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Effect of Process Parameters and Cr Addition on Microstructure, Hardness and Wear Rate of Surface Modified High Carbon Steel

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Abstract

The effect of process parameters on microstructure and hardness of High Carbon Steel (HCS) surface modified with Cr has been investigated in this study. Gas Tungsten Arc (GTA) was used as the heat source for surface modification process. Cr with a coating thickness of 125µ was applied on the substrate and surface modification was done. The Carl Zeiss metallurgical optical microscope was used for the microstructural evaluation and Vicker's micro hardness tester was used for the hardness measurement. Wear test was conducted using a Pin-On-Disc wear tester. Microstructural evaluation showed that grain refinement occurs on the modified layer as a result of surface modification process. Hardness as well as wear rate was taken for the substrate, simply refined and Cr surface alloyed specimens. Increase in hardness was observed after surface modification process. Hardness increased from 320HV to 916 HV after Cr addition. Wear rate decreased with increase in hardness. The results obtained were comparable with that of previous studies.

Keywords: High carbon steel, Surface modification, GTA, Hardness.

Introduction

Surface Modification Process is emerging as a promising as well as alternative method when compared to the traditional coating methods like CVD, PVD etc for improving the surface properties of ferrous as well as non-ferrous alloys. Surface modification process involves melting the surface of a substrate with an appropriate heat source and allowing it to cool so that a modified layer forms upon solidification.

The so formed modified layer exhibits improved surface properties which can be utilized for the industrial applications

Researches were conducted on the effect of surface modification process on various steels and are as follows. Eroglu. M and Zdemir. N. O conducted a study on low carbon steel using Tungsten Inert Gas surface alloying. They showed that surface alloying increased the hardness as well as wear resistance of the alloy [1]. Suleiman et.al. observed the effect of laser surface melting on the microstructure and mechanical properties of low carbon steel. A fine structure was observed on the laser surface melted layer and they attributed this to the fast cooling rate after surface melting [2]. Marek investigated the Laser surface alloying of medium carbon steel and found that the cavitation erosion resistance increased due to surface alloying [3]. Kwok.C.T et.al. observed an increase in hardness on tool steels by laser surface melting process [4]. Shunsuke Yagi et.al. used Alternating Pulsed Electrolysis for alloying Fe-Cr to the carbon steel surface [5]. Dyuti.S et.al. observed an enormous increase in mechanical properties of mild steel by surface modification technique [6]. Babu.P.D et.al showed a significant increase in surface hardness of low alloy steel by laser transformation hardening technique [7].

High carbon steels are alloy steels which contain 0.8-1 wt% carbon. Owing to its good strength, hardness and wear properties it is widely used in the manufacturing of tools, rail steels, high strength steels etc. In view of the above conducted literature survey it can be concluded that the effect of surface modification process on high carbon steel has not been studied yet. Hence, an investigation was done to evaluate the effect of GTA process parameters on microstructure, hardness and wear rate of high carbon steel surface modified with Cr. The viability of using GTA as a heat source is evaluated. The effect of simple surface refining as well as that of Cr addition on the microstructure, hardness and wear rate was also investigated.

Experimental Procedure

High carbon steel specimens were procured and the chemical composition was checked using arc spectrometry. Table 1 shows the results of spectrometry analysis.

Table 1: Chemical Composition

Specimen	Wt % C	Wt % Fe	Wt % Si	Wt % Mn
HCS	1.02	97.01	0.25	0.68

The specimens were machined to 30X30X150mm dimension bars. The machined specimens were taken for surface refining using GTA as the heat source and another set of specimens were coated with Cr of 125 µm thickness. The Cr coated specimens were then taken for surface modification process. The GTA parameters like electrode tip distance (3mm), electrode angle (60°), speed (2mm/s), argon flow rate (12ltr/min) and electrode diameter (2.4mm) were kept constant whereas current was varied (125, 150, 175 and 200 A) respectively. Thoriated tungsten was used as the electrode material. The microstructural examination was conducted using a metallurgical optical microscope and hardness was measured on the surface of the modified layer as well as along the depth using Vicker's micro hardness tester. 100 gmf load was applied for a duration of 15 sec for the measurement. Hardness was measured at various locations and an average value was taken. Wear test was conducted using a Pin-On-Disc tester. A diamond like coated disc was used as a counterface material to conduct the wear test. The test was conducted as per ASTM G99 standard under dry sliding conditions in air. The wear testing parameters used are given in Table 2.

Table 2: Wear Testing Parameters

Parameter	Unit
Load	20 N
Speed	424 RPM
Track diameter	110 mm
Time	600 s
Velocity	2.5 m/s
Sliding distance	1500 m

Figure 1 shows the GTA equipment which was used as the experimental setup.

Figure 1: GTA equipment

Results and Discussion

A. Microstructure

Figure 2, 3 and 4 shows the microstructure of substrate, simply refined and Cr surface alloyed high carbon steel specimens. It can be observed from the figures that grain refinement occurs because of surface refining process. This is due to the rapid coolingas a result of surface refining process.

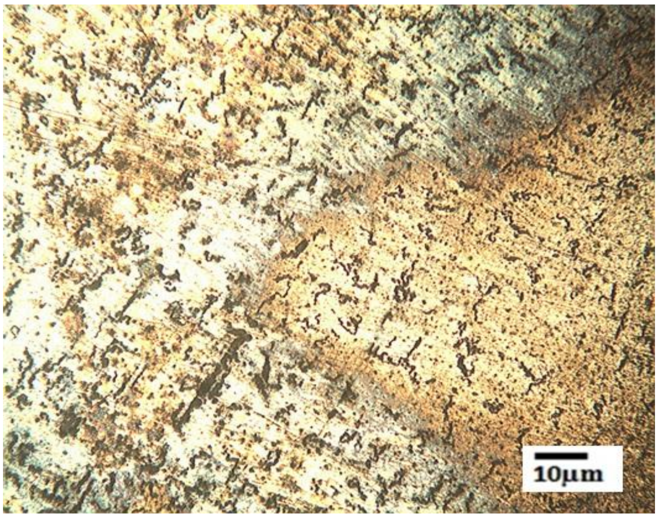

Figure 2: High Carbon Steel Substrate

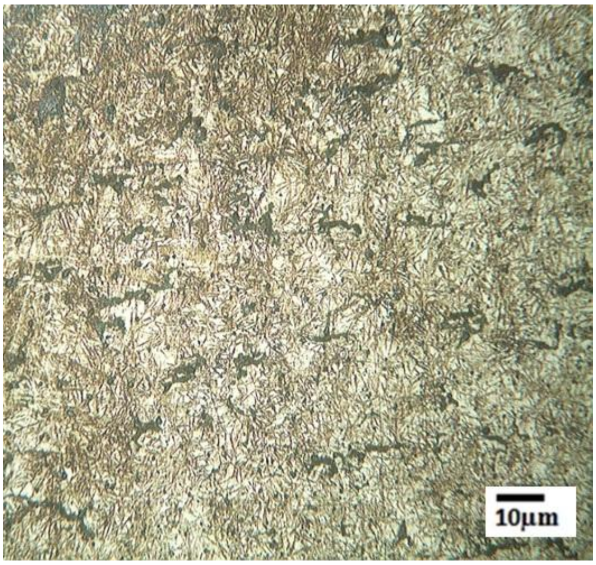

Figure 3: Simply Refined High Carbon Steel

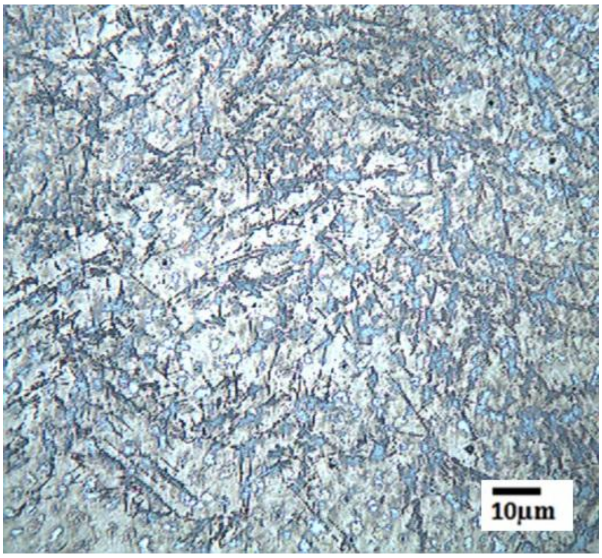

Figure 4: Cr alloyed High Carbon Steel

Figure 5 shows the Energy dispersive spectrometry (EDS) of High carbon steel modified with Cr.

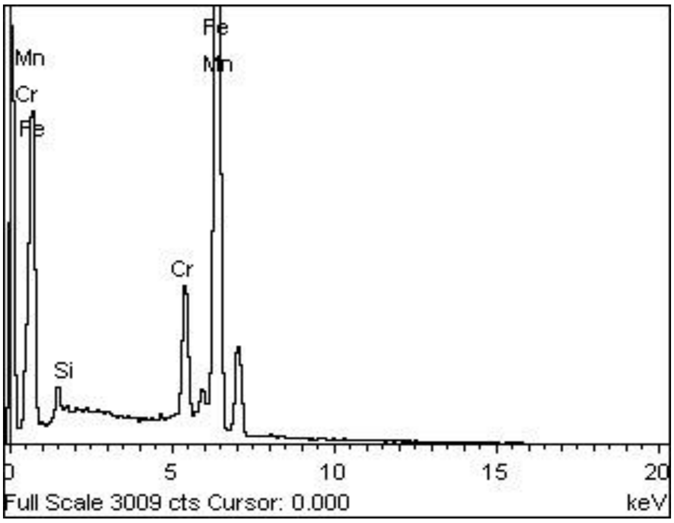

Figure 5: EDS Spectrum Of Modified Layer

B. Width and depth

Figure 6 shows the surface modified layer alloyed with Cr.

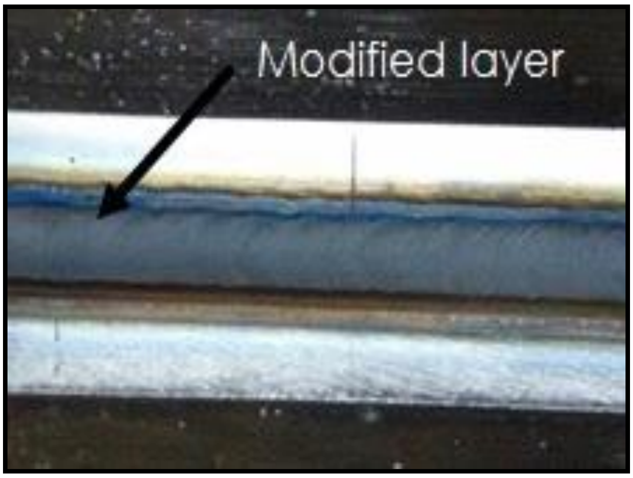

Figure 6: Modified layer

Figure 7 shows the variation of width and depth of the modified layer with current. It is observed that a maximum width of 8mm and a depth of 3.1 mm was obtained with 200A current. It is also inferred from the graph that width and depth of the modified layer increases with current.

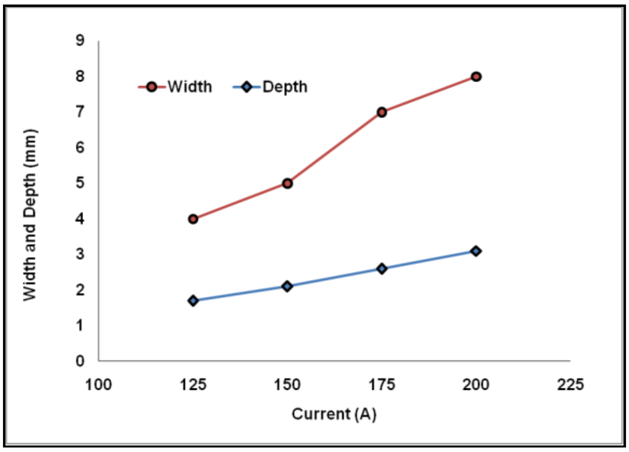

Figure 7: Width And Depth Variation With Hardness

C. Hardness

Figure 8 shows the variation of hardness with current after simple surface refining. It is observed from the figure that the hardness increased from 320HV to 453HV as a result of simple refining. This is attributed to the carbide formation owing to rapid solidification after surface refining. It can also be found that hardness increases with increase in current. The area of refinement will be more when current is increased.

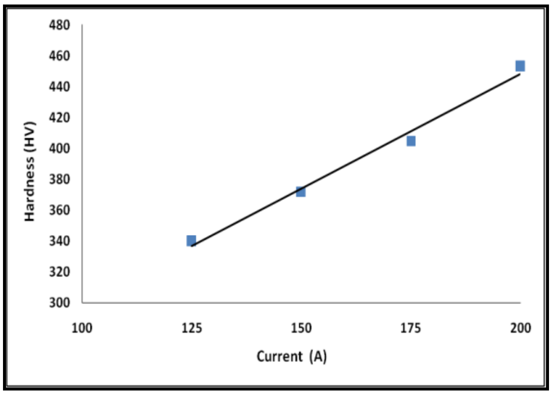

Figure 8: Hardness vs. current (Simply refined)

Figure 9 shows the hardness variation of Cr alloyed specimen with current. A significant increase in hardness was obtained for Cr alloyed specimen with increase in current.

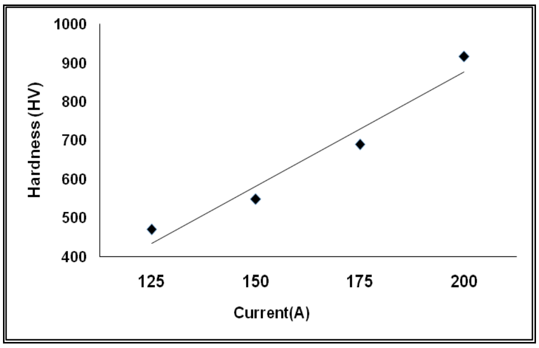

Figure 9: Hardness vs. current (Cr alloyed specimen)

Figure 10 shows the variation of Cr content on the surface of the modified layer with current. It is observed that the Cr content decreased with current because of the increase in Cr dissolution as current is increased.

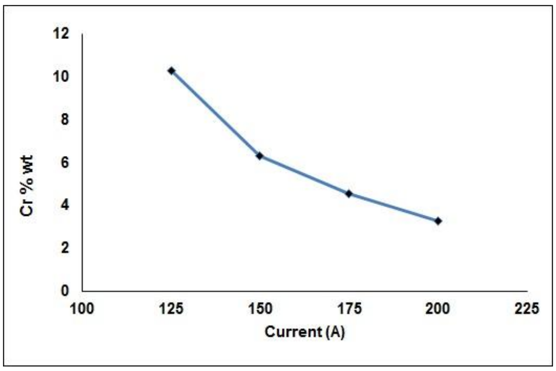

Figure 10: Cr Variation With Current

The increase in Cr dissolution with current results in the formation of hard Cr Carbide phase. As a result, a significant increase in hardness was observed for the surface alloyed specimen. The hardness of the substrate increased from 320HV to a peak hardness of 916HV after surface modification process.

Figure 11 shows the variation in hardness along the depth of Cr alloyed and simply surface refined specimen. A gradient in hardness was observed as we move along the depth of the Cr alloyed specimen. High gradient is observed due to the addition of Cr.

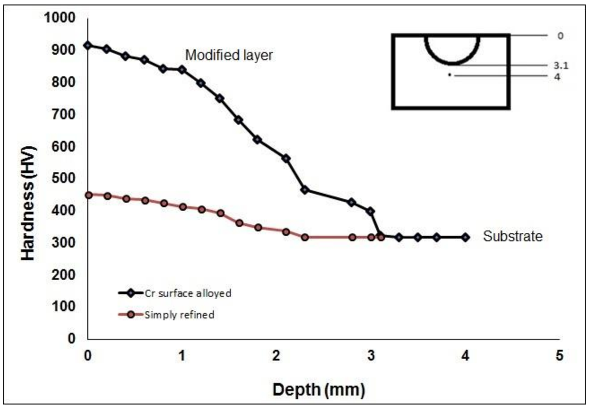

Figure 11: Hardness Profile

Figure 12 shows the hardness results obtained for substrate, simply refined and Cr alloyed specimen. It is observed from the bar chart that the maximum hardness was obtained for the Cr surface alloyed specimen.

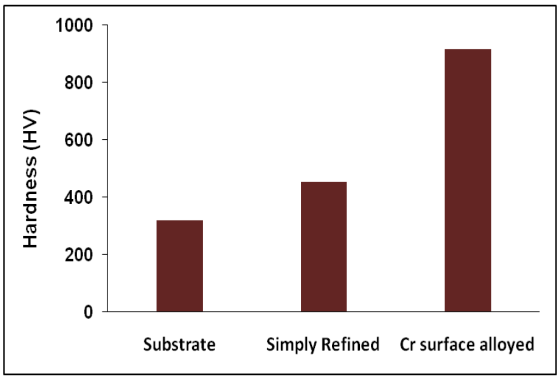

Figure 12: Hardness Data

Figure 13 shows the bar graph comparing the hardness obtained in this study with that of studies reported in the literature. It can be clearly inferred from the graph that the results obtained in this study are quite comparable with that of previous studies.

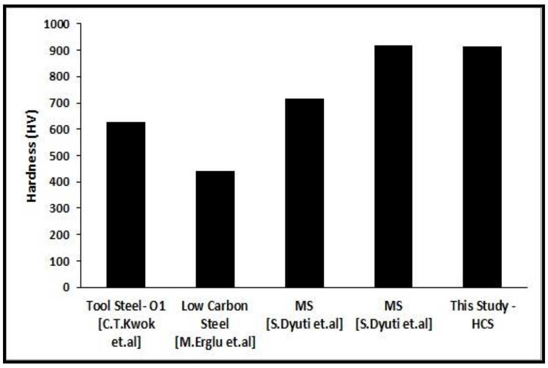

Figure 13: Hardness Comparison Data

D. Wear Rate

Figure 14 shows the variation in wear rate with hardness. It is inferred from the graph that wear rate decreases with increase in hardness. This finding is in agreement with that of Archard's wear theory (Archard J.F, 1953) [15].

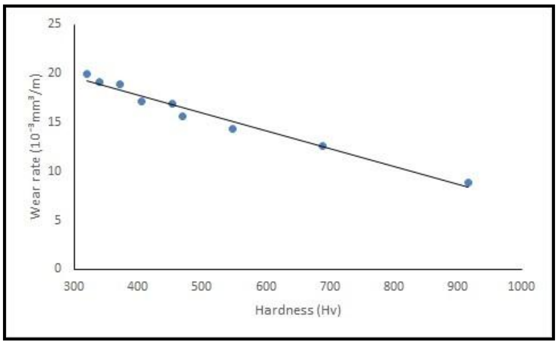

Figure 14: Hardness vs wear rate

Figure 15 shows a bar chart comparing the wear rate of substrate, simply refined as well as surface alloyed specimens. It can be observed that the lowest wear rate is achieved for the surface alloyed specimen.

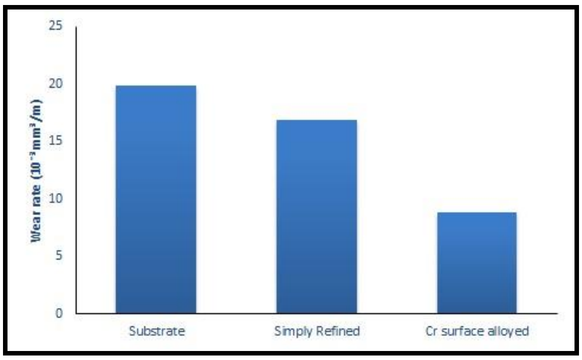

Figure 15: Wear rate data

Figure 16 shows the wear debris of surface modified high carbon steel. It is observed from the image that the wear mechanism is adhesive in nature.

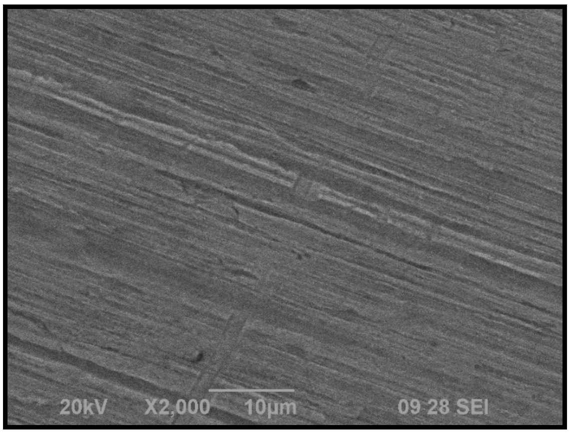

Figure 16: Wear debris

E. Coefficient of Friction

Figure 16 shows the variation in Coefficient of Friction with hardness. The frictional coefficient values remains constant irrespective of hardness. A constant value of 0.4 has been obtained for this study.

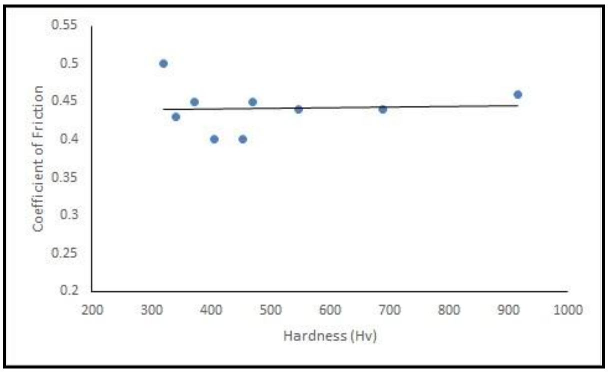

Figure 16: Hardness Comparison Data

Conclusions

The effect of GTA process parameter and Cr addition on microstructure and hardness of surface modified High carbon steel was investigated and the following conclusions were made:

- Grain refinement occurs as a result of surface modification process.
- Hardness increased after surface modification due to martensitic transformation.
- Surface hardness was found to increase with current.

- A gradient in hardness was obtained along the depth of the modified layer as a result of Cr addition.
- Wear rate was found to decrease with hardness.
- The coefficient of friction remains a constant irrespective of hardness.
- The obtained results are comparable with that of previous studies.

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