

Effect of Fe-Cr-C based Electrodes Coating on Hardness and Abrasive Wear Resistance

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Abstract: The aim of this study is to investigate the abrasive wear resistance of the two commercially available electrodes that are used in the sugarcane industries for hardfacing. Study shows that the iron based alloys having variation in amount of chromium, carbon and other alloying element enhances the corrosion resistance and formation of austenite phase of Cr-C, cause increase in the hardness. Hardfacing was applied to mild steel plate by shielded metal arc welding. Abrasive wear test was performed on the pin-on-disc tribo test equipment. Microhardness measurement by the Vickers hardness test and microstructure analysis done by finite element scanning electron microscopy (FESEM) and electron disperse X-ray (EDX) spectra. Test results shows that the hardness increases from 230 to 750 HV_{0.5} and the increase in chromium element enhanced the abrasive wear resistance or reduce loss of materials of hardfaced surface.

Keywords: hardfacing, microhardness, abrasive wear, FESEM and EDX

1. Introduction

Abrasive wear occurs whenever a solid object is loaded against particles of materials that have equal or greater hardness. Any material, even if the bulk of it is very soft, may cause abrasive wear if hard particles are present for example, an organic material, such as sugar cane is associated with abrasive wear of cane cutters and shredders because of the small fraction of silica present in the plant fibers [1]. Improvement of the wear resistance of machine components may be achieved by an adequate selection of abrasion resistant materials for the deposition of hardfacing layers on the bulk parts. The addition of alloying elements and rapidly solidified fine crystalline microstructure containing finely distributed hard phase can exhibit an excellent combination of hardness and toughness of the hardfaced alloys. Coarse hard phases and high hardness are important to achieve high abrasion resistance. The hardness of the hard phases and/or the hardness of the matrix should be higher than the hardness of the abrasive [2]. In welding, surfacing refers to the deposition of a filler metal on a base metal to impart desired property to the surface that is not intrinsic to the underlying base metal. Several types of surfacing exists; hardfacing, weld cladding, buildup and buttering. Hardfacing is a form of surfacing that is applied for the purpose of reducing wear (abrasion, adhesion, and erosion) galling or cavitations [3]. From Fe-Cr-C composition the hypoeutectic and eutectic composites were found and consists of three phases of austenitic solid solution, (Cr, Fe)₃C, and (Cr, Fe)₇C₃, in hypoeutectic structure of (Cr, Fe)₇C₃ is have fine lamellar structure and the hypereutectic structure consists of three phase ferritic solid solution, (Cr, Fe)₂₃C₆ and trace amount of (Cr, Fe)₇C₃ carbides. The presence of lamellar eutectic structure will resist crack spreading along the grain boundaries [4]. Hardness has a linear variation with the pearlite and for martensite varies with a square root of the carbon percentage whereas wear resistance has a function of particle/ grit size and free ferrite path for non-pearlite, ferrite and spheroidised cementite steels. Due to vary grit size hence chip formed during material removal is also be vary therefore wear resistance is also different [6].

2. Experimental Setup

2.1 Sample preparation

In the present study, the mild steel plate select of 84×20×10 mm dimensions, chemical composition shown in table.1 (results on the basis of spectroscopy test) was prepared for hardfacing. The plate were coated through SMAW at the parameters 30 volts and 130 ampere, by electrodes E1 and E2 chemical composition shown in table 2 and table 3 (results on the basis of spectroscopy test) respectively. For microstructural examination, the specimens were etched with Vilela.

Table 1: Chemical Composition of Base Metal (wt %)

C	Mn	Si	S	P	Fe
0.16-0.18	0.70-0.90	0.40	0.04	0.04	Bal.

Table 2: Chemical Composition of the Electrode Shield (wt %)

	E1	E2
MnO ₂ +CaO+MgO+TiO ₂ +NiO	14.0	14.0
Fe ₂ O ₃ +SiO ₂ +Al ₂ O ₃ +Na ₂ O	10.4	10.4

Table 3: Chemical Composition of Electrodes (wt %)

	C	Mn	Si	Cr	Mo	V	Fe
E1	0.35	1.650	0.52	1.56	0.18	0.51	Bal.
E2	0.50	0.8	0.6	6.0	0.5	0.3	Bal.

2.2 Hardness test

Hardness value was measured on the Vicker's hardness testing machine using a 500 gm load and a 136° diamond pyramid indenter. Hardness of the hardfaced surfaces were measured along the length (including base material, HAZ and welded zone at the difference of 1 mm) and depth wise (starting below 0.5 mm of coated surface in the weld zone).

2.3 Wear test

Wear behavior of the hardfaced surfaces were investigated on the pin-on-disc tribo test machine, at 20 N load, speed 350 rpm and 40 mm diameter. Samples cut in 10×10×20 mm

size and polished for the abrasion test. Wear rate was determined according to weight loss of samples for 10 minute.

2.4 Wear surface study

Before observation wear surface were washed by Vilela solution. Worn out surfaces were observed under the FESEM to characterize the surface morphology and inaugurate possible mechanism for material removal.

3. Results and Discussions

Figure 1 shows the hadrfaced surfaces of both electrodes at the corresponding parameters.

3.1 Microhardness

The microhardness measured by Vickers Hardness at the hardfaced surfaces, shown in fig.2. From the fig.2, hardness of the base metal was recorded 230 HV_{0.5} and for hardfaced surfaces of E1 and E2 were measured 420 and 730 HV_{0.5} respectively. The microhardness from the coated surface to 4 mm below the surface in the weld zone is shown in fig.3. E2 has hardness values in between 710 to 390 HV_{0.5} and for E1 the hardness varies from 447 to 280 HV_{0.5}.

3.2 SEM and EDX analysis

The increase in microhardness is due to the formation of hard phases as increase in chromium and other alloying elements, the phases can be visible in FESEM analysis as shown in fig. 4 and fig. 5 for both the electrodes E1 and E2 respectively. The presence of elements in percentage can be seen with the help of EDX spectra that shows the different elements presence in hardfaced surface, as shown in fig. 6

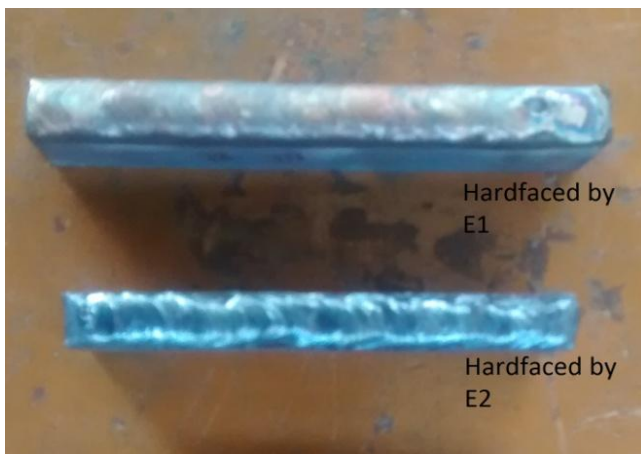


Figure1: Hradfaced surface by electrode E1 and E2

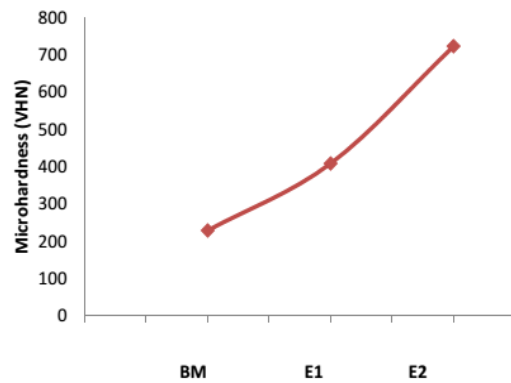


Figure 2: Microhardness variation for BM, E1 and E2

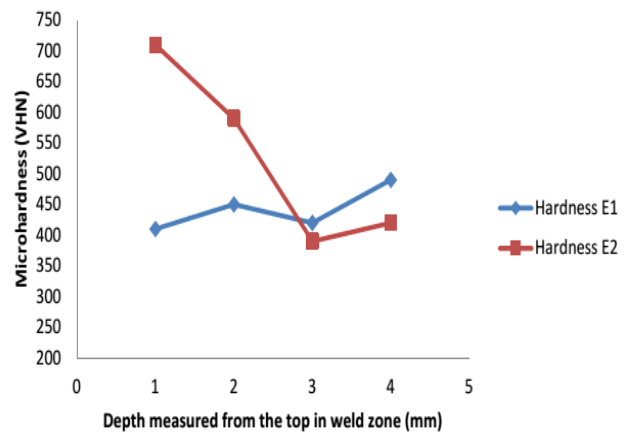


Figure 3: Microhardness profile of the specimens along the depth of the coating

and fig. 7 for electrodes E1 and E2 respectively, from fig. 4 and fig. 5 can be seen that the formation of the austenite phase of Cr-C takes place, both chemical composition are in the range of austenite phase of Cr-C but the only difference is in variation of chromium element in E2 as compared to E1, and as the chromium percentage increases in the E2 more segregation of chromium compound near the grain boundaries takes place that causes the increase in the hardness, in fig. 2 as all the elements almost has small variation causes formation of iron based compound, formation of austenitic phases seen in picture, in fig. 4 as the chromium element increased formation of Cr-C phases, from fig.5, it is clear that chromium segregated near grain boundaries and make Cr-C phases that is visible in figure.

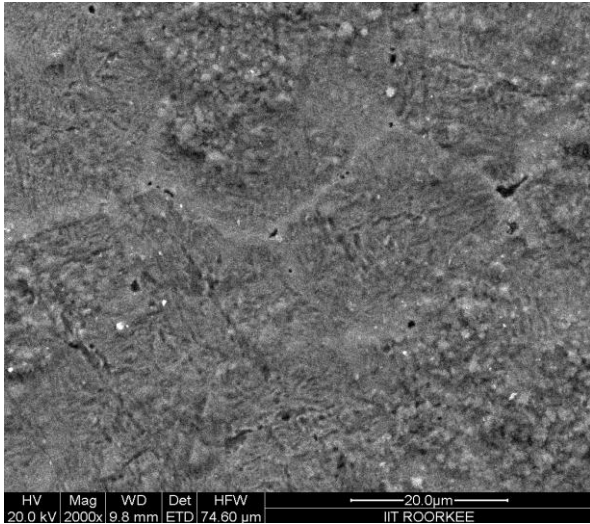


Figure 4: SEM analysis of Hardfaced by E1

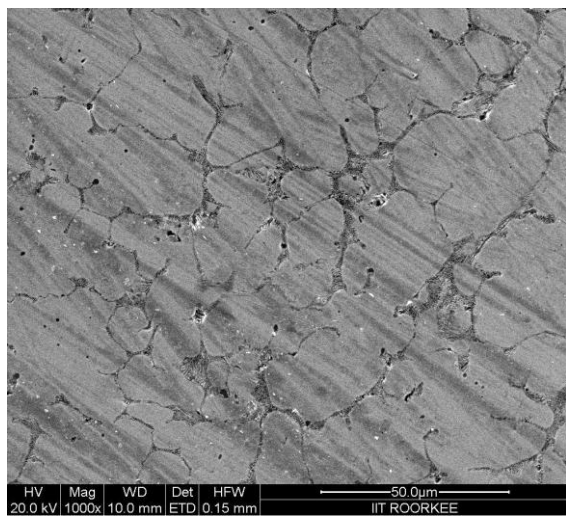


Figure 5: SEM Analysis of Hardfaced by E2

From EDX spectra of both the electrodes shows iron peaks are at maximum height that shows overall more percentage of Fe in composition, apart from this in fig. 6 chromium peaks are lesser than chromium peaks in fig. 7 that shows more percentage in electrode E2 than electrode E1.

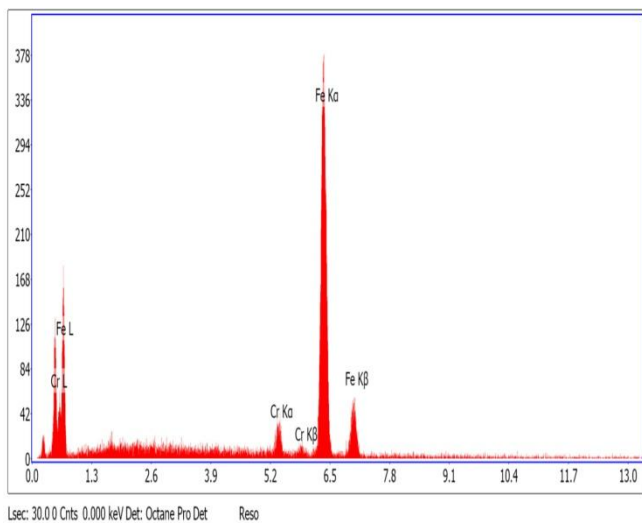


Figure 6: EDX spectra of Hardfaced by E1

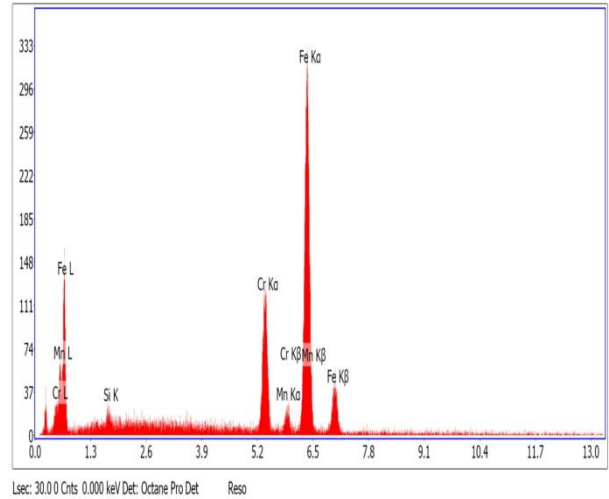


Figure 7: EDX spectra of Hardfaced by E2

3.3 Wear Test Result

Abrasive wear test is performed on the pin-on-disc tribo test, which has the sliding distance of meter, for this the loss of the materials from the coated surface is measured, from fig.8; it can be seen that material loss in E1 is 0.20 gm and in E2 is 0.02 gm, hence the loss of material in case of coated E2 is less than coated E1.

Table 4: Wear rate and loss of materials for both electrodes

Type of Electrode	Weight before wear (gm)	Weight after wear (gm)	Wear rate (gm/cm)
E1	25	24.80	0.45×10^{-3}
E2	24	23.98	0.045×10^{-3}

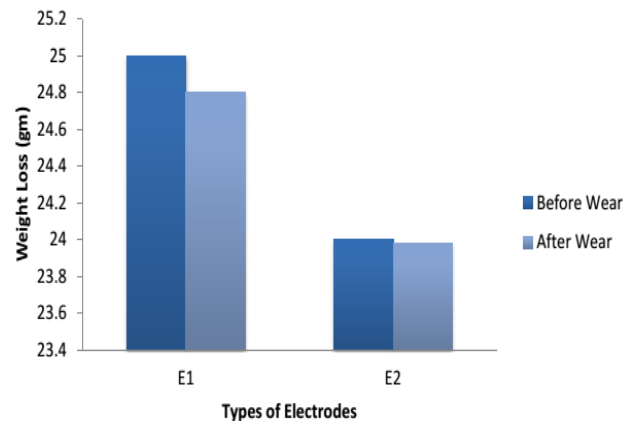


Figure 8: Weight loss measurement

3.4 Optical Microscopy of Worn Out Surfaces

Due to the presence of austenitic solid solutions and (Fe, Cr) 3 C phases the morphology of worn out surfaces were recorded and conclusion on the basis of SEM and EDAX images of coated surface are found that micro cutting and ploughing mechanism takes place, micro cutting is due to

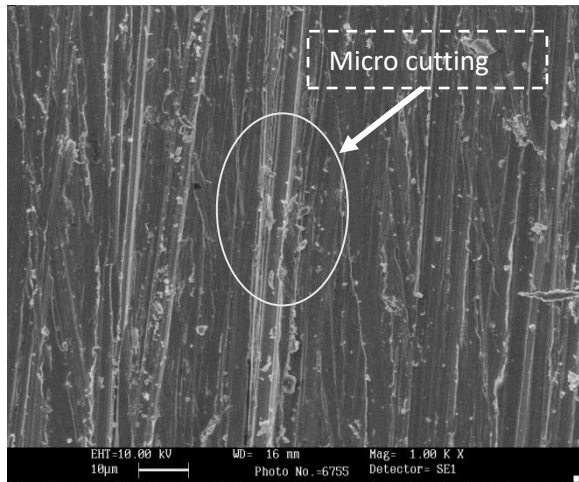


Figure 9: Worn surface of E1

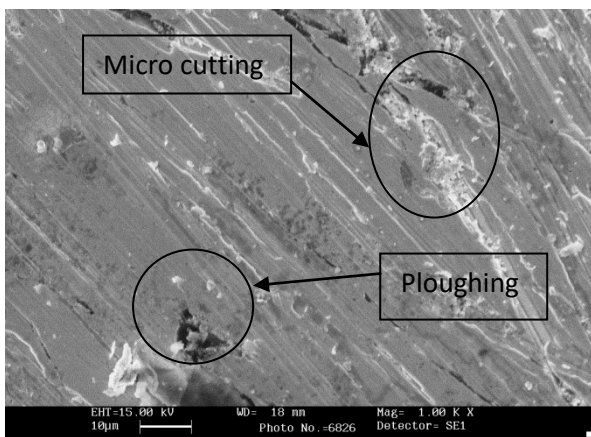


Figure 10: Worn Surface of E2

presence of (Fe, Cr) $3C$ phase as the hardness is more cracks initiates easily, about ploughing, due to presence of austenitic solid solution, more tough but less hard as the load applied absorb more energy, formation like build up edges and suddenly fracture takes place and removed surround material at the point of applied load from the coated surface.

4. Conclusions

Hardness and wear test were conducted for both the hardfaced surface and the following points were concluded:

- 1) Microhardness value was increased from 230 VHN to 420 VHN and 730 VHN for E1 and E2 respectively in both the hardfaced surface.
- 2) Wear rate or material remove rate is decreased with increasing chromium components. The loss of materials from worn surface is measured and found that 0.20 gm and 0.02 gm for E1 and E2 respectively.
- 3) From the study of worn surfaces, the micro cutting and ploughing mechanism are present. As the chromium composition increases more segregation of carbon component near the Chromium compound and formation of $M3C$ phases takes place, as the formation of hard phases takes place and ploughing mechanism forms, as bulk amount of material removed from the hardfaced surface.

References

- [1] I. Kovarikova, B. Szweczykova, P. Blaskovits, E. Hodulova, E. Lechovic, Institute of production technologies, Faculty of material science and technology, Slovak University of Technology.
- [2] Yuksel N, Sahin S, Wear behavior-hardness-microstructure relation of Fe-Cr-C and Fe-Cr-C-B based hardfacing alloys, Materials and Design 58 (2014) 491-498.
- [3] M. Eroglu, Boride coating on steel using shielded metal arc welding electrode, microstructure and hardness 203 (2009) 2229-2235.
- [4] Chieh Fan, Ming-Che Chen, Chia-Ming Chang, Weite Wu, Microstructure change caused by $(Cr, Fe)_{23}C_6$ carbides in high chromium Fe-Cr-C hardfacing alloys, surface and coatings technology, 201 (2006) 908-912.
- [5] A. Frenk and W. Kurz, Micro structural effect on the sliding wear resistance of a cobalt-based alloy, Wear, 174 (1994) 81-91.
- [6] M.A.Moore, The relationship between the abrasive wear resistance, hardness and microstructure of ferritic material, wear, 28 (1974) 59-68.
- [7] M. M. Khrushov, Principle of abrasive wear, Wear, 28 (1974) 69-88.
- [8] Chia-Ming Chang, Yen-Chun Chen, Weite Wu, Micro structural and abrasive wear characteristic of high carbon Fe-Cr-C hardfacing alloy, Tribology International, 43 (2010) 929-934.
- [9] S. Chatterjee, T. K. Pal, Wear behavior of hardfacing deposits on castiron, Wear 255 (2003) 417- 425.
- [10] Chia-Ming Chang, Chi-Ming Lin, Chih-Chun Hsieh, Jie-Hao Chen, Weite Wu, Micro-structural characteristics of Fe-40 wt%Cr-xC hardfacing alloys with [1.0-4.0 wt%] carbon content, Journal of alloys and compounds, 487 (2009) 83-89.