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"IMPROVING WEAR RESISTANCE AND MICROHARDNESS OF SAE 1020 STEEL BY THERMOCHEMICAL CARBURIZATION"

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ABSTRACT

This study examines how pack carburisation affects surface hardness and tribological performance of SAE 1020 low-carbon steel. The specimens were carburized at 920°C for 8 hours to enrich the surface with carbon, increasing their wear resistance and mechanical strength. Following treatment, the samples underwent Vickers hardness testing, pin-on-disc tribological assessment under dry sliding circumstances, and surface characterisation by Field Emission Scanning Electron Microscopy (FESEM). When compared to their untreated counterparts, carburised specimens showed a considerable increase in hardness and a noticeable decrease in wear rate. FESEM examination indicated smoother worn surfaces and reduced material loss in carburised samples, indicating the creation of a homogeneous and hardened surface layer. These findings support the effectiveness of pack carburisation in improving the durability and performance of SAE 1020 steel, making it more appropriate for applications that need high surface strength and wear resistance.

Key Words: *SAE 1020 steel, carburization, surface hardness, wear resistance, microstructural analysis.*

I. INTRODUCTION

Heat treatment is a procedure of heating and cooling operations; it is determined by the amount of time spent soaking a specimen or alloy in the solid state so that it acquires the required qualities." The basic heat treatment procedures for steel include the creation of martensite and the degradation of austenite. The quality of these converted products defines a steel's physical and mechanical qualities. Carburization produces residual changes in carbon content and carbide volume from the surface to the core, as well as a progressive conversion of mechanical and wear characteristics. Heat treatment and carburization enhance mechanical and wear resistance. Carburizing is the process of introducing carbon to the surface of low-carbon steels at temperatures ranging from 850 to 950°C, at which austenite, with its carbon solubility, is the stable crystal structure. Hardening occurs by quenching the high-carbon surface layer, resulting in martensite.

A high-carbon martensitic casing with excellent fatigue and wear resistance protected a robust, low-carbon steel core. However, surface carbon is typically limited to 0.9% because excessive carbon content can result in the production of retained austenite and brittle martensite. The initial stage in heat treating steel is to expose the specimen to a high temperature environment for an amount of time that is within or over the critical range in order to generate austenite. Carburizing is a traditional and very inexpensive method for Case heat. A low steel, typically 0.20% carbon or below, is set in air containing appropriate levels of carbon monoxide. Carburization is simply the expansion of carbon to the outside of low carbon steel at temperatures ranging from 850 to 950 degrees Celsius. However, surface carbon is typically limited to 0.9% because too much carbon can cause held austenite and weak martensite.

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II. Literature Review

Steels are frequently employed in industrial production due to their superior manufacturing performance. However, their moderate surface strength and hardness restrict their performance and longevity in many applications, especially in the domains where surface hardness, fatigue resistance and wear resistance are of essential relevance. In the mid-1980s, low-temperature nitriding or carburizing procedures were developed to enhance the surface characteristics of austenitic stainless steel by generating the interstitially supersaturated austenite, specifically, the so-called "S-phase" or "expanded austenite" [1-4]. The enlarged austenite layer holds high surface hardness (>HV1000) [5, 6], considerable surface compressive residual stress (> -2 GPa) [7], good surface wear [8,9] and corrosion resistance [10-13]. Though research on the mechanical characteristics of expanded austenite layer has been undertaken in recent decades, the majority of them have only focused on the impacts of expanded austenite layer on the overall properties of the treated sample [14-16].

Li [17] made a new attempt to explore the mechanical characteristics of the enlarged austenite layer by carburizing through a 50 µm thick 316L stainless steel foil and discovered that the maximum tensile stress was only ~500MPa, and the fracture strain was just 0.9%. In fact, the restrictions of substrate impact mechanical characteristics of expanding austenite layer substantially. In the surface carburized layer, for example, substantial number of C or N interstitial atoms might cause expansion of the lattice which is restricted by substrate. The specimen's undamaged substrate causes significant surface compressive residual stress ranging from ~-1.4 to ~-3.5 GPa [5, 7, 18, 19] in the enlarged austenite layer. However, if the substrate thickness is insufficient to limit the deformation of the surface layer, fracture [20] and possibly pulverization will occur [21]. Stinville et al. [22] studied the fracture behavior of plasma nitrided expanded austenite layer and anounced that the surface was exceedingly brittle and cracks were all perpendicular to the tension direction.

Review of current literature reveals that the carburizing procedure has demonstrated a bigger influence to increase the tribological response of the steel substrates. Carburization process has helped to increase the corrosion resistance of ferritic steel and ferritic-martensitic steel. The approach has enhanced the different steel grades for their wear and hardness responses. Given the application limitations of the examined steels, increasing the carbon potential to 1.1 may alter the substrate's wear resistance.

III. Materials and Methodology

3.1. Sample preparation

SAE 1020 steels were cut into discs of 25 mm diameter and 6 mm thickness. Table 1 showed the elemental composition of SAE1020 steel. The test samples used for evaluation were prepared as the the ASTM standards.

Table 1 Elemental composition of SAE 1020 steel

Element	**C**	**Si**	**Mn**	**S**	**P**	**Cr**	**Ni**	**Mo**	**Cu**	**Fe**
Weight%	0.189	0.249	0.54	0.02	0.3	1.31	1.58	0.28	0.24	Balance

3.2. Carburization of SAE 1020 steel samples

SAE steel samples were designed for mechanical and wear property testing. It was subjected to the pack carburization treatment method. In the carburizing procedure, SAE steel samples were placed in a gas carburizing furnace with a mild steel wire coiled around them. At that point it was brought into the gas carburizing heater and subsequently kept up the carburization temps of 920^{0}C with the drench timeframe of 8 hours. The carburized samples were then tempered for a certain temperature and time and after that it handled for different sort of mechanical and wear test. When utilized with Lindberg/MPH's HYEN endothermic generator, the furnace ensures work surfaces free from oxidation and decarburization. Lindberg/MPH also provides gas-fired atmosphere and non-atmosphere box furnaces with operating temperatures ranging from 374^{0}F to 2500^{0}F.

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Fig. 1 Gas carburizing furnace

3.3. Hardness, tribological testing and surface topography

The samples' Vickers hardness was determined using a microhardness tester with a 500 g load and a dwell duration of 15 s. Multiple indentations were made across the surface to ensure accuracy and reproducibility. A pin-on-disc tribometer was used to examine tribological behavior at ambient temperature while sliding dry. The counterface was made of EN31 steel, and testing were carried out in accordance with ASTM G99 norms. The coefficient of friction and wear rate were recorded for comparative study. Post-test surface morphology and wear processes were investigated using Field Emission Scanning Electron Microscopy (FESEM), which allows for high-resolution imaging of worn surfaces and the detection of microstructural changes caused by sliding wear.

IV. RESULTS AND DISCUSSION

4.1. Field emission scanning electron (FESEM) results

High resolution imaging and elemental analysis are performed using a Hitachi 3600 N Scanning electron microscope with a 5-axis motorized stage and an ultra dry Compact EDS Detector. The major capabilities of SEM/EDS include a stage transverse X/Y of 150mm/110mm, a sample thickness of 70mm, and 3nm resolution at high voltage. The analyzer can resolve a 5eV peak shift (typically ±3eV between 1% and 60% dead time) from minimum to maximum count rate at 30^{0}C working temperature.

SAE 1020 samples are examined for their microstructure in a variety of situations, including carburised samples, samples without carburisation, and worn-out samples under various loads. The SAE 1020 samples were ground with silicon carbide sheets ranging in grit size from 320 to 1500 and diamond polished with 1-micron diamond paste. Fig. 2 showed that the samples are mirror polished, with few or no fractures.

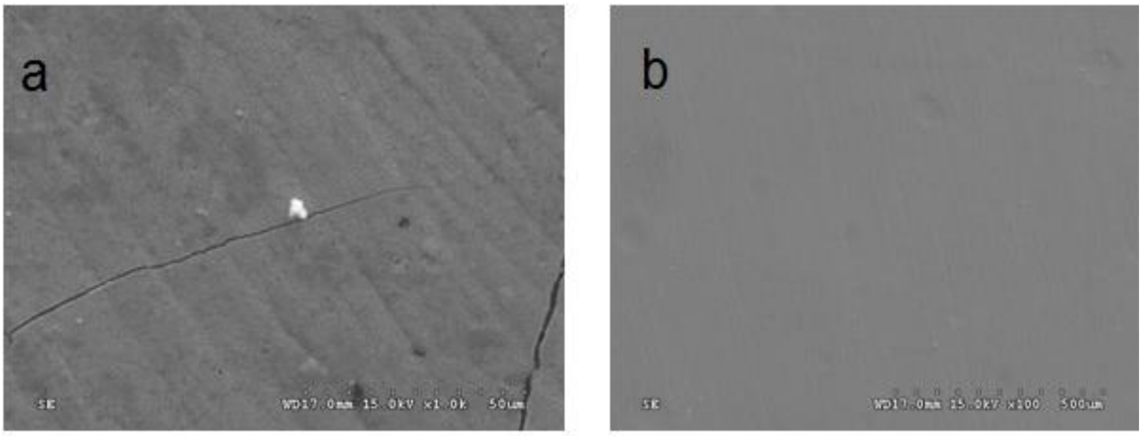

Fig. 2 Polished sample

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SAE 1020 grade steel is carburized at 920^{0}C for 8 hours, and the microstructure is investigated further. The analysis demonstrates a homogeneous distribution of carbon atoms in the matrix, which will undoubtedly assist to improve the tribological response of the samples being investigated.

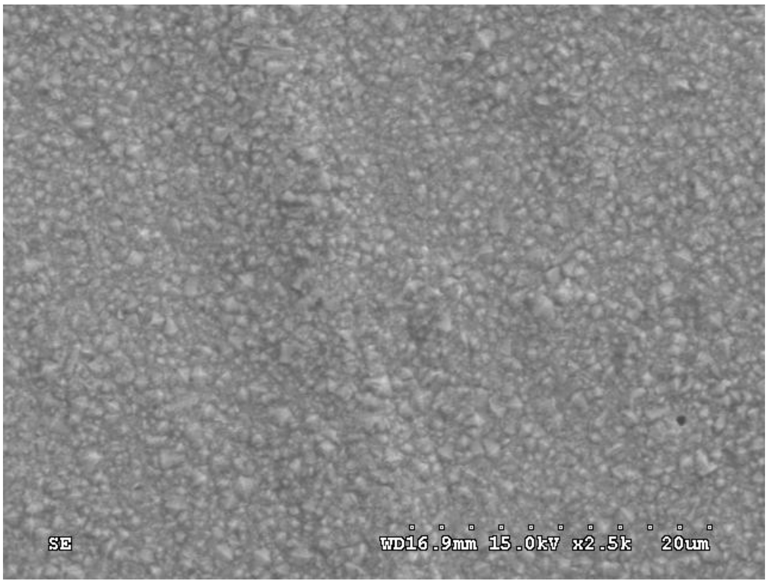

Fig. 3 Carburised sample

Steel samples of grade SAE 1020 without carburisation are evaluated for wear resistance using a pin-on-disc tribometer, and the microstructure is further investigated. The experiment found that under a standard load of 15 N, the non-carburized samples have surface peeled off and so exhibit poor tribological performance.

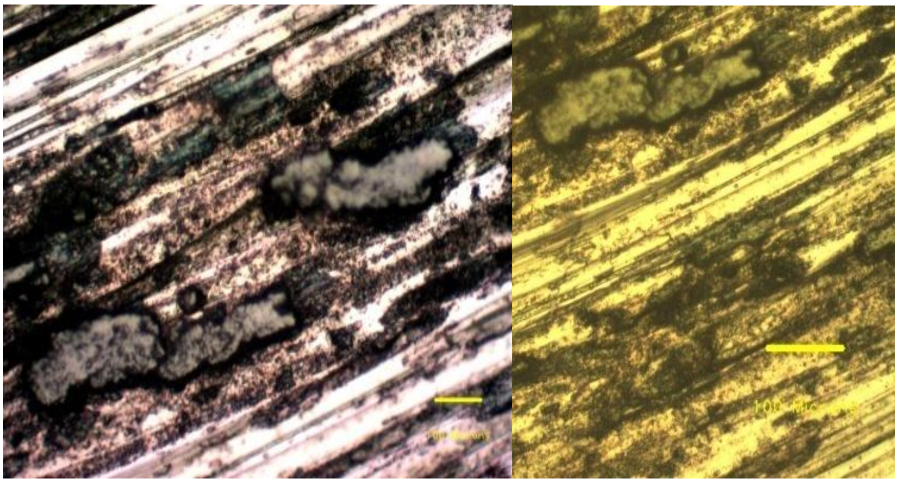

Fig. 4 Wear tested without carburisation (Load: 15N)

With a normal applied stress of 20 N, SAE 1020 samples without carburisation are evaluated for wear resistance on a pin-on-disc tribometer, and the microstructure is further investigated. As the load increased, the tribological response of the non-carburized substrate degraded further, and the surface peeled away due to poor wear resistance. Figure 4 clearly showed that the infusion of carbon atoms on the surface of SAE 1020 substrates improved the samples' tribological performance or wear resistance. The diffusion of carbon atoms helps to change the surface properties of the substrate, enhancing its wear resistance. The optical microscope image also shows that when carburised samples are compared to non-carburised samples, the wear out of the surface layer decreases for the same applied stress.

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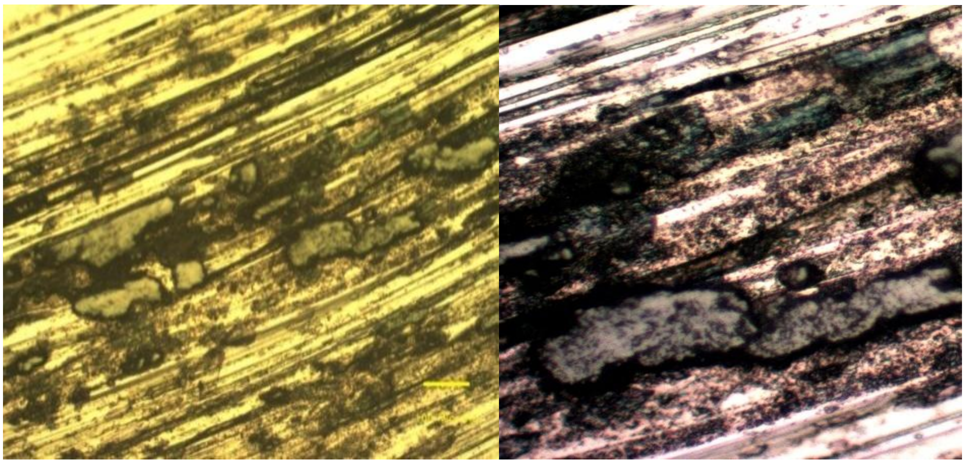

Fig. 5 Wear tested carburisation (Load: 15N)

Figure 5 clearly shows that the infusion of carbon atoms on the surface of SAE 1020 substrates improved the samples' tribological performance or wear resistance. The diffusion of carbon atoms helps to change the surface properties of the substrate, enhancing its wear resistance. The optical microscope image also shows that when carburised samples are compared to non-carburised samples, the wear out of the surface layer decreases for the same applied stress. However, increasing the applied load may deteriorate the condition because it may have an adverse effect on the substrate's tribological properties; however, when compared to non-carburised substrates exposed to the same load, carburised substrates exhibit significantly better tribological responses.

4.2. Hardness evaluation results

The nanoindentation technique is commonly used to determine the mechanical characteristics of a small volume of material since the indentation depth (and hence volume) is substantially lower than in traditional indentation measurements. In this procedure, the load-displacement curve is constantly recorded throughout loading and unloading; the hardness HN is extracted from the loading section, and the Young's modulus E is derived from the unloading part. Nanoindentation is very useful for investigating the mechanical characteristics of films grown on a substrate. Accurate assessment of such parameters is challenging due to the inherent substrate influence and surface roughness. A lesser indentation depth would minimize the substrate impact while increasing the roughness effect, and vice versa. As a result, a compromise must be made, and the appropriateness of the option is evident in the quality of the load-displacement curves. The hardness results are shown in fig. 6.

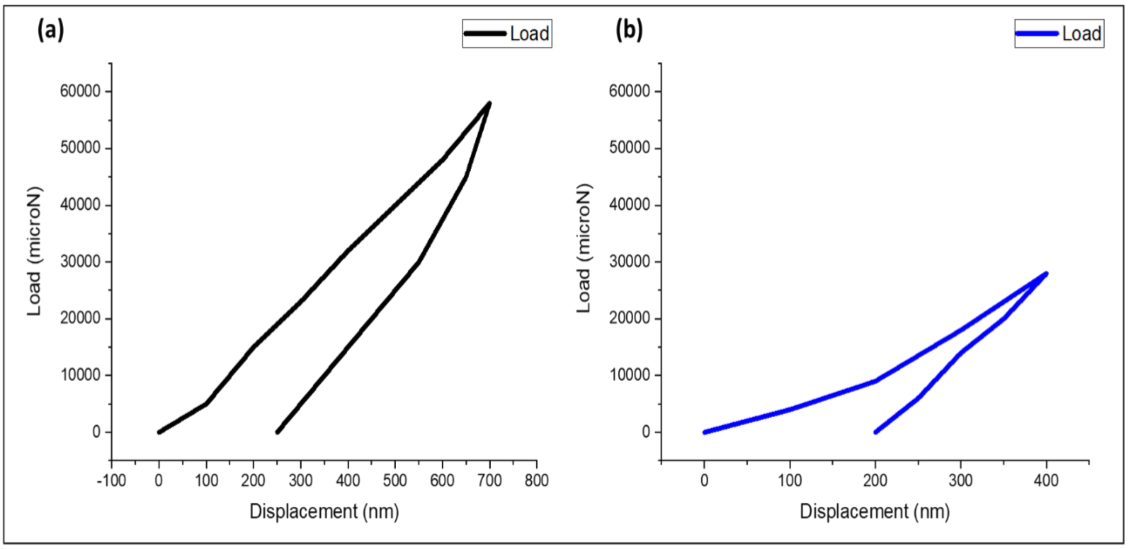

Fig. 6 Hardness results of non-carburised and carburised samples

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V. LITERATURE REVIEW

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