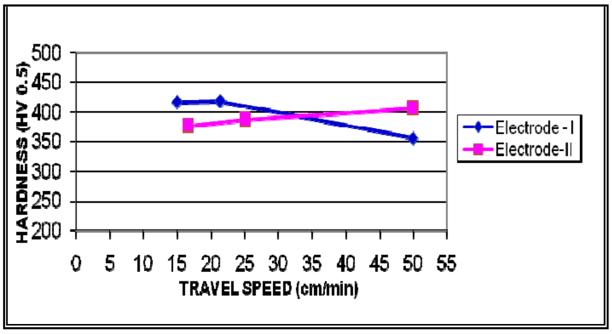


Figure. 3 Hardness v/s. travel speed keeping current (200Amp) and voltage (25 volts) constant

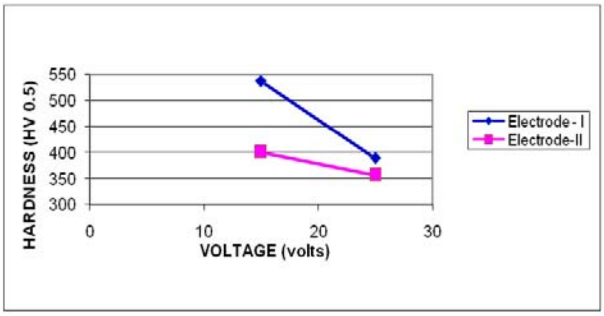


Figure. 4 Hardness v/s voltage keeping current ( 215Amp) and travel speed (37.5 cm/min) constant

## 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.

ISBN: 978-988-19253-5-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

These surface values are plotted in the form of a graph shown in Figure 5. 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.

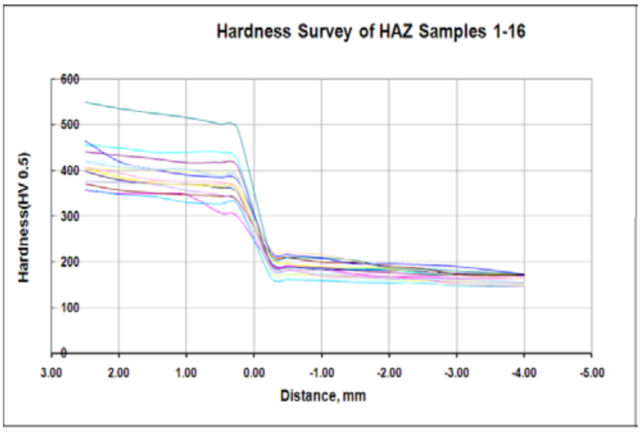


Figure. 5 Hardness Survey of HAZ

*B. Dry sand abrasive wear test*

Sample of 26x75x6mm 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 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. 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. 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.

## V. CONCLUSION

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.

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ISBN: 978-988-19253-5-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)