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Study of the Effects of Surface Finish and Carburizing on the Hardness of Medium Carbon Steel

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ABSTRACT: *As hardness is a critical Mechanical property. The value is linked to the wear resistance ability of the material and resistance to fatigue. Medium Carbon Steel is the material of Interest in this study. Spectroanalysis was conducted on the material to determine the element composition concentration. Samples of scale sizes 3 mm, 5 mm, 7 mm, 8 mm, 9 mm, 10 mm were machined using lathe machine. Samples were carburized and surface finishes such as turning, grinding and polishing were as well done using the grinder and polisher.Micrographical examination was doneon the as received and carburized samples to view the possible changes in grain structure alignment due to some surface and heating operations carried out on the samples. From the results obtained, it was concluded that Hardness of Material is dependent on Surface Finish, heat treatment and scale sizes. Further results, revealed that surfaces with lower asperities as assumed with Carburized Polished Sample slows down Carbon diffusion rate into the surfaces of the sample scales.*

KEYWORDS: *Hardness, Carburize, Steel, Surface Finish*

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I. Introduction

Medium Carbon Steel is a very important material use mostly in engineering components due to the desirable features inherent. Materials are frequently subjected to loads when they are in use. The knowledge of Medium Carbon Steel behaviour is known through the test of mechanical properties. The main Mechanical Property of interest in this study is the Hardness Test. This was done to determine the effect of surface finishes such as grinding, turning and polishing on Carburized samples of different Scale sizes. Hardness is the resistance to plastic deformations such as local dent and scratches. Material deformation can be permanent or temporary. Carburizing is a diffusion process that involves migration of Carbon atoms from a region of high concentration to a region of low concentration. In materials that are homogeneous, atoms are routinely moving around in a random pattern. In materials that are inhomogeneous, all the atoms are moving near randomly, but there is migration of atoms to areas where their concentrations are lower. Surface finish and treatments arising from manufacturing processes are both important considerations for fatigue design. In fact, the impact of surfaces on the fatigue life of metals have been recognized for many years.[1] Thus, they are crucial from the manufacturers' point of view.[2] Surface finish is often measured by the material surface roughness. The lesser the roughness, the microscopic grooves becomes smaller and the bigger the valley radius becomes in proportion to the height of the groove.In the investigation of the effect of vacuum carburizing and reheating to refined grain size and gas-carburizing specimen. It was observed that reheating gives the best results. [7] It is important to have a total investigation that will evaluate and quantify surface finish and heat treatment effects on bending fatigue specimens of commonly used steel under cyclic load condition.It was concluded that the increase of fatigue strength is directly proportional to increase in tensile strength.[6] The best results are obtained for the specimen tempered at 200 ^{0}C. The highest endurance limit was shown by the specimens.

In a work on Fatigue failure and testing method, it was opined that surface defects, such as roughness or scratches and notches or shoulders all reduce the fatigue strength of a part.[3] Various metals differ widely in their susceptibility to the effect of roughness and concentrations or notch sensitivity. For a given material subjected to a prescribed state of stress and type of loading, notch sensitivity can be viewed as the ability of that material to resist the concentration of stress incidental to the presence of a notch.Microstructural examination wasperformedon the case-hardened mild steel.[4] In their work, they investigated the effect of cyanide on pack cynide of Mild Steel for casehardening using $BaCO_3$ and $BaCl_2$ as energizers. The study revealed that, at high temperature there is Carbon diffusion into the case of Medium Steel from cassava leaf powder. Similarly, it was shown that at low temperatures, there is a diffusion of N and that diffusion proceeds from the case to the core of the mild steel with increasing treatment temperature and increasing treatment time. The authors found that, the optimum hardness of the pack cyanided medium steel was achieved at a high temperature of 900^{o}C. It was opined in a work that hardness value at the failure region was lower (699 HV1) than other locations (716 HV1) and it is the cause for the rapid wear of the crankpin at the contact region. This failure initiation is propagated by improper lubrication. It causes the stress and wear at this region to be more.[5]A point was made that “common surface modification processes, often simultaneously increase the surface yield stress and induce a residual compressive stress to decrease the surface cyclic tensile stress, are based on heat treating.[7]Silva et al. (2007) Diamond films from graphite at different temperatures prepared instead of utilizing conventional hydrocarbon in the feed gas. The diamond nucleation and growth rate showed a strong dependence on the graphite temperature, with higher quality and growth rate at higher temperatures.[8]It was observed that the cyanide content of the cassava leaf is ranged between 3% and 4%, this is 100 times more than the quantity found in tubers. Using the cassava leaf to pack cyanide mild steel is in the right direction.[9]

II. Experimental Procedure

The material of interest is medium carbon steels due to its wide applications in components under fatigue failure. In automobiles, aircraft, industrial machines and so on, many components fail due to repeated load applications. Specimens’ scale ranges from 3 mm, 5 mm, 7 mm, 8mm, 9 mm and 10 mm for the centre grooved diameters were machined using the lathe machine. An element concentration report was prepared through a detailed spectroanalysis done. The heat treatments were done using some carburizing powders such as Anthracite coal, barium carbonate. Crucibles for the heat treatment were made and cassava leaves (both dry and pulverize) were also used. The Samples were prepared for micro examination. Samples preparation for metallographical examination include preliminary stages such as grinding, polishing and etching before final examination. This was done using accuscope microscope with camera interfaced with a computer device. It intends to xrays the impact of the technological factor on micro grains of the structure of medium carbon steel. This examination is expected to reveals the pearlite and ferrite distribution pattern of the sample at different states. Hardness Test was done using an Instron Hardness Tester 2000. This was done to indicate the sample hardness accuracy.

Figure 1 Hardness Testing Machine

III. Results And Discussion

3.1 SpectroanalysisResult

The spectroanalysis examination was done on the medium carbon steel to reveal the element compositions as presented in table 1 below.

Table 1Spectroanalysis Report

Elements	C	Si	Mn	S	P	Cr	N	Al	Fe	Ti
Composition	0.320	0.203	0.514	0.038	0.003	0.215	0.093	0.046	98.255	0.006

Source: Universal Steel Ltd in Nigeria (2018)

The report showed clearly that the material was purely a Medium Carbon Steel with some other crucial micro element composition.

3.2Microstructural Views

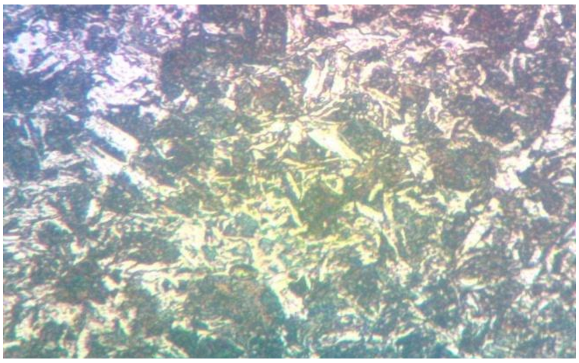

Figure 2Micro Structure Views of Specimen for as Received indicating the Microstructure Composition of Ferrite (Light Colour Region) and Pearlite (Dark Colour Region)

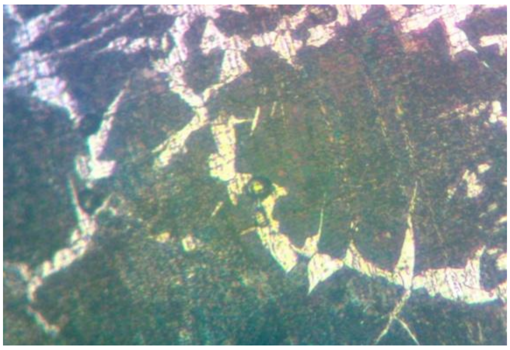

Figure 3Micro Structure Views of Carburized Sample indicating the Microstructure Composition of Ferrite (Light Colour Region) and Pearlite (Dark Colour Region)

The above microstructures shows that the specimen is made up of the ferrite and pearlite regions represented by the light and dark coloured regions respectively. It was shown clearly that machining and subsurface operations influences the structural arrangement. Analysis of the carburized test showed a combination of martensite and austenite close to the surface and martensite and bainite in the core. Matensite is a disirable region in carburized sample.

3.3 Hardness Test Result

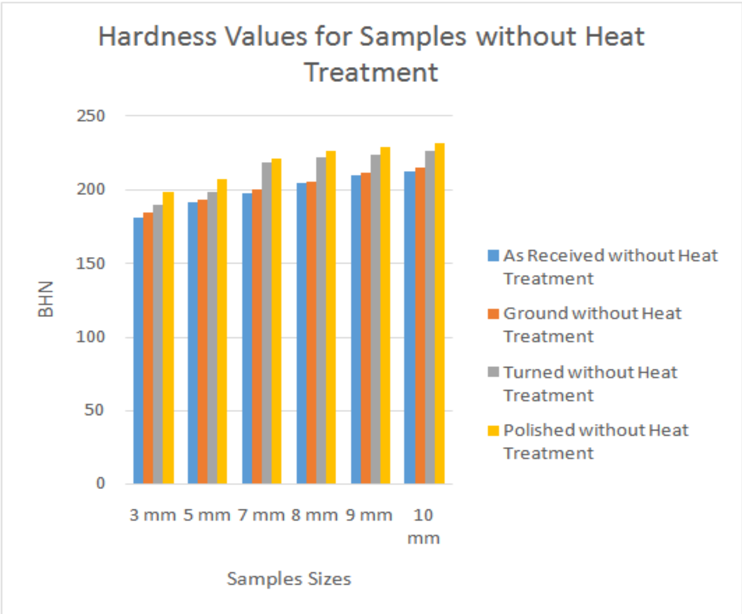

Figure 4 Effects of Surface Finish on Hardness Values for Scales Sizes

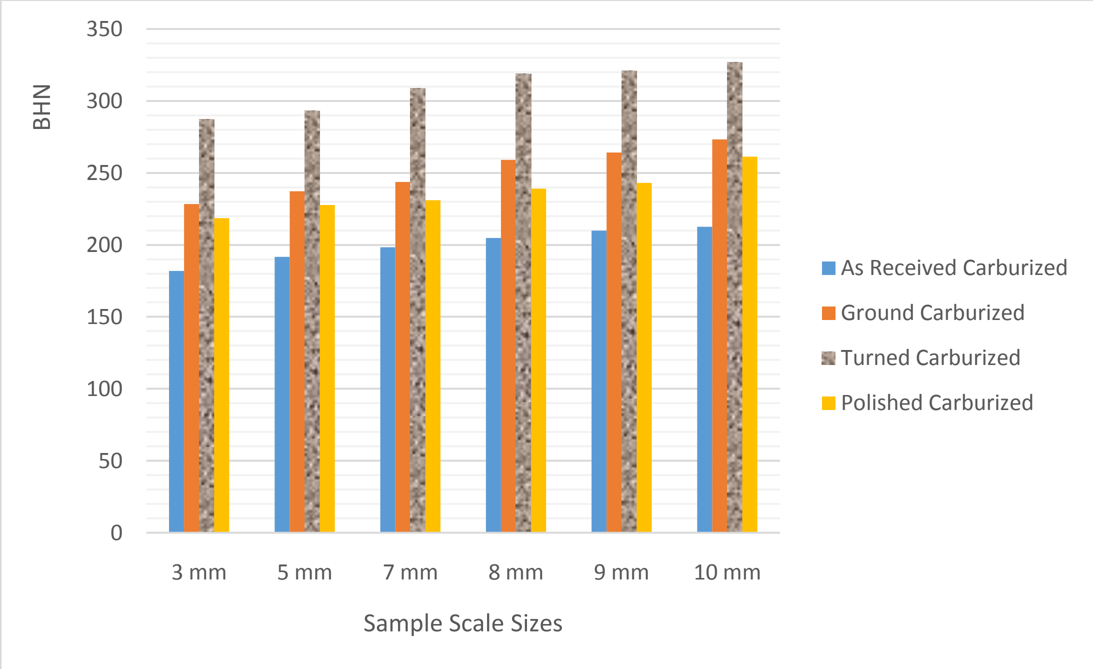

Figure 5 Effects of Surface Finish and Carburizing on Hardness Values for Scales Sizes

Hardness is a measure of resistance to localized plastic deformation induced by mechanical indentation or abrasion. This test is linked to strong intermolecular bonds and is dependent on some properties of the material under investigation. According to Hall Petch Relationship, hardness increases with a decreasing particle size. By changing the grain size, it is possible to influence the number of dislocation pile up at the grain boundary. Scale Samples linked to carburizing heat treatment shows higher values of hardness when compared to the as received samples. It is clear from the hardness value obtained with carburized samples, that better wear resistance material is obtained. From the results as shown above in figures 4 and 5, it revealed that brinel hardness number increases with increase in scale sizes. For a scale of 3 mm, hardness of 181.94 BHN,184.81 BHN, 190.37 BHN and 199.01 BHN for as received, grinded, turned and polished respectively without heat treatment and 189.33 BHN, 228.34 BHN, 287.31 BHN, 218.63 BHN, for as received, grinded, turned and polished carburized respectively. Comparing the hardness values of different surface finish of 3 mm scale size, it was noticed clearly that there was about 20 %, 51.75 %, and 15.47 % hardness increase for ground, turned and polished when compared to as received carburized sample. The BHN obtained clearly indicates that BHN is higher with carburized samples than as received. Furthermore, polished sample shows a lower value of BHN when compared to grinding and turning samples. This is probably due to low surfaces asperities which is believed toslow down carbon diffusion process.

IV. Conclusion

It is known that hardness of material is a very important mechanical property of any material. The results showed that hardness of material is a function of surface finish, heat treatment and scale sizes of the material under investigation. The results revealed that surfaces with lower asperities slows down carbon diffusion rate into the surfaces of the sample scales. This is seen as in carburized polished surfaces that showed a lower BHN compared to other carburized surfaces excluding carburized as received.

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