Microstructure Development of Low Carbon Steel Surface Hard-Faced by Chromium Carbide Alloy

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Abstract

In this investigation, the microstructure changes of low carbon steel hard-faced by chromium carbide containing alloy was studied using XRD and SEM analysis. Three group of samples were used in the study. First group of samples was pure low carbon steel without any surface treatment. Second and third group of samples were weld coated with different concentration of chromium contents with 3.2 and 3.8 %. XRD and SEM analysis results show that the microstructure of the surface treated samples consist of little ferrite and much of pearlite. XRD test shows the chromium contents of both of ferrite and pearlite have increased significantly. Increasing of pearlite amount and increasing the chromium concentration in every phases affect to increase of hardness from 140 to 410 HB. Chromium content was increased in pearlite an ferrite up to 2.8 and 3.25 respectively. This increasing causes the phases hardness to be increased.

Key words: Steel, microstructure, phase, hardness, chromium, carbon

1. Introduction

Carbon steel is one of the main materials of metal structure in the machine industry and is divided into 2 groups depending on the intended use. The first group covers structural steels of higher quality and is used in the manufacture of components such as gears, shafts and other machine parts. The second group contains general purpose steels and is produced in the form of sheets, pipes and others. These steels have a carbon content of up to 0.3 percent, so they are considered low-carbon steels. Low-carbon steel is used to manufacture the body of the equipment and parts of supports, joints, and fasteners especially in construction.

The working units of mining, agriculture, and road construction machines that work in the environment of excess abrasive wear are prepared with high-quality special steel and alloy. For example, high-chromium white cast iron and high-manganese steel are commonly used in mining equipment [1, 10]. However, due to the high cost of these alloys, they cannot be used in all parts that work in mechanical and abrasive environments. In such cases, low-cost low-carbon steel is often used. For example, ore transportation, storage and transfer devices, mixing equipment, hydrocyclone pipes, etc. They work in chemically active environments and abrasive friction, so they wear out quickly and need to be replaced more often. To avoid this, the surface of low-carbon steel is coated with wear-resistant materials. In production conditions, the method of improving wear-resistant coatings on metal surfaces by all kind of electric arc welding is widely used [2-8].

Alloys prepared in the form of powder and wire with various quality elements are used for surface quality improvement process. Among these quality materials, iron-carbon-chromium ternary alloy is the most commonly used. This is because this type of alloy is inexpensive but forms a wear-resistant chromium carbide phase when it was coated on steel surface [1-10]. In practical conditions, alloys containing a lot of chromium carbide are the High-chromium white cast iron which is widely used in slurry pumps [10].

There are many experimental and research works on improving the surface of steel by coating of high chromium white cast iron. These works are performed mostly for parts, such as conveyor chute, connection pin and sliding bearing shaft [1].

The following research works have been carried out to improve the surface of low carbon steel with high chrome white steel and increase its wear resistance and other mechanical properties [1,10].

These works investigated the results of coating low-carbon steel surfaces to materials with different chromium contents by various methods of welding.

2. Materials and methodology

100x40x12 mm work pieces of St-3 low-carbon steel were used in the work. The total samples are divided into 2 groups. The first group of them has not undergone any processing and is intended to be used as a basis for comparison of study results. The second group is the workpieces whose surface has been improved with 2 different contents of chromium and carbon, and these are used to evaluate how chromium affects the mechanical properties of the surface. The improvement process was carried out by electric arc welding of high-chromium white cast iron powder. The surface of the improved steel billets was grinded and polished, and the chemical composition and hardness values were measured. Chemical composition was measured using a spectrometer analyzer and hardness was measured using a Brinell tester. Then, the surface of the workpieces was polished and prepared using standard methods for evaluation by optical microscopy and SEM analysis. Number of sandpapers and 1 μm diamond powder were used for polishing the samples. The chemical composition of the phases of each specimen was evaluated by XRD analysis, and the results were compared with the analysis results of base steel.

After the microstructure analysis, abrasive wear tests were conducted using the Pin on Disk method. Wear was expressed by weight per minutes or g/min.

3. Results and discassion

3.1 Chemical contents of the samples

Table 1 shows the chemical composition values of each samples of all three groups 1, 2 and 3. Surfaces of group 1 are un treated and groups 2 and 3 treated with two different contents of chromium compositions.

Table 1. Chemical composition of the samples

Group of samples	Chemical contents, %				
	C	Cr	Ni	Mn	Fe
Group 1	0.14	0	0.3	0.4	баланс
Group 2	0.37	3.2	0.143	1.0	баланс
Group 3	0.42	3.8	0.163	1.0	баланс

As can be seen from Table 1, the surface chromium and carbon content of the threated samples has increased sufficiently. For example, carbon increased from 0.14 to 0.42%, chromium from 0.3% to 3.8%, and the grade of quality steel was reached. Thus, the surface of low-carbon steel has reached the level of medium-carbon steel with sufficient chromium content.

3.2 Hardness and wear test results

After threating with chromium carbide alloy, the hardness of the workpiece increased almost 4 times from 150 to 410 HB. It appears like almost to reach the hardness of quenched steel (Figure. 1).

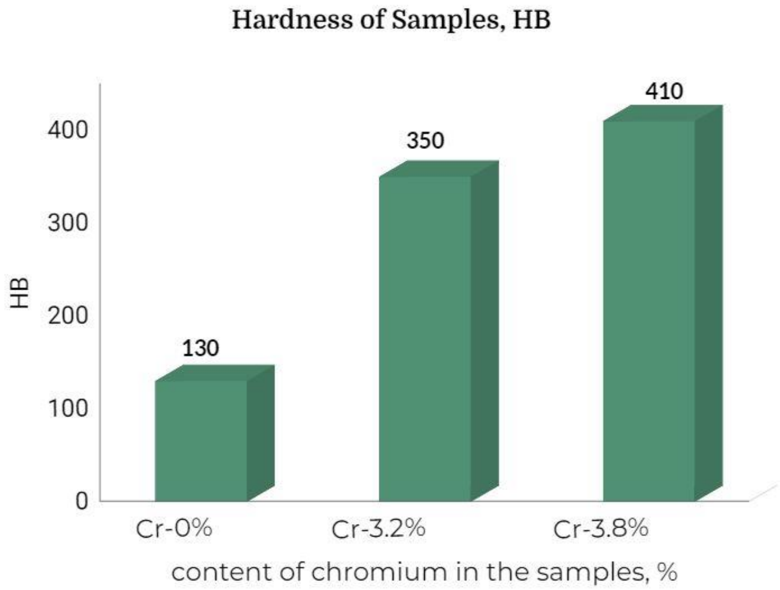


Figure 1. Hardness of the samples, HB

The increase in hardness is explained as follows. After refinement, the surface carbon content of the steel increased to 0.42%, but remained hypo-eutectoid structure of steel. Therefore, the structure consists of pearlite and ferrite. Pearlite is a mechanical compound of ferrite and cementite. An increase in carbon will increase the amount of pearlite, and chromium will dissolve in ferrite to improve mechanical properties. On the other hand, chromium enters the structure of cementite and forms M_3C type carbide.

Chromium increases the ability of steel to thermal hardening, high resistance to corrosion and oxidation, provides increased strength at elevated temperatures, and also increases resistance to abrasive wear of high-carbon steels.

The result of the wear test is shown in Figure 2.

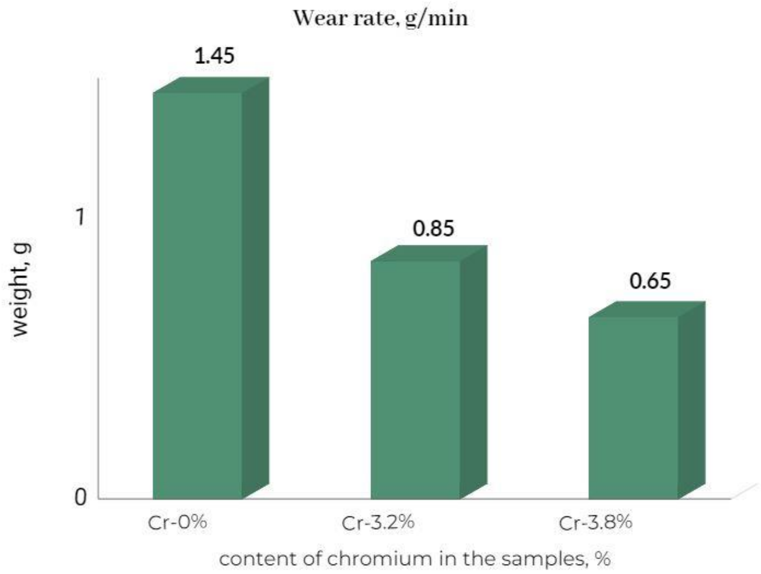


Figure 2. Wear test results of the samples

In the figure 2, the wear amount significantly decreased after surfece treating process. In sample with 0% of chromium the wear amount was 1.45 g/min. But after surface treatment enabling to have 3.8 % of chromium the wear rate has decreased to 0.65 g/min. From these results, it seems that chromium gives big effect to wear resistance of steel surface.

3.2 Microstructure

Figure 3 shows the optical microstructure of each nonthreated and threated samples.

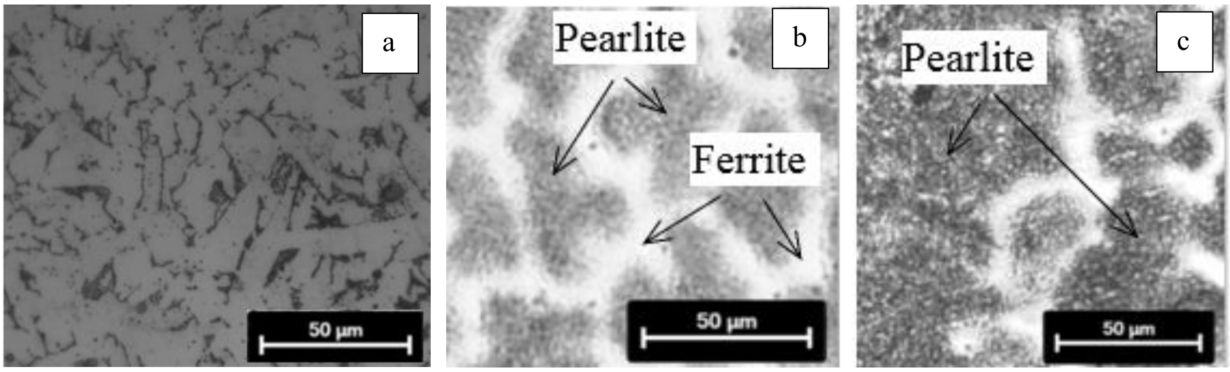
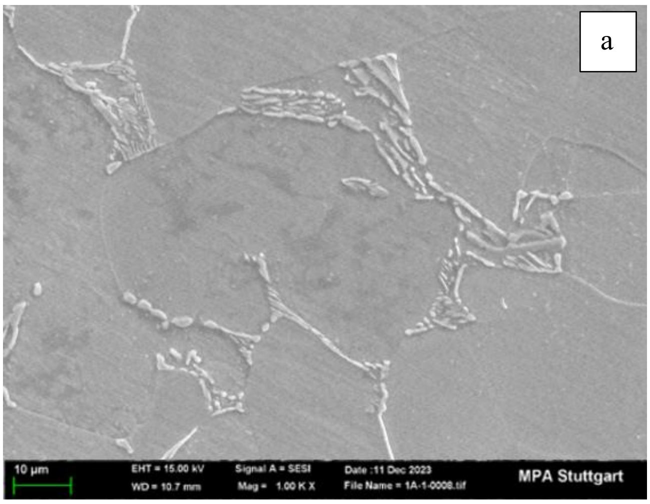


Figure 3. Microstructure of samples: a- sample without surface treatment, b- sample with 0.37% C and 3.2% chromium, c- sample with 0.42% C and 3.8% chromium

As can be seen from the optical microstructure images of all the workpieces, the microstructure of low carbon steel has been changed dramatically after the improvemental process. The structure of hypoeutectoid steel consists of pearlite and ferrite. After the improvement, it can be seen that the amount of pearlite increased significantly and the amount of ferrite decreased. This I explained by increasing of carbon content added by coating process using high chromium white iron.

3.3 SEM analysis

Figure 4 shows SEM images of each three pieces of specimans. In the SEM image of the speciman 1 which is without surface treatment, the ferrite phase occupies the majority and the pearlite is very little. However, after surface treatment with chromium alloy, the ratio of pearlite-ferrite has changed greatly and the amount of pearlite has increased dramaticaly. Chromium content in pearlite and ferrite was determined by XRD analysis and shown in the following figure (Figure 4).



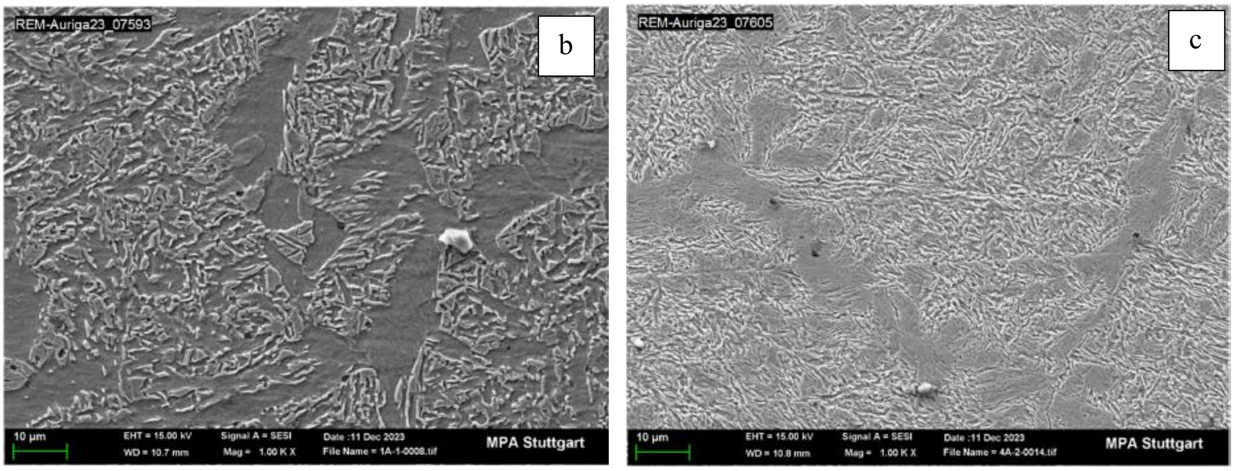
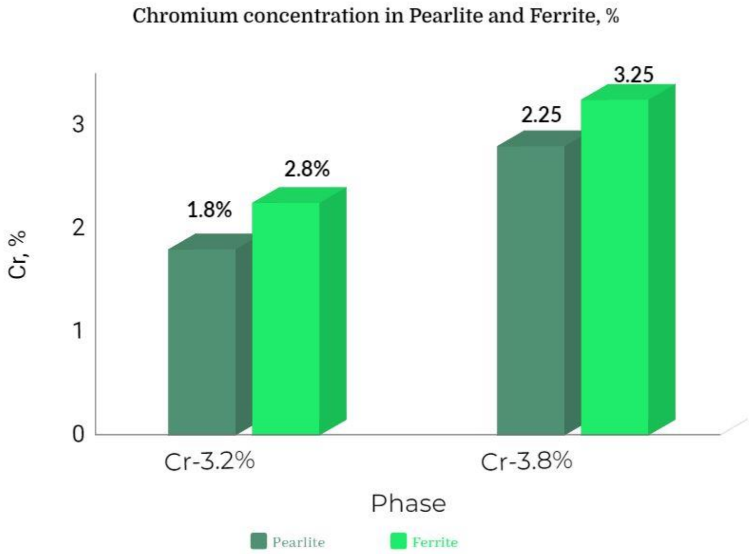


Figure 4. SEM images of the samples: a- sample without surface treatment, b- sample with 0.37% C and 3.2% chromium, c- sample with 0.42% C and 3.8% chromium

Figure 5 shows that the pearlite structure of the alloy with 3.2% chromium contains 1.8% of chromium while the ferrite phase contains 2.25%. As well as in case of sample 3 with 3.8 % of chromium the pearlite structure contais 2.8% and the ferrite phase 3.25% chromium respectively. Here, the chromium contained in the alloy dissolves in both ferrite and pearlite, simultaneously improving their mechanical properties. As the chromium content of the surface increases, the solubility of chromium in ferrite and pearlite increases.



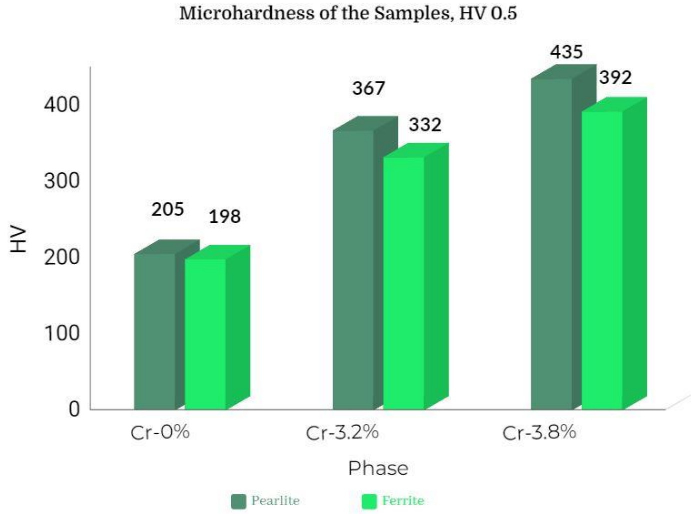
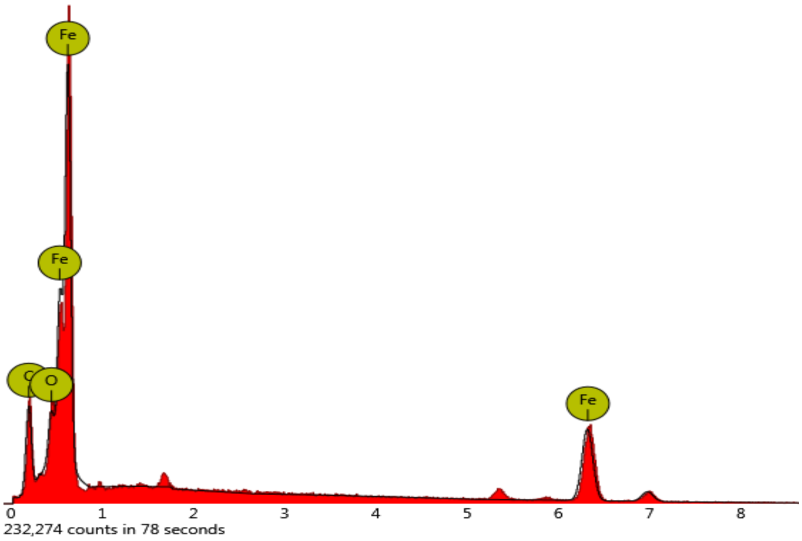
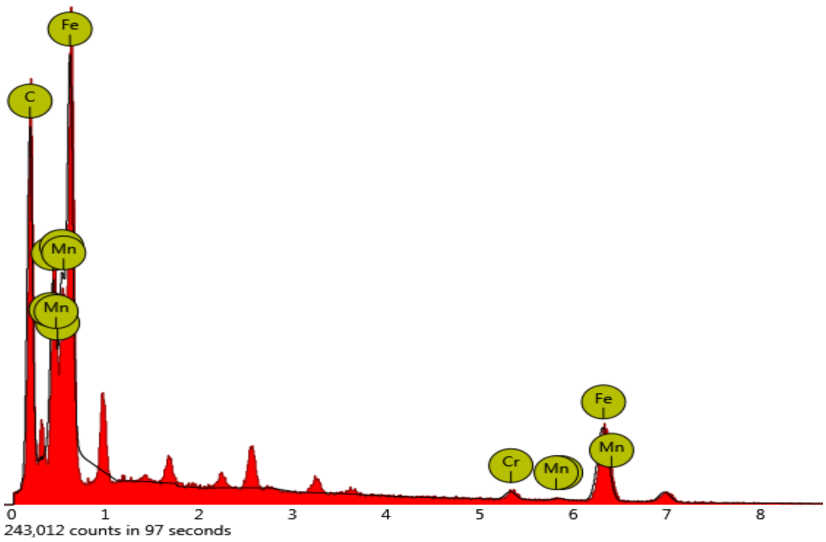


Figure 5. Chromium content in pearlite structure and ferrite phase and the microhardness of the samples

The XRD diagram of each preparation is shown in the following figure (Figure 6).





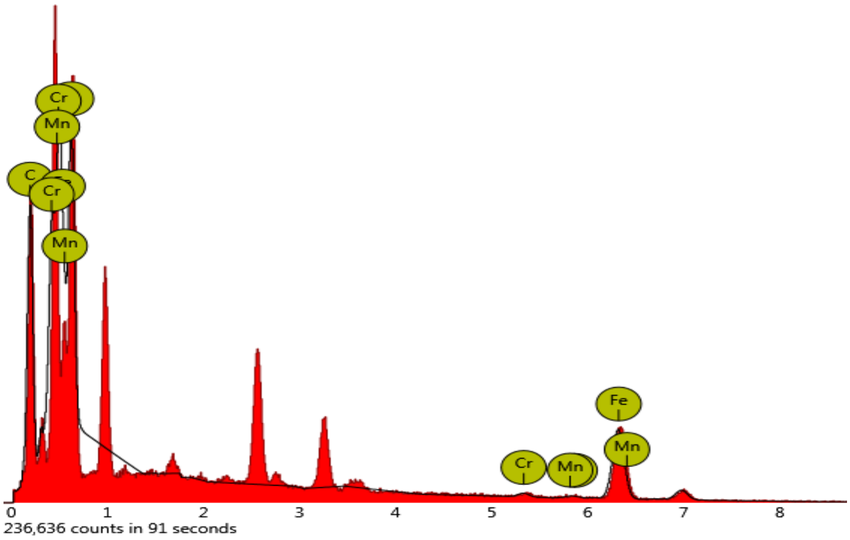


Figure 6. XRD diagrams of the samples

CONCLUSION

Surface treatment of low carbom steel with high chromium alloy dramatcally affects on mechanical properties such as hardness and wear resistance through quality increasing of structure and phases of the surface. This results obtained by number of processes including next:

1. During the coating treatment chromium and carbon contents of surface increased up to medium carbon and low alloyed steel grade
2. Implemented carbon increases pearlite and which affects hardness of the surface
3. Implemented chromium simmultiniuse dissolves into ferrite and eutectoid cementid and cause to increase both hardness and wear resistance.

Low carbon steel can be used in hard and abrasive working conditions after surface treated by coating by cheap chromium carbid containing alloy like high chromium white iron.

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