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Wear Characteristics of AISI 310 Grade Stainless Steel Material by Carbonitriding Process

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Abstract. The investigation on the microstructure and mechanical behaviour of steel AISI 310 has been carried out during a Carbonitriding process aiming to improve the wear performance. The comparison study was made to treated specimens with untreated sample. Carbonitriding is a viable technique to enhance the wear resistance of the stainless steel material. The present study focused in the direction of investigating the effect of microstructure, hardness and wear resistance of AISI 310 stainless steel material. In carbonitriding process the case depth was found to be from 13, 16.5 and 19 Microns which is treated 2 hrs, 4hrs and 6 hrs respectively. The combination action of strong adhesion, abrasion and severe plastic deformation are the primary reasons for the continuous material loss in the untreated specimens during testing. The Optical microscope, SEM analysis and wear test are conducted to find out the various results.

1 Introduction

Steel is an alloy whose major component is iron with carbon content between 0.02%and 1.7%by weight, depending on grade. In metallurgy stainless steel, also known as inox steel or inox from French "inoxydable", is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass. Stainless steel does not stain, corrode, or rust as easily as ordinary steel, but it is not stain-proof. It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment the alloy must endure. Stainless steel is used where both the properties of steel and resistance to corrosion are required. Stainless steel differs from carbon steel by the amount of chromium present. Unprotected carbon steel rusts readily when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide (1-6). Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure (7, 8). It is customary to divide stainless steel in groups according to metallurgical structure like Martensitic stainless steel, Ferritic stainless steel, Duplex (Ferritic –austenitic) stainless steel, Precipitation-hardening stainless steel and Austenitic stainless steel (9). Carbonitriding is often applied to inexpensive, easily machined low carbon steel to impart the surface properties of more expensive and difficult to work grades of steel. These processes are most normally utilized on low-carbon, low-alloy steels.(10) Carbonitriding process is commonly conducted on low carbon steel to enhance surface hardness, wear, and fatigue characteristics through the formation of carbonitrided layer. Carbonitriding with the addition of carbon and/or nitrogen were investigated, which shows that less significant hardness drop was obtained in carbonitrided low-carbon-steel specimen after tempering as compared to the carburized one due to the secondary precipitation mechanism [11]. The effects of ammonia flow rate on the microstructure, distortion, hardness and strength have been investigated, but still focused on the low carbon steel [12]. Abrasion with shallow and narrower wear track was the predominant wear mechanism of carbonitrided AISI 310 at 50 N; whereas, high friction sliding mechanism at 150 N was controlled by plastic deformation [13-15]. However, the microstructure evolution on high carbon chromium bearing steel during

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carbonitriding and the friction behavior of carbonitrided specimens are extremely meager and incomprehensive.

Table 1.1 Composition of AISI 310 ASS

Elements	C	Mn	Si	P	S	Cr	Mo	Ni
%	0.25	2.0	1.5	0.045	0.03	26	2.00-3.00	22

2 Experimental Procedure

The pin type AISI 310 grade stainless steel were reduce into small pieces of size 30mm, diameter 8 mm, with the assist of wire cut EDM process and disc of equal fabric is used, with 150mm diameter and 10 mm thickness. The disc fabric used to be floor hardened. Material composition: Carbon: 0.25%, manganese: 2.0%, silicon: 1.5%, sulphur: 0.03%, phosphorous: 0.045%, nickel: 22%, chromium: 26%. Mechanical specification: Tensile strength: 520 mpa, yield strength: 205 mpa, elongation: 40 %. Carbonitriding for another three specimens was also performed CN11-2hr, CN22- 4hr, and CN33-6 hr. Procedure of wear test with the pin was held against the counter face of a rotating disc. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens was conducted under the normal loads of 30N and 40Nrespectively. The wear rate was calculated from the height loss technique and expressed in terms of wear volume loss per unit sliding distance. In this, the test was conducted with the parameters like Load, Speed and Distance. In the present experiment the parameters such as speed, time and load are kept constant throughout for all the experiments.

Table 2.1 Wear test working parameters

Parameter	Value
Load	30N,40N
Constant Track diameter	10mm
Diameter of disc	150mm
Height of disc	10mm
Diameter of pin	8mm
Length of pin	30mm
Material of disc	Stainless steel
Material of pin	310
Speed	500 rpm
Density	8000kg/m³
Time	5 mins(constant)

Table 2.2 – Wear track reading at 30N load

S NO	SPECIMEN	Weight before testing (gms)	weight after testing (gms)	weight loss (gms)	volume wearloss (mm³)	Frictional force(n)
1	UNT	11.64	11.568	0.072	9	5.7
2	CB1	11.75	11.726	0.024	3	8.2
3	CB2	11.63	11.612	0.018	2.25	10.9
4	CB3	12.09	12.077	0.013	1.625	18.6
5	CN1	9.66	9.645	0.015	1.875	12.0
6	CN2	11.91	11.902	0.008	1	15.2
7	CN3	11.97	11.966	0.004	0.5	20.2

Table 2.3 – Wear track reading at 40N load

S NO	SPECIMEN	Weight before testing (gms)	weight after testing (gms)	weight loss (gms)	volume wearloss (mm³)	Frictional force(n)
1	UNT	11.568	11.470	0.098	12.25	3.6
2	CB11	9.06	8.998	0.062	7.75	5.0
3	CB22	8.64	8.600	0.040	5.0	8.9
4	CB33	8.37	8.358	0.012	1.5	9.5
5	CN11	8,82	8.76	0.060	7.5	1.63
6	CN22	7.90	7.857	0.043	5.3	3.6
7	CN33	8.49	8.456	0.034	4.25	10.5

3 Result and Discussion

The thickness of the nitrided specimens was measured under the Optical Microscope. The type of Optical Microscope used is of Olympus GX51 version with a magnification range of 5X - 100X .To find the coating thickness of the specimens; they were first cut into a small 3mm disc and are mounted into a disc by cold setting process. The process of setting involves placing the cut specimen into a mounting disc and adding silica or Bakelite powder and setting liquid and leaving them aside for 30 min to fuse together around under the chemical reaction. This mounting is removed from the cold setting disc and made to rub against various grades of emery paper starting from grit size 160 to 1200 until a smooth mirror faced finish is obtained. This mounted specimen is made to observe at various magnifications and at the range of 100X a clear view of coating thickness is obtained. The coating thickness is measured from the measurement table on horizontal/vertical distance between the two selected points i.e. one on the specimen edge and the other on the coating thickness edge.

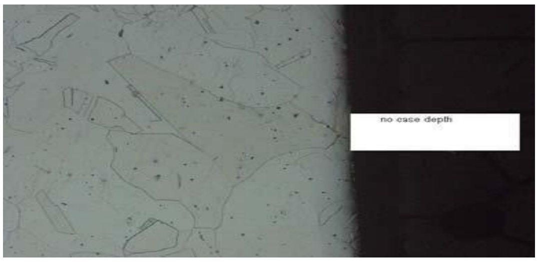
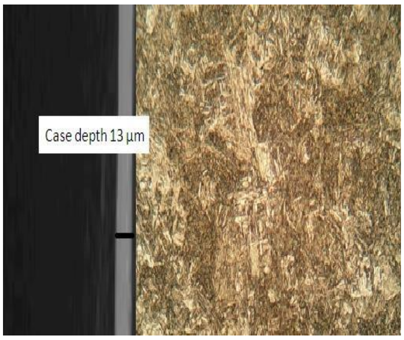


Fig. 3.1 Optical Microscope results for untreated specimen



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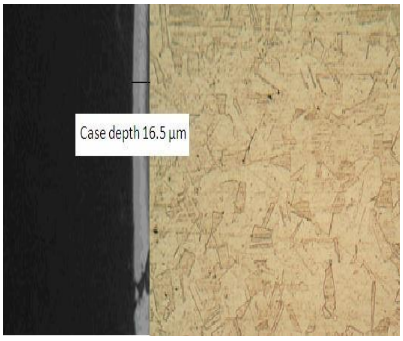

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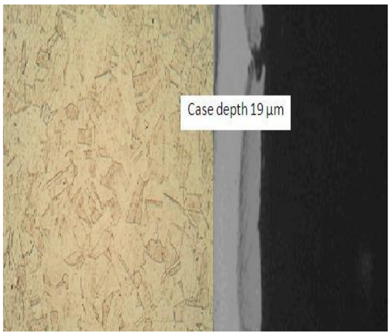


(3)

Fig, 3.2 Optical microscopy images of Carbonitriding specimen CN11, CN22 and CN33.

From the above optical microscope results, case depth were noted. It was seen that as the time of heat treatment increases, case depth also increases. For an untreated specimen, no case depths were found. The case depth increases from 11.5 microns to 14 microns in carburizing specimens and 13 microns to 19 microns in carbonitriding specimens.

Surface morphology and microstructural analysis of 310 Austenitic stainless steel is carried out before and after surface treatment under scanning electron microscopy (SEM) using SEM-JEOL-JSM- 6480 LV machine operated at an acceleration voltage of 15 kV. SEM makes use of the focused beam of the high- energy electrons to generate a variety of signals at the surface of solid specimens. The signals obtained from the electron beam and surface interaction gives the information about its morphology or texture. Generally the beam is focused onto a specified area of the specimen. The analysis of the samples was done at 5000x.

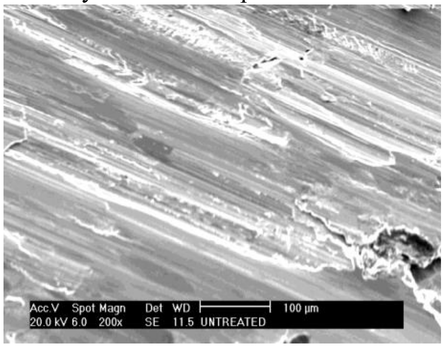
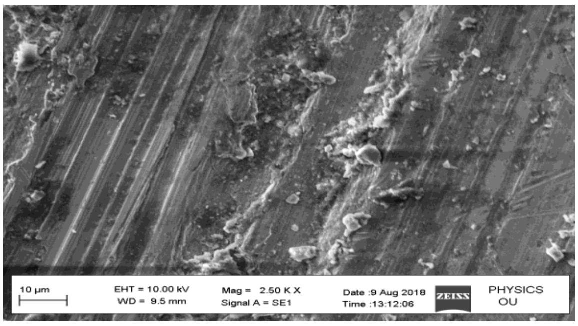


Fig 3.3 SEM image of untreated specimen



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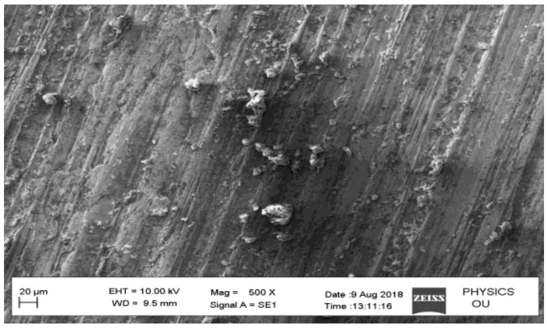

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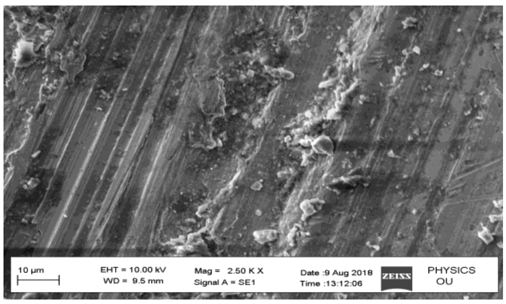

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Fig. 3.4 SEM images of Carbonitriding specimen CN11, CN22 and CN33

From the scanning electron microscope results, it was found that more peel of material from untreated specimen. As the time of heat treatment increases, wear decreases and wear loss decreases on the stainless steel material. There found to be less wear of material when it is subjected to load. Thereby wear resistance of the material increases, improving the property of ductility in stainless steel material and thereby increasing the hardness.

4 Conclusion

In this work, carbonitrided treated 310 grade stainless steels was performed and the wear behaviour was studied. Here a comparison study was made to treated specimens with untreated sample. Carbonitriding is a viable technique to enhance the wear resistance of the stainless steel material. Several researchers investigated the effect of carbonitriding on mechanical and surface behaviour of carbon steels. Only little information is available on the wear behaviour of AISI 310 grade austenitic stainless steel material. The present study focused in the direction of investigating the effect of microstructure, hardness and wear resistance of AISI 310 stainless steel material. The major conclusions are as follows.

1. In carbonitriding process the case depth was found to be from 13, 16.5 and 19 Microns which is treated 2 hrs, 4hrs and 6 hrs respectively. From the pin on disc- wear study it was found to be that, CN specimen has a very highest wear resistance to time. In general, the wear resistance of the carbonitrided specimens is found to be superior to the untreated specimens. The wear loss in carbonitriding process (CN1, CN2, CN3) were found to be 1.875, 1.00, 0.50 mm^3 at 30 N, 7.50, 5.30, 4.25 mm^3 ss at 40 N.
2. The combination action of strong adhesion, abrasion and severe plastic deformation are the primary reasons for the continuous material loss in the untreated specimens during testing. Whereas the wear on the carbonitriding specimen due to less case depth wear is reduced.
3. In SEM analysis, a carbonitrided specimen reveals very minute micro etches pits. They are visualized in the compound layer indicating the uneven distribution of carbon and nitride particles.
4. The results of this work confirm that carbonitriding has effectively improving its wear resistance. The wear resistance for the plasma nitriding is observed to high compared to others, because it has every even distribution of nitride on the surface.
5. As the time for treatment increases the case depth, hardness increases. In general, the wear resistance of the carbonitrided specimens is found to be superior to the untreated specimens.

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