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EFFECT OF SOOT AND PAWPAW LEAVES ON CASE HARDENING OF LOW CARBON STEEL

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Abstract: Investigation was carried out into hardness and wear properties of low carbon steel subjected to case hardening treatment using soot which contains carbon and pawpaw leaves which contains cyanide (carbon and nitrogen) at 850^{0}C temperature and at different holding time of 30, 60 and 90 minutes, quenched in oil and tempered at 550^{0}C. It was observed that, as the soaking time increases, the hardness and wear resistance increases with carburizing sample having wear resistance at 90 minutes soaking time of 0.556 x 10^7 cm^{-2}.
Keywords: low carbon steel, quenching, hardness, wear resistance, carburizing

1. INTRODUCTION

Carburizing is known as one of the most widely used surface hardening technique. The process involves diffusing carbon in to low carbon steel alloy to form a high carbon steel surface. Carburizing steel is widely used as a material of machines, gears, springs, automobiles and wires which are required to have high strength, toughness, hardness and wear resistance [1]. Hardening is accomplished when the subsequent high-carbon surface layer is quenched to form martensite so that a high-carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low-carbon steel core [2]. There are four main types of surface hardening which are case hardening, nitriding, flaming hardening and induction.

Case hardening is one of the most used for producing a hard surface on a ductile steel, case hardening is a technique whereby both surface hardness and fatigue life are enhanced for steel alloy. This is accomplished by a carburizing or nitriding process whereby a component is exposed to a carbonaceous or nitrogenous atmosphere at an elevated temperature [3]. A carbon or nitrogen rich outer surface layer is introduced by atomic diffusion from the gaseous phase. Carbon diffusivity in austenite varies both with carbon concentration and carburizing temperature [4-6]. Carburizing process can be in solid media which is known as pack-carburizing, or in liquid bath (cyaniding). Cyaniding is a method of case hardening which involves the diffusion of carbon and nitrogen into the surface layer of steel. Its principal purpose is to increase the hardness, wear resistance, and fatigue limit of steel products. During cyaniding, the cyanide salts are oxidized with the liberation of atomic carbon and nitrogen, which diffuse into the steel. The disadvantages of cyaniding are high cost and the toxicity of the cyanide salts.The major influencing parameters in carburization are the holding time, carburizing temperature, carbon potential and the quench time in oil [7].

The aim of this research work is to obtain a hardened case of low carbon steel and apparently a tough core with soot and pawpaw leaves to improve the case hardening properties of low carbon steel for automobile applications.

2. MATERIALS AND METHOD

The materials used for this research work are Mild steel with the chemical composition shown in Table 1, below was sourced from Universal steel company, Ogba Industrial Estate, Ikeja, Lagos, Carbon black was sourced from Rubber Research Institute of Nigeria, Iyanomo, Edo-state and Industrial engine oil as quenching medium.

Table 1: Chemical composition of Low Carbon Steel.

%C	%Si	%Mn	%S	%P	%Cr	%Ni	%Cu
0.083	0.016	0.360	0.030	0.034	0.054	0.026	0.058
%Nb	%Al	%B	%W	%Mo	%V	%Ti	%Fe
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.007	99.33

— Test Specimen Preparation.

The low carbon steel was machined to standard test sample sizes of abrasion and hardness tests. These were done according to ASTM's specifications on standard abrasion sample dimensions.

— Carburizing of Low Carbon Steel Samples

The test samples prepared to specification were placed in steel pot, covered with soot was put in muffle furnace which was air tight to prevent CO from escaping and prevent unwanted furnace gas from entering the steel pot during heating with addition of sodium carbonate as energiser. The furnace temperature was adjusted to the required temperature (850°C) and the loaded steel pot was charged into the furnace. When the furnace temperature reaches the required carburizing temperature, it was then held at that temperature for required time 30, 60 and 90 minutes respectively. After the material was held at the specified time, the steel pot was removed from the furnace and the material was quenched in industrial engine oil.

— Cyaniding of Low Carbon Steel Samples

While for prepared mixture of pulverised pawpaw leaves which contains between 3% and 4% of cyanide were put into the packing box with little quantity placed on the floor of the box and with the prepared samples placed on the first layer of the medium without touching the floor of the mild steel box and the box was then packed with mixture of pulverised pawpaw leaves to three quarter of its depth while the packed box was heated in the muffle furnace slowly to the required temperature of 850°C and was soaked for 30, 60 and 90 minutes respectively before quenching in industrial oil.

— Tempering of the Carburized and Cyanided Samples

The carburized and cyanided test samples were then tempered at a temperature of 550°C, held for one hour, and then cooled in air. After the cycles of heat-treatment, the test samples were subjected to hardness and wear test.

— Hardness Measurement

The hardness for the carburized and cyanided samples for low carbon steel which were tempered, were evaluated using a Vickers Hardness Tester (LECOAT 700 Microhardness Tester).The test samples were polished to obtain flat and smooth surface finish after this, a direct load of 490.3 MN was applied on the specimens for 10 seconds and the hardness reading evaluated following standard procedures, the average readings were calculated and recorded as the hardness.

— Wear Measurement

The wear measurements for tempered carburized and cyanided low carbon steel were evaluated using Rotary platform abrasion tester (Model: TSE-AO16). The prepared samples of disc size 200 mm diameter and 6 mm thick were subjected to rubbing action on the abrasion wheel during the rotational. The resulted weight were taken and subtracted from the initial weight to give the weight loss during operation, from which other parameters were used to determine volume loss, wear rate and wear resistance.

3. RESULTS AND DISCUSSION

From figure 1, as received samples had the case hardness value of 42.3H_{RA}, while carburizing sample at holding time of 30 minutes has the hardness value of 57.3H_{RA} while the hardness value for cyaniding samples at 30 minutes holding time is 47H_{RA} , we discovered that the case hardness value for carburizing sample is higher than the as received and also the cyaniding sample, this may be as a result of high diffusion rate of carbon into the surface of the low carbon steel as compared to the diffusion rate of carbon and nitrogen into the surface of the low carbon steel.

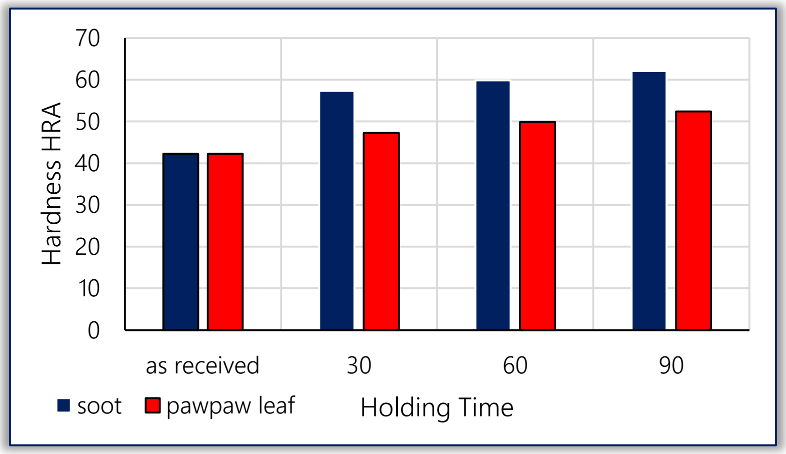

Figure 1. Effect of carburizing, cyaniding temperature on hardness of the samples

Table 2: Hardness Properties of the Carburized, Tempered Samples

Holding time (850^{0}C) (minutes)	Case hardness (H_{RA})
As-received	42.3
30	57.3
60	59.9
90	62.1

Table 3: Hardness Properties of the Cyanided, Tempered Samples

Holding time (850^{0}C) (minutes)	Case hardness (H_{RA})
As-received	42.3
30	47.3
60	49.9
90	52.4

When we look at the holding time at 60 minutes for carburizing sample, we discovered that the hardness value has increased to 59.9H_{RA} while that of cyaniding sample has also increased to 49.9H_{RA}, up to the 90 minutes of holding time, the hardness values for both the carburizing samples and cyaniding samples keep on increasing which means at constant temperature but with varied holding time, as the holding time increases, the hardness value increases.

Table 4: Wear Properties of the Carburizing Samples

Time (minutes)	Temperature (°C)	Weight loss (g)	Wear volume $cm^3 \times 10^{-2}$	Wear rate $cm^2 \times 10^{-2}$	Wear resistance $cm^{-2} \times 10^7$
As received		0.65	8.33	5.88	0.170
30	850	0.32	4.08	2.89	0.346
60	850	0.22	2.80	1.98	0.505
90	850	0.20	2.55	1.80	0.556

Table 5: Wear Properties of the Cyaniding Samples

Time (min)	Temperature (°C)	Weight loss (g)	Wear volume $cm^3 \times 10^{-2}$	Wear rate $cm^2 \times 10^{-2}$	Wear resistance $cm^{-2} \times 10^7$
As received		0.65	8.33	5.88	0.170
30	850	0.55	7.01	4.97	0.201
60	850	0.43	5.47	3.86	0.259
90	850	0.37	4.71	3.32	0.301

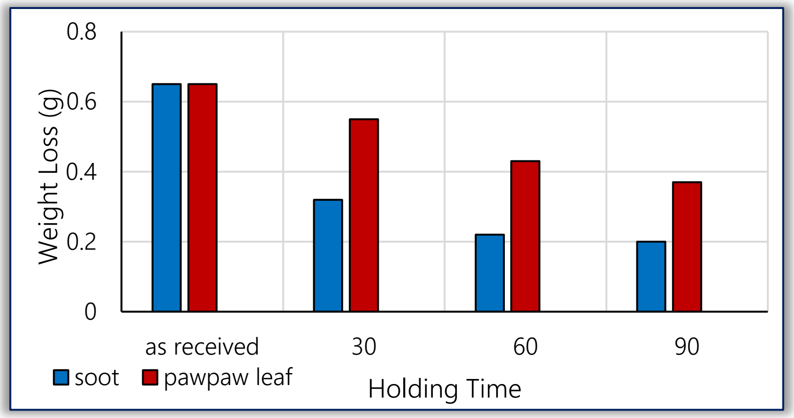

Figure 2. Effect of carburizing, cyaniding temperature on weight loss of the samples

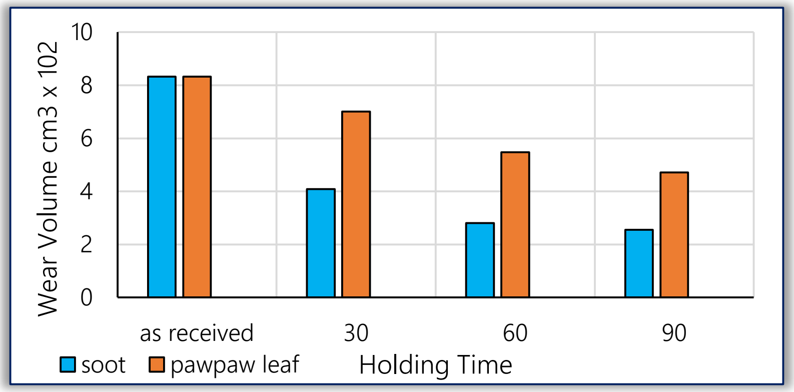

Figure 3. Effect of carburizing, cyaniding temperature on wear volume of the samples

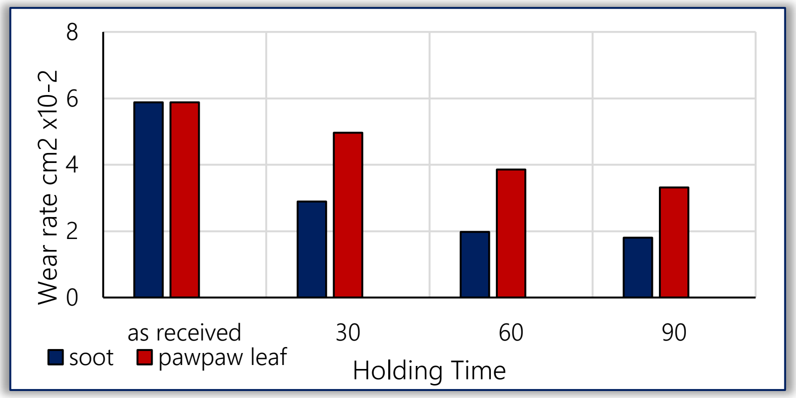

Figure 4. Effect of carburizing, cyaniding temperature on wear rate of the samples

From Figure 2, the weight of the as received sample is 0.65g, while the weight of carburizing and cyaniding samples at 30 minutes holding time are 0.32 and 0.55g respectively, the carburizing sample has a lower weight loss as compared to cyaniding sample. As the holding time increases to 60 minutes, the weight loss for both the carburizing and cyaniding samples reduces to 0.22g and 0.43g respectively. When the holding time increases to 90 minutes, the weight loss drop for carburizing and cyaniding samples to 0.20g and 0.37g respectively.

Figure 3 shows that the as received sample has the highest wear volume of 8.33 x 10^{-2} cm^3 as compared to the carburizing and cyaniding samples at various holding time, it was discovered as the holding time increases, the wear volume reduces with carburizing samples having lower wear volume when compared to cyaniding sample, at 30 minutes holding time, the wear volume for carburizing and cyaniding samples are 4.08 x10^{-2} cm^3 and 7.01 x 10^{-2} cm^3 respectively.

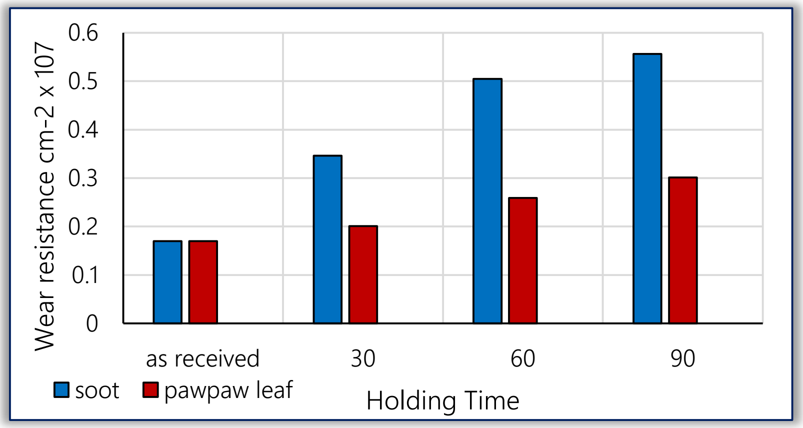

Figure 5. Effect of carburizing, cyaniding temperature on wear resistance of the samples

The higher the wear rate, the lower the wear resistance and the lower the wear rate, the higher the wear resistance, so the figure 4 and 5 explained this relationship. From Figure 4, the as received sample has the wear rate of 5.88 x 10^{-2} cm^2 which is the highest and the carburizing sample at 90 minutes holding time has the lowest wear rate of 1.80 x 10^{-2} cm^2. It is shown as the holding time increases from 30 minutes up to 90 minutes, the wear rate reduces with the carburizing samples having the lower wear rate as compared to cyaniding samples.

4. CONCLUSIONS

In this experimental study, where soot and pawpaw leaves were made used for case hardening, heating to 850^0 C and soaking time of 30, 60 and 90 minutes, the following conclusions can be expressed.

(a) The carburizing and cyaniding samples produced case hardness values greater than the as- cast with the carburized samples having a better hardness values.
(b) The wear properties for carburizing samples were better when compared with the cyaniding samples.
(c) As the soaking time increases, the hardness and the wear properties also increases which promotes increase diffusion of carbon in soot and carbon and nitrogen in pawpaw leaves.

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