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A Study on Hardness of Carburised and Non-Carburised SAE 1020 Steel

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Abstract

In present day materials, surface properties needs to be altered, maintaining the properties of base material as same. Especially, sometimes hardness is of utmost importance and needs to be enhanced to avoid wear on the surface of material and thus the deterioration of the surface. Present paper deals with carburized SAE 1020 steel for evaluation of hardness and wear resistance. The study shows that the carburised samples have exhibited the larger resistance towards surface wear. The hardness curve for the non-carburised samples showed the displacement of around 800 nm while carburised sampled exhibited the displacement of about 400 nm which indicates that the hardness of carburised samples has been improved considerably as compared to non-carburised samples

Keywords: *Hardness, Tribology, Carburisation, Wear, Normal load, SAE 1020*

1. Introduction

Heat treatment is a process of heating and cooling operations; it depends upon time applied for soaking to a specimen or alloy in the solid state in such a way that it will acquire desired properties." Basic heat treatment processes of steel consist of the formation of martensite and decomposition of austenite. The quality of these transformed products determines the physical and mechanical properties of any given steel. The carburization provides residual changes in carbon content and carbide volume from the surface to the core, and gradual conversion of mechanical and wear properties. The heat treatment and carburization helps to improve the mechanical and wear resistance. Carburizing is the impingement of carbon to the surface of low-carbon steels at temperatures generally ranging between 850 and 950°C at which austenite, with its solubility for carbon, is the stable crystal structure. Hardening is done by quenching the high-carbon surface layer to form martensite. High-carbon martensitic case with good fatigue and wear resistance covered a tough, low-carbon steel core. However, surface carbon is generally restricted to 0.9% because too high a carbon content can result in formation retained austenite and brittle martensite. The first step in the heat treatment of steel is to allow specimen to expose with high temperature environment for some time in or above the critical range in order to form austenite. Carburizing is the old and one of the more affordable procedures of Case heat. A low steel commonly about 0.20 % carbon or lower is set in an air that contains adequate measures of carbon monoxide. Carburization is only basically characterized as the expansion of carbon to the outside of low carbon steel at temperature typically extending between 850-950C. Be that as it may, surface carbon is regularly restricted to 0.9% in light of the fact that too high a carbon substance can bring about held austenite and weak martensite.

2. Literature review

Steels have been widely used in the industrial production due to their favourable manufacturing performance. However, their modest surface strength and hardness limit their performance and lifetime in many applications, especially in the fields where surface hardness, fatigue resistance and wear resistance are of crucial importance. In the mid-1980s, low-temperature nitriding or carburizing techniques were developed to improve the surface properties of austenitic stainless steel by forming the interstitially supersaturated austenite, namely, the so-called "S-phase" or "expanded austenite" [1-4]. The expanded austenite layer owns high surface hardness (>HV1000) [5, 6], great surface compressive residual stress (> -2 GPa) [7], excellent surface wear [8,9] and corrosion resistance [10-13]. Though researches on the mechanical properties of expanded austenite layer were conducted in the past decades, but most of them merely focused on the effects of expanded austenite layer on the whole properties of treated sample [14-16]. Li [17] made an innovative attempt to investigate the mechanical properties of the expanded austenite layer by carburizing through a 50 μm thick 316L stainless steel foil and found that the ultimate tensile stress was only ~500MPa, and the fracture strain was only 0.9%. In fact, the restraints of substrate affect mechanical properties of expanded austenite layer greatly. In the surface carburized layer, for example, large amount of C or N interstitial atoms can cause expansion of the lattice which is constrained by substrate. As a result of the restraint of the unaffected substrate of the specimen, huge surface compressive residual stress ranging from ~-1.4 to ~-3.5 GPa [5,7,18,19] is produced in the expanded austenite layer. However if the thickness of substrate is too thin to restrain the deformation of surface layer, fracture [20] even pulverization will happen [21]. Stinville et al. [22] investigated the fracture behavior of plasma nitrided expanded austenite layer and anounced that the surface was very brittle and cracks were all perpendicular to the tensile direction.

Review of available literature suggests that the carburizing process has shown a larger impact to enhance the tribological response of the steel substrates. Carburization technique has helped to improve the corrosion resistance of ferritic steel and ferritic-martensitic steel. The technique has improved the different steel grades for their wear and hardness responses. In view of the application limits of the investigated steels, the carburization, if carbon potential is increased to 1.1 could influence the wear resistance of the substrate.

3. Experimentation

SAE 1020 steels were obtained and the test samples were set up by utilizing the machine activity. The percent arrangement of SAE 1020 steel by (wt %) is given as C-0.189, Si- 0.249, Mn-0.54, S-0.020, P-0.30,Cr- 1.317, Ni-1.589, Mo-0.280, Cu-0.249, Al-0.020 and Fe. The test sample for examination of mechanical and wear properties like hardness and wear are set up according to ASTM standard.

Carburization of SAE 1020 steel specimen

The test samples developed of mellow steel for mechanical and wear properties testing. It was exposed to pack carburization treatment process. In Carburizing process the mellow steel samples were put in to gas carburizing heater with the assistance of gentle steel wire twisted around it. At that point it was brought into the gas carburizing heater and afterward kept up the carburization temperatures of 920^{0}C with the drench timeframe of 6 hours. The carburized samples were then tempered for a specific temperature and time and after that it handled for different kind of mechanical and wear test. When used with Lindberg/MPH's HYEN endothermic generator, the furnace assures work surfaces free from oxidation and decarburization. Gas-fired box furnaces Lindberg/MPH also offers gas-fired atmosphere and non-atmosphere box furnaces in operating temperature range from 374° F to 2500° F.

Fig. 1 Gas carburizing furnace

4. Results and Discussion

Microstructural analysis

Hitachi 3600 N Scanning electron microscope with a 5 axis motorized stage coupled with ultra dry Compact EDS Detector is used for high resolution imaging and elemental analysis. The main Capabilities of SEM/ EDS are Stage transverse X/Y- 150mm/110mm, sample thickness of 70 mm, 3nm resolution at HV. Resolution of 5eV peak shift (±3eV typical between 1% and 60% dead time) from minimum to maximum count rate at a given analyzer time constant and operating environment of 30^0C.

Fig. 2 Scanning Electron Microscope

SAE 1020 samples are studied for their microstructure under different conditions like carburised samples, samples without carburisation and worn out samples under different mentioned loads. Fig. 3(a) and 3(b) depicts the microstructure of the as received and polished samples. The SAE 1020 samples were ground using silicon carbide papers of grit size 320 to 1500 and diamond polished using 1 micron diamond paste. It is evident from the images that the samples are finely polished and exhibit very less or no cracks.

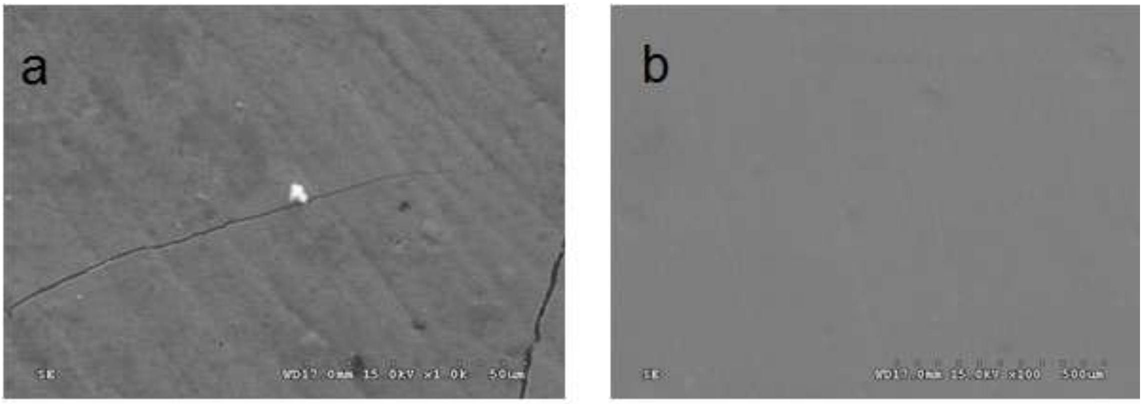


Fig. 3(a) and 3(b) Polished sample

SAE 1020 grade steel is carburised at 920^{0}C for 6 hours and the microstructure is further studied. The study reveals the uniform distribution of the carbon atoms in the matrix which will be definitely helpful to enhance the tribological response of the samples under investigation.

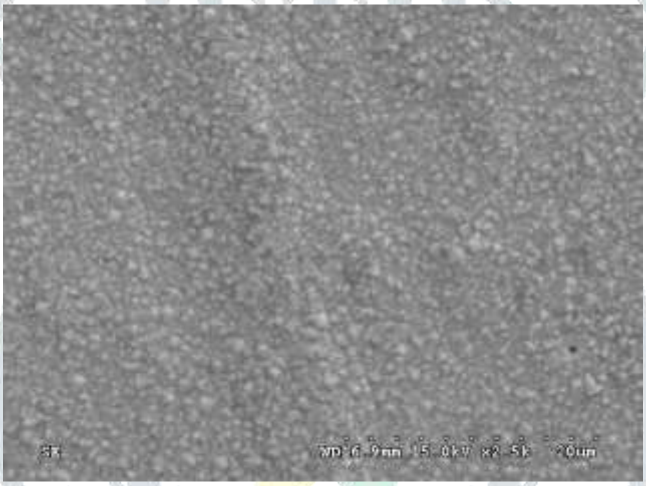


Fig. 4 Carburised sample

Steel samples of grade SAE 1020 without carburisation are tested for wear resistance on pin-on-disc tribometer and and the microstructure is further studied. The investigation revealed that at a normal load of 15 N, the non carburised samples have surface peeled off and thus are prone to poor tribological behaviour.

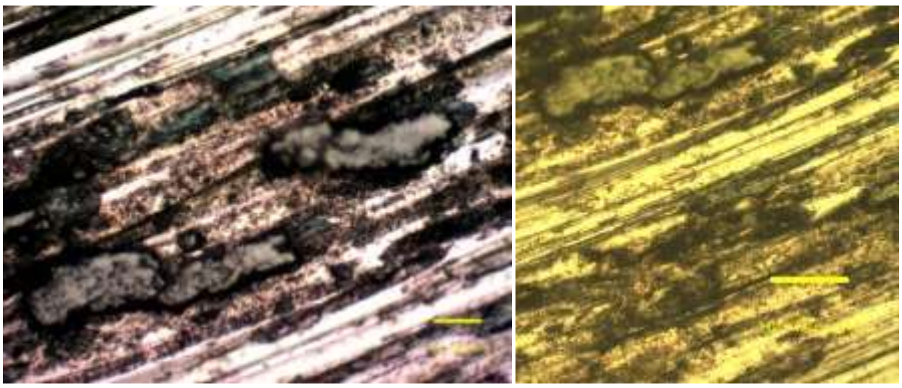


Fig. 5-6 Wear tested without carburisation (Load: 15N)

With a normal applied load of 20 N, the samples of grade SAE 1020 without carburisation are tested for wear resistance on pin-on-disc tribometer and and the microstructure is further studied. As the load incresed, the tribological response of the non carburised substrate further deteriorated and the surface peeled off due to poor wear resistance.

It is clearly evident from the fig. 7 that the infusion of the carbon atoms on the surface of SAE 1020 substrates enhanced the tribological behaviour or the wear resistance of the samples. Diffusion of carbon atoms help to modify the surface characteristics of the substrate thus increasing its wear resistance. It is also evident from the image obtained from optical microscope that the wearing out of the surface layer decreased for the sample and same applied load when carburised samples are compared with the non carburised samples.

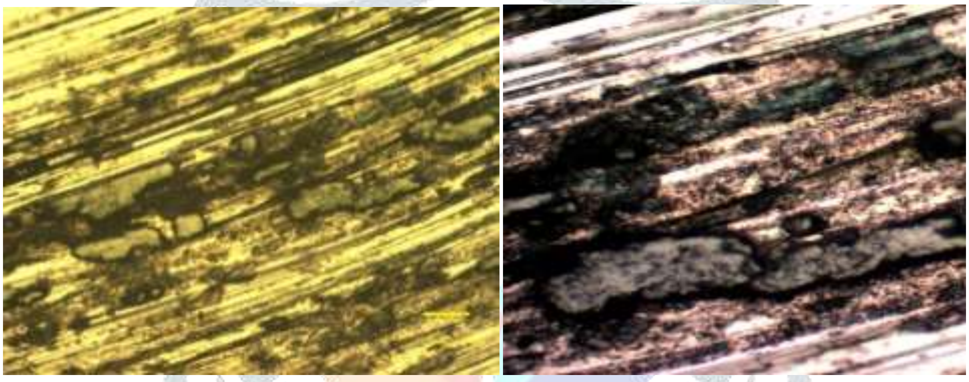


Fig. 7-8 Wear tested carburisation (Load: 15N)

It is clearly evident from the fig. 8 that the infusion of the carbon atoms on the surface of SAE 1020 substrates enhanced the tribological behaviour or the wear resistance of the samples. Diffusion of carbon atoms help to modify the surface characteristics of the substrate thus increasing its wear resistance. It is also evident from the image obtained from optical microscope that the wearing out of the surface layer decreased for the sample and same applied load when carburised samples are compared with the non carburised samples. But further increasing the applied load may deteriorate the condition as it may have adverse effects on the tribological characteristics of the substrate but also, when compared with non carburised substrate exposed to same load then the carburised substrates exhibit considerably better tribological response.

Hardness results

Nanoindentation technique is usually employed in the determination of the mechanical properties of a small volume of material because the indentation depth (and hence volume) is much smaller than that in conventional indentation measurements. In this method, the load–displacement curve is continuously recorded upon loading and unloading; the hardness HN is extracted from the loading part while the Young’s modulus E is extracted from the unloading part of the load–displacement curve. Nanoindentation is particularly suitable for studying the mechanical properties of films formed on a substrate. Accurate determination of such properties, however, is difficult due to unavoidable substrate effect, and to surface roughness. A smaller indentation depth would reduce substrate effect, but magnify the roughness effect, and vice versa. Thus a compromise has to be made, and the appropriateness of selection is reflected in the quality of the load–displacement curves.

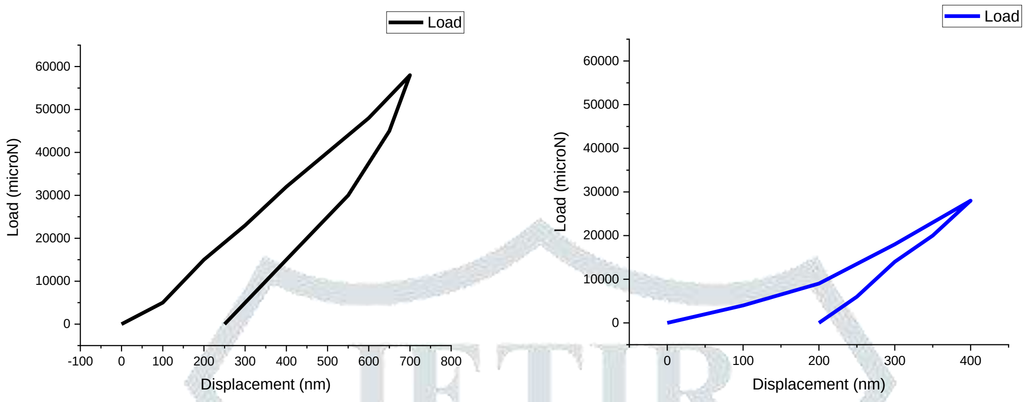
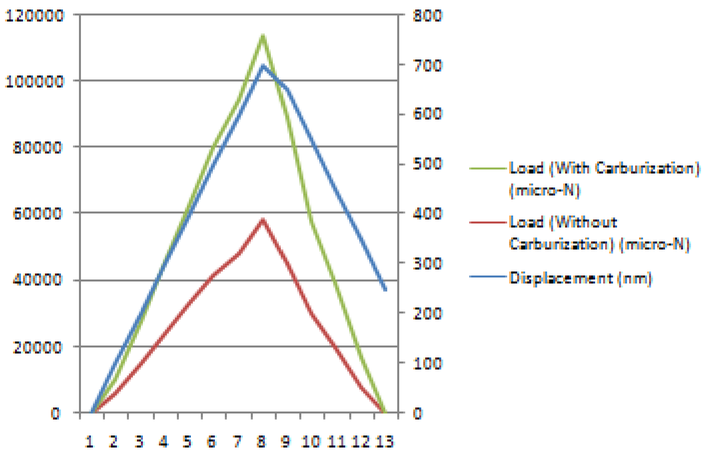


Fig. 9-10 Hardness results of non-carburised and carburised samples



Displacement (nm)	Load (Without Carburization) (micro-N)	Load (With Carburization) (micro-N)
0	0	0
100	6000	4000
200	15000	13000
300	24000	22000
400	33000	30000
500	41000	39000
600	48000	47000
700	58000	56000
650	45000	44000
550	30000	28000
450	20000	19000
350	8000	9000
250	0	0

5. Conclusion

In the present examinations on mechanical properties of carburized SAE 1020 grade steel, carburization has shown a widespread impact. Carburisation has shown a greater impact on the surface morphology of the substrates under investigation. Hardness curve for the non-carburised samples showed the displacement of around 800 nm while carburised sampled exhibited the displacement of about 400 nm which indicates that the hardness of carburised samples has been improved considerably as compared to non-carburised samples. Optical images of the wear tracks also indicate that the carburisation of the samples assisted significantly in enhancing the wear resistance of the SAE 1020 samples.

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