Impacts of Carburizing Temperature and Holding Time on Wear of High Speed Steel Cutting Tools.

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ABSTRACT: The paper presents a report on effects of variation in carburizing temperature and time on cutting tool to enhance its use in engineering applications. 30 pieces of HSS cutting tools (200 x 14 x 14 mm) sizes were used for the project and its composition was analyzed with the UV-VIS spectrometer before carburization. The tools were carburized with pulverized carbon (Palm Kernel Shell) using 25 % Barium trioxocarbonate (V) as an energizer in a muffle treatment furnace of about 1500oC. The performance evaluation of the tool was done by measuring its wear volume, wear resistance, weight loss and wear rate on all the samples (treated and untreated) using Rotopol –V. Minimum wear rate of the tool was 1.095 X 10 -8 cm2/N at carburizing temperature with time of 950oC and 120 minutes, 2.190 X 10 -8 cm2/N at 800oC and 60 minutes while those of the control sample (untreated) was 1.127 X 10 -8 cm2/N. It can be concluded that the carburized tool has a lower wear rate at high carburizing temperature with time over at low carburizing temperature with time and control (untreated sample) in the tests carried out. The result of the performance evaluation tests corroborated the higher qualities of the carburized cutting tool at high temperature with time over others.

Keywords: Cutting tool, tool wear, carburization, machining, wear rate, Perm Kernel Shell, Energizer.

1. INTRODUCTION

Cutting tools always available in form of single point and multi points with essential properties of high hardness and wear resistance. Cutting tool material consist of Carbon steels, High- Speed Steel (HSS), Cemented Carbides, Ceramic and Synthetic diamonds. Cutting tools must have the following requirements; high oxidation resistance, high yield strength at elevated cutting temperature, high wear resistance, high fracture toughness, high fatigue resistance, high thermal capacity and high conductivity [1].

The tool may experience repeated impact loads during interrupted cuts, and the work piece chips may chemically interact with the tool materials. Useful life of a cutting tool may be limited by a variety of wear processes such as crater wear, flank wear or abrasive wear [2]

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Determination of optimal cutting parameters for cutting tools is the best to achieve good condition of the tool in its cutting speed, feed rate, cutting depth and time. It is of good benefits if cutting tools could be produced under optimal parameters since tool wear may result to poor dimensional accuracy, determination of work piece surface and increase cost of replacement. Tool wear usually affects dimension and surface quality of the work piece and this is major determinant of tool [3].

The optimum performance of cutting tool does not depend on the cost but best tool is the type that has been carefully chosen to get the job done on time, efficiently and economically [4]. The physical properties and work piece materials dictate the work force and energy for the applied cutting conditions. And the optimal performance of a cutting tools will requires a correct proportion combination of the cutting force and the materials composition of the work piece. In reference to ISO standard that cutting tool materials can be group into the below that are generally known by the manufacturer; hard metals (H), ceramics (C), boron nitride (B) and diamond (D) [5]. High Speed Steel (HSS) is an high alloy of tungsten, vanadium, molybdenum, and cobalt that is designed to cut other materials efficiently at high speeds. At elevated temperature and must able to withstand the extreme heat generated at the tool's cutting edge of temperature to reach at least 1000^o C. Generally, HSS must have high attainable hardness with a minimum of HRC 63 and high carbon content, high wear resistance to enhance edge retention during cutting with high volume of wear resistance carbide in its microstructures in resisting abrasion, enough impact toughness to withstand interrupted cutting applications to avert breakage and chipping during cutting and high hardness at elevated temperature due to composition of cobalt with more tungsten and molybdenum to promote the red hardness. Hardened steel usually have two-phase microstructure that consist of body centered cubic ferrite and small particles of cementite, free cementite particles are easily generated along the tool flank face in hard turning [6].

Tool wear usually affects the surface quality and dimension of the workpiece and it is also one of the important factors that affect the tool life. Monitoring of tool wear is an essential requirement to achieved automated manufacturing. Since tool wear play a significant role in machine down time, product rejects and problems to the personnel that is involved. The three areas of most important factors in tool wear monitoring are determination of the tool's wear caused by abrasion and other types of wear, identification of tool breakage and detection of collisions, any form of contact between the tool and the work piece [7].
Tool wear rate model could be derived from one or several wear mechanisms and the rate of volume loss at the tool face per unit contact area per unit time is related to many cutting operation variables, it gives information about wear growth rate as a result of some wear mechanism. The worn tool force model was used to capture the total cutting forces as well as force contributions from both the crater and flank wear which has been used to determine the force variation tendency during the process of tool wear progression [8].

Carburization is a method of heat treatment used for improving the wear resistance of carbon steel and this can be done by any of three methods are liquid carburizing, solid carburizing and gas carburizing. Solid carburization is much capable of improving the hardness and wear resistance of a steel compare to other methods. The important of carburization is to increased interface area generated by the formation of carbide at grain boundaries causing impurities which usually resulted to increase in ductility as the carburizing temperature increases. An increase in the carburizing temperature enhances and aids excessive austenite grain growth and deteriorated the furnace condition. And the effect of time on case depth is interdependent with carburizing temperature. The rates of carburizing temperature usually affect the mechanical properties of cutting tools and the degree of mechanical properties of carbon steels increase in proportion with the rise in concentration of carbon that dissolved in austenite prior to quenching during hardening heat treatment which may be as a result of transformation of austenite into martensite [9].

The toughness and mechanical strength of medium carbon steels can be improved by quenching in appropriate medium (oil, water or air), note that the major influencing factors in the choice of the quenching medium are the types of heat treatment in use and composition of the materials. The content of carbon steel usually has comparative property with iron phase, low carbon steel possess low tensile strength which resulted to low malleability, brittleness and ductility and apart from its low cost. It has a microstructure offerrite and pearlite that are relatively soft and weak which enable its easy machinability [10].

2. MATERIALS AND METHODS

2.1 Material

The materials used for the work were 30 pieces of 200 x 14 x 14 mm sizes of High speed Steel cutting tools, palm kernel shell, iron rod . Barium trioxocarbonate (v) (BaCO3), Engine Oil, units of steel boxes of density 800g/cm3, 15 units of fabricated iron boxes and 100litres of Engine Oil. The machines used are; grinding machine, muffle electric furnace of 15000C capacity, lathe machines, grinding machine, digital weigh scale, hacksaw, Rotopol-V machine and UV-VIS Spectrometer.

2.2 Methods

High Speed Steel cutting tools of 30 pieces (200 x 14 x 14 mm) sizes were used for the project. The composition of the cutting tool was analyzed with the UV-VIS spectrometer before carburization as shown in Table 1. The pulverized carbon was prepared at Federal Institute of Industrial Research Oshodi Lagos. (FIIRO). 50 kg of raw palm kernel shell was grinded with grinding machine and then milled by miller and sieved in order to achieve finest form of carburizer. Summarily, the pulverized carbon was prepared from palm kernel shell by drying, grinding, milling and sieving.

Heat treatment by carburization was carried out at Engineering Materials and Development Institute, Akure (EMDI). The prepared 30 samples were inserted in the pulverized palm kernel shell with 25% proportion of Barium trioxocarbonate (v) salt ($BaCO_3$) as an energizer. The carburizer was weighed and packed inside steel boxes of density 700 g/cm3 and tightly filled up with powdered palm kernel shell cover to prevent the CO from escaping and prevent unwanted furnace gas from entering the steel box during heating.
The loaded steel box was charged into the muffle furnace one after the other at the carburizing temperatures of 800, 850, 900 and 950 °C respectively and at difference holding time of 60, 90 and 120 minutes. All the tools were quenched in engine oil at interval of discharge from the furnance. Each sample was carburized base on proportion to specific holding time and temperature as scheduled. The wear resistance and strength of martensite structure increased sharply with increase in carbon content with an increase in carburizing temperature and holding time. Contribution to the strength arises from the carbon in solid solution, carbides precipitated during the quench, dislocations introduced during the transformation, and the grain size. The performance evaluation of the tool was done by measuring its weight loss, wear volume, wear rate and wear resistance on all the samples using Rotopol –V. which was carried out at SON, Enugu as indicated in Table 2.

3. RESULTS

3.1 Composition of HSS cutting tool.

The composition of the material was analyzed before carburization and this enable us to get composition analysis of the cutting tool as shown in Table 1.

3.2 Wear test

The test was carried out on treated (carburized) cutting tools and untreated one as a control at Standard Organization of Nigeria, Enugu with the following equipment; Rotopol –V, Impact tester. and all the treated and untreated cutting tools samples were weighed to get the initial weight and grit was fixed at a point for each sample to revolve at a specific time 600sec/10mins. Weight loss was now calculated by subtracting the final weight from the initial weight of each sample as shown in Table 2 and Figure 1.

The machine, Rotopol -V has provision for carrying out wear resistance as result shown in Table 2 and Figure 3 on any material. The surface was placed parallel to the surface of the rotating disc of the machine. Care was taken to ensure that the sample under test was firmly held to the surface of the rotating disc during the test so that the sample does not fling out while running the test. The wear volume for each sample was measured at particular time 10mins during cutting as result shown in Table 2 and Figure 2.The wear rate of the treated and untreated tools were taken for each sample as shown in Table 2 and Figure 4

Table 1 : Composition analysis of the cutting tool.

Element(s)	Composition (%)

C	0.65
Si	1.22
Mn	0.334
P	0.026
S	0.036
Cr	4.34
Ni	0.16
Mo	0.890
W	1.67
V	0.393
Co	0.012
Al	0.010

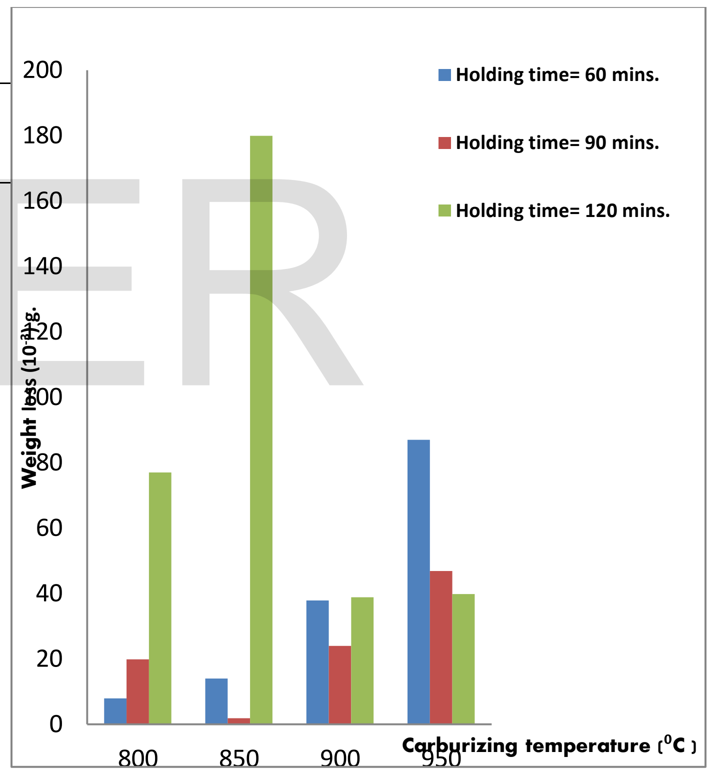
Table 2.: Wear test results.

Sample(s)	Weight Loss(g)	Wear cm^3 Volume	Wear Rate (cm^2)	Wear Resistance
950^0C,120mis	0.040	0.00516	1.095 $X10^{-8}$	$9.13X10^7$
950^0C,90mins	0.047	0.00606	$1.287X10^{-8}$	7.77 $X10^7$
950^0C, 60mins	0.087	0.01120	2.382 $X10^{-8}$	4.20 $X10^7$
900^0C,120mis	0.039	0.00503	1.068 $X10^{-8}$	9.37 X 10^7
900^0C, 90mins	0.024	0.00310	6.571 $X10^{-9}$	1.52 X 10^8
900^0C,60mins	0.038	0.00490	1.040 $X10^{-8}$	9.62 X 10^7
850^0C,120mis	0.018	0.00232	$4.928X10^{-9}$	2.03 X 10^8
850^0C, 90mins	0.002	0.00026	5.476 $X10^{-10}$	1.83 X 10^9
850^0C, 60mins	0.014	0.00181	$3.833X10^{-8}$	2.61 X 10^7
800^0C,120mis	0.077	0.00994	2.108 $X10^{-8}$	4.74 X 10^7
800^0C, 90mins	0.020	0.00258	5.476 $X10^{-9}$	1.83 X 10^8
800^0C,60mins	0.008	0.00103	2.190 $X10^{-8}$	4.57 X 10^7
Control	0.075	0.00968	$2.053X10^{-8}$	4.87 X 10^7

3.3 Discussion of Result

Carburizing the High Speed Steel cutting tool has a significant improvement on the wear resistance and wear rate of the samples. The used of energizer Barium trioxocarbonate (v) ($BaCO_3$) in 25% proportion increased the rate of carbon penetration into the layers of the tools. It was observed in Table 2 that the sample carburized at 950^oC held for 120 minutes has the higher resistance of $9.13X10^7$ over control sample (untreated) of $4.87X10^7$and at minimum carburizing temperature 800 ^oC and time 60 minutes shown lower value of 4.57 $X10^7$. This shown in Table 2 and Figure 4 that the higher the carburizing temperature with longer holding time the higher its wear resistance while at lower carburizing temperature the cutting tools will experience lower wear resistance.

It was observed that the wear resistance at carburizing temperature of 850^oC and 90 minutes has the highest wear resistance of 1.83 X 10^9followed by 900^oC and 90 minutes with wear resistance 1.52 X 10^8 this was caused as a result of the decrease in penetrating concentration of energizer and carbon additive into the surface and core of the cutting tools. Lower wear rate of 1.095 $X10^{-8}$ at carburizing temperature of 950^oC and time 120 minutes was recorded compare to control sample (untreated) of $2.053X10^{-8}$. This agreed with research carried out by [11] Considering Figures 3 and 4 shown some cases of low carburizing temperature with less holding time having higher wear resistance and lower wear rate than with more time. This sometimes caused if the amount of carbon in the carburizer and energizer has been exhausted, in such case prolonging the holding time at higher temperature may not much significant effects on the cutting tool.



4.57 $X10^7$

4.87$X10^7$

Figure 1: Effects of carburization with holding time on weight loss.

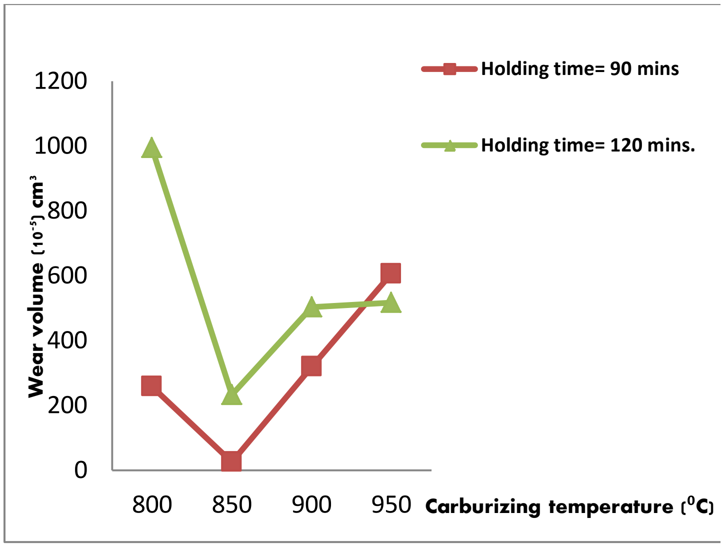


Figure 2: Wear Volume against Carburizing Temperature.

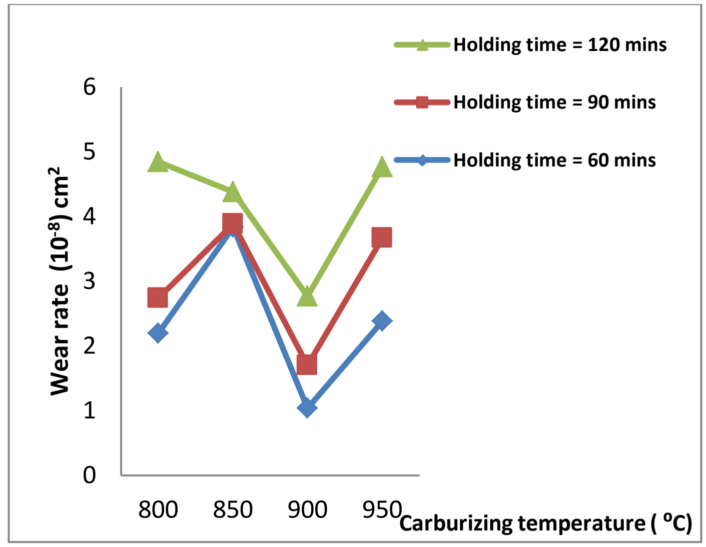


Figure 4: Wear rate against Carburizing Temperature

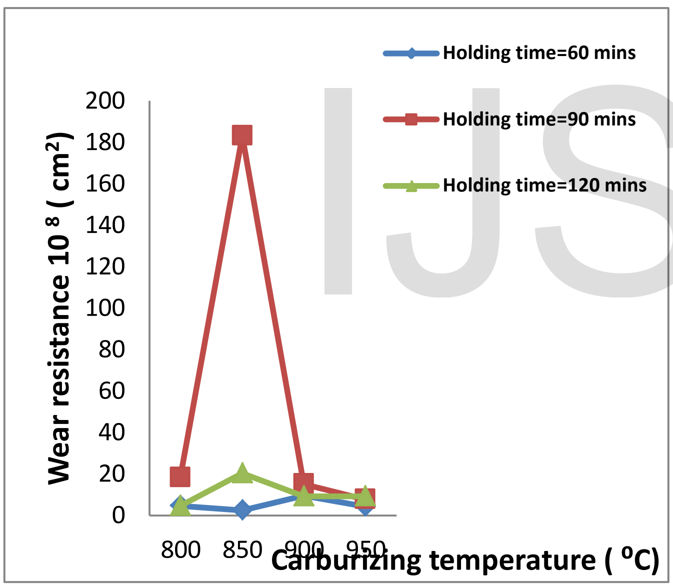


Figure 3: Wear resistance against carburizing Temperature

4.0 Conclusion

Carburizing of High Speed steel using palm kernel shell as shown a significant improvement in wear resistance and wear rate with lower weight loss and wear volume over the control (untreated) sample.

The graphical representation of the results gave the best optimal cutting tools parameters which were applicable in the production of the cutting tools especially in the area of selection of materials, carburization and experimental analysis. The carburized HSS cutting tool showed higher value in wear resistance and lower wear rate. The hardness and strength of martensile structure increased sharply with increase in carbon content as a result of carbides precipitated during the quenching with oil that introduced dislocation during the transformation.

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