Dry and Wet Abrasive Conditions of Fe-C-B Wear Resistance Hardfacing Alloy on Mild Steel

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Abstract

In this research, Fe-C-B hardfacing layer fabricated with cored wire contains ferroboron on mild steel by FCAW process. OES, ICP, XRD, OM, SEM, and microhardness method were used for study of characteristics of hardface layer. The chemical analysis test results show that boron was absorbed in hardface layer. The XRD, OM, SEM, EDS results, shows that the microstructure consisted of primary Fe_2B, FeB and eutectic structure (A+M+Fe_2B) in hardface layer. The hardness test (HRC) results show that hardness of hardface layer was increased than that the base metal. The wear test results shows, in dry (ASTM G65) and wet (ASTM G105) conditions, the Fe-C-B hardface layer has higher wear resistance than that the mild steel and the wet wear resistance of the Fe-C-B hardface is higher than that the dry conditions. In addition, SEM observation of worn surfaces indicated that the wear micromechanism of hardface samples in dry condition was microploughing with cutting, but in the wet condition, was microploughing with pitting.

Keywords: Fe-C-B, Hardfacing, FCAW, Mild Steel, Abrasive wear.

1. Introduction

Wear is a damage to a solid surface as a result of relative motion between its and another surface or substance [1]. The damage usually results in the progressive loss of material [1,2]. For increasing the service life, weld hardfacing techniques are employed to produce composite layers that are resistant to elevated-temperature, corrosion and abrasion on the surfaces of equipments [3].
The Fe-C-X hardfacing alloys used in abrasive wear applications [3]. In the Fe-C-X hardfacing alloys, type and amount of alloy elements are selected regarding to wear condition and mechanism of hardface layer [4]. The Mn elements add to the Fe-C-X system, for improving the wear resistance in impact condition [5]. In addition elements as: V-Mo [6], Nb [7] and Ti [8] are added to improving severed abrasive wear resistance of the Fe-C-X hardface alloys. The boron has been used in the hardface alloys with carbon and other alloy elements[9-13].
Surface alloyed layer with ferrous boron on the plain carbon steel has the well distributed primary iron boride phases as in-situ composite structure and includes the eutectic structure between the primary boride phases took place in the alloyed layer [9].
In addition, primary borides can be helpful to improve the abrasive wear resistance due to the high potential of excellent wear resistance resulted from the high hardness of primary borides [13].
Boron with carbon and other carbide former elements can be produce carboboroids such as: $M_3(CB)$, $M_7(CB)_3$ and $M_{23}(CB)_6$ in microstructure [9,10]. In addition, boron without carbon can be produces boride with other elements in hardface layer system [10,11]. Titanium Boride (TiB_2) and Iron Boride (FeB, Fe_2B) are the most common boride-based hard particles in hardface systems. The addition of boron to the hardface systems is mainly performed to providing abrasive wear resistance [9-12]. The purpose of this research is study of the microstructure and abrasive wear resistance in dry and wet conditions of Fe-C-B hardfacing alloy on mild steel.

2. Materials and Methods

AISI 1010 mild steel with 12×200×400 mm dimensions used as base metal. The flux cored wire (KJTUBO-720) contains ferroboron was used as filler metal. Before welding, the surface oxides of base metal were removed by machining and rinse with acetone. The FCAW process was used for fabricated hardface layer. Table 1. given welding parameters. After welding the specimens were cut from second layer of hardface, and tests were done on them.
The chemical composition test was done by OES (Optical Emission Spectroscopy) method. In addition, ICP-MS was used to determine the boron

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element in hardface sample. The metallographic examination, samples were polished and etched by 3% nital solution. The OM and SEM (Scanning Electron Microscope) were used for study of microstructure. EDS point analysis was used for determining of chemical analysis of phases.

Table 1. Welding parameters.

Process	**pass**	**Polarity**	**Welding speed** $\left(\frac{mm}{min}\right)$	**heat Input** $\left(\frac{KJ}{mm}\right)$
FCAW-self shield	2	DCEP	500-600	1.15-1.20
Wire feeder $\left(\frac{m}{min}\right)$	**Wire diameter** (mm)	**Arc length** (mm)	**Voltage** (V)	**Current** (A)
5-7	2.8	4-5	27-29	350-400

The X-ray diffraction was used for determining of hardface phases that appeared in microstructure. The Vickers microhardness by 200 gr forces was used for determining the hardness of microstructure, in addition macrohardness (HRC) method used for determining hardness of hardface samples. The dry wear test was done accordance to ASTM G65 standard (dry sand rubber wheel) with 130N force, and the wet wear test was done according to ASTM G105 standard with 222N force in water environment. After wear test for determining micromechanism the worn surface of each samples was observed by SEM.

3. Results and Discussion

3.1. Chemical Composition and Microstructure

Table 2. given the chemical composition of hardface sample. Table 2. denote that the amount of existing boron element in the hardface sample is, at the range of 4.40-4.85 Wt%, that is indicated an absorption of the boron element in hardface layer.

Table 2. Chemical composition (wt.%) of hardface layers.

C	Si	Mn	B	Fe
0.65-0.82	1.25-1.58	2.5-3.1	4.40-4.85	bal

Fig. 1. shows the XRD pattern of hardface layer. It is clear that austenite, martensite, Fe_2B and FeB phases are present in microstructure. The phases of the microstructure can be study by the Fe-B phase diagram.

Fig. 2. shows the Iron-Boron binary phase diagram. According to this diagram (Fig. 2.) with existing of boron in the range of the 4.40-4.85 wt.% at the 910 to 1174 °C temperature, the primary proeutectic Fe_2B phases with (Fe_2B +austenite) eutectic are present in microstructure. After solidify,

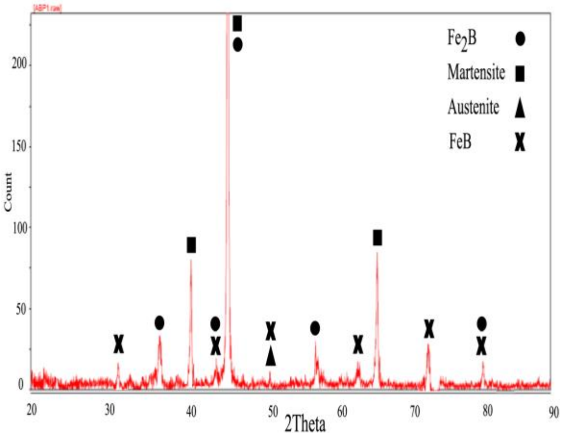


Fig. 1. XRD pattern of Fe-C-B hardface layer.

due to high cooling rate and existing of the relatively high amount of carbon (0.65-0.82 Wt%), there is no enough time to appear ferrite phase, so at room temperature the martensite with austenite are present in eutectic structure. The present of the FeB in microstructure due from decreasing of the boron solubility with temperature in solid state [9]. Therefore, the microstructure consisted of eutectic (martensite + austenite + Fe_2B) with primary proeutectic Fe_2B and FeB.

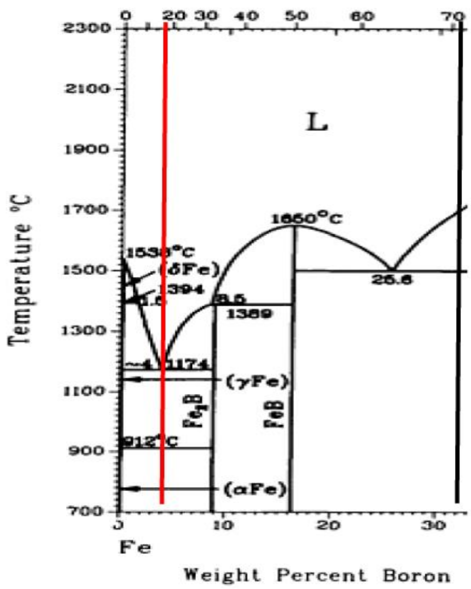


Fig. 2. Binary diagram of Iron- Boron.

Fig. 3. shows an optical micrograph of hardface layer. It can be seen that cubic-like primary proeutectic Fe_2B with colonies of (A+M+ Fe_2B) eutectic are presented in microstructure.

Fig. 4. shows the SEM of micrograph of hardface layer. The FeB phase that has formed due to decreasing of boron solubility in solid state, is

present as the precipitations around the primary Fe_2B (Fig. 4a). The EDS from the particles of primary proeutectic Fe_2B in microstructure shows in Fig. 4b, it can be clear that indicate precipitations were reached from Iron and boron (Fe_2B).

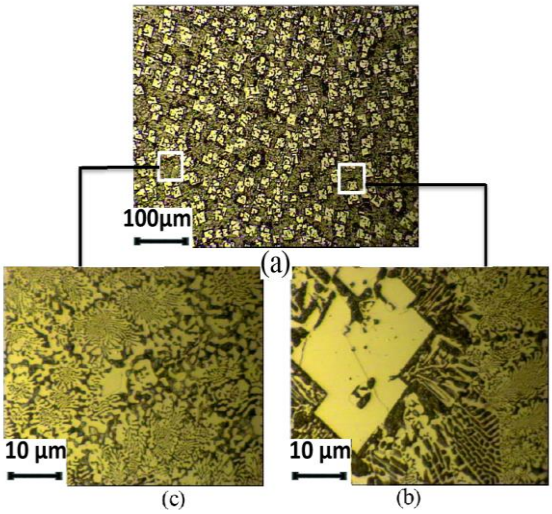


Fig. 3. a) Optical micrograph of hardface layer, b) Fe_2B, c) Eutectic colonies ($M+A+Fe_2B$).

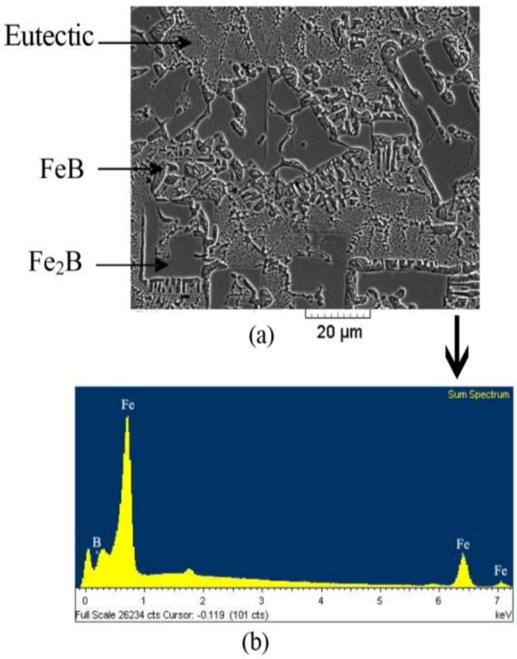


Fig. 4. a) SEM micrograph of hardface layer, b) EDS analysis of precipitations.

3.2. Hardness and Wear Resistance

At 0.6wt.% boron concentration, the primary borides were started to precipitate and these precipitates resulted in an improvement of the abrasive wear resistance. further increasing of boron concentration above 1.0wt.% the resistance of abrasive wear was almost saturated due to the negligible change of primary borides' size and volume fraction. [13].

Fig. 5. shows the micro and macro hardness test result of hardface layer. It can be seen that the primary Fe_2B particles have high hardness (1800 HV). The hardness of eutectic colonies (A+M+ Fe_2B) that is formed in the matrix, is 900HV. It is obvious that (Macro) hardness of surface is much higher than that the base metal.

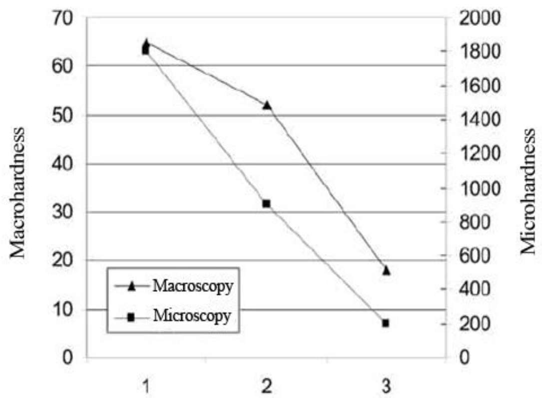


Fig. 5. Macrohardness (HRC) and microhardness (HV0.2) of hardface sample.
Microhardness: 1. Fe_2B 2. eutectic colonies 3.base metal.
Macrohardness: 1. second pass 2. first pass 3.base metal.

Fig. 6. shows the dry and wet wear test results of hardface sample. It is indicate that by increasing of wear distance, the mass loss of the samples increased.

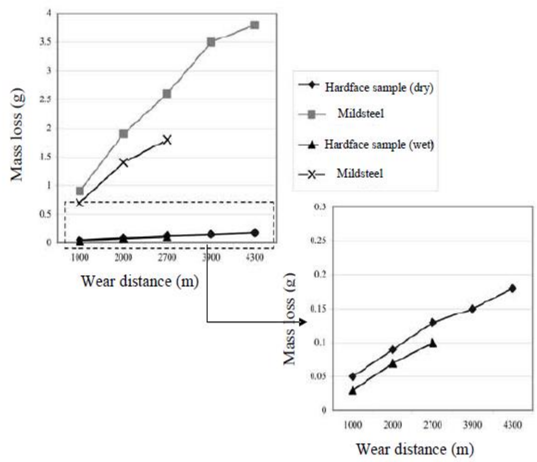
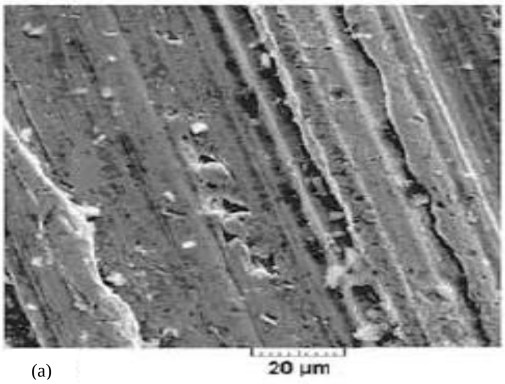


Fig. 6. Wear test results of hardface sample in different test conditions.

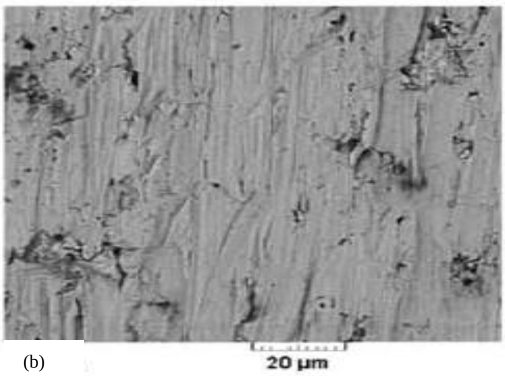
It is show that dry wear resistance of the Fe-C-B hardface layer is higher than that base metal (AISI 1010), while mass loss of the base metal (AISI 1010) is 3.6gr in 4300m wear distance, but in the Fe-C-B hardfacing sample, it is 0.17gr. The cause of higher resistance of dry and wet wear in Fe-C-B hardface layer than that the base metal was due to high hardness of hardfacing layer. The mass loss of sample in wet condition shows the higher wear resistance of hardface sample. In addition, comparison of the wet and dry wear resistance of the Fe-C-B hardface sample, indicate that in wear distance, loss mass of Fe-C-B hardface sample in wet is less than dry condition. The reasons of difference in dry and wet wear resistance conditions of the Fe-C-B hardface layer can be clear by study of micromechanisem of samples.

Fig .7. indicate the SEM micrograph of the worn surface of Fe-C-B in dry and wet conditions. The SEM observation determine that wear micromechanism of hardface sample in dry condition (Fig. 7a) was microploughing with less cutting, but in wet condition (Fig. 7b), was microploughing with pitting.

The SEM micrograph (Fig. 7a,b) determine that the particles of primary proeutectic Fe_2B have affected as a barrier against abrasive particles in dry wear condition and when they were encountered by abrasive particles, they have cut and separated due to high stress. In the wet condition, the primary proeutectic Fe_2B shown high resistant, however they have exposed to pitting in eutectic colonies (martensite and austenite). Since the phases of primary Fe_2B and eutectic Fe_2B constitute the great part of microstructure, so, in same conditions, wet wear resistance of the Fe-C-B is higher than that dry condition.



(a)



(b)

Fig. 7. SEM micrograph of worn surfaces of the hardface layer. a) Dry wear conditions of wear test accordance ASTM G65, b) Wet conditions of wear test accordance ASTM G105.

4. Conclusions

1. The microstructure of the Fe-C-B hardface layer consisted of primary proeutectic Fe_2B with FeB and eutectice colonies (Fe_2B+austenite+martensite).
2. Present of the Fe_2B, FeB and eutectic (Fe_2B+A+M) in microstructure is caused to significant increasing of hardness in the Fe-C-B hardface layer.
3. The dry and wet wear resistance of the Fe-C-B hardface layer is higher than that the base metal (AISI1010).
4. The wet wear resistance of the Fe-C-B hardface is higher than that the dry conditions.
5. The SEM observation of worn surface determined that in the dry condition the wear micromechanism was microploughing with less cutting, and in the wet condition micromechanism was microploughing with pitting.

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