International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 19 (2017) pp. 8995-9003
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Experimental Analysis of the Wear Properties of Carburized HSS (ASTM A600) Cutting Tool

Sunday A. Afolalu[1,*], Enesi Y. Salawu[1], Imhade P. Okokpujie[1], Abiodun A. Abioye[1], Oluwabunmi P. Abioye[1], Mfon .O Udo[1], Olajide R. Adetunji[2], Omolayo M. Ikumapayi[3]

[1]Mechanical Engineering Department, Covenant University, Ota. Ogun-State, Nigeria.
[2]Mechanical Engineering Department, Federal University of Agriculture Abeokuta Ogun-State, Nigeria.
[3]Mechanical and Mechatronics Engineering Department, Afe Babalola University Ado. Ekiti State, Nigeria.

[1]Orcid ID: 0000-0002-1186-001X

Abstract

Prediction and control of undesirable deterioration of cutting tools are the most essential challenges emanating in the design of tool which has to be checked. As a result of an increase in wear rate of HSS cutting tools, so has the need for wear resistant. The result has been a progression of carburizing the tools for better performance. Based on the theoretical analysis and study of tool wear and parameters that mitigates against wear resistance of cutting tools, this research work presents an experimental investigation and analysis of the wear properties of carburized HSS cutting tools. Twelve Samples under consideration were carburized HSS (ASTM A600) tools (0.65% C) treated at 800,850,900 and 950^{o}C with holding time of 60, 90 and 120 minutes respectively. The wear properties of weight loss, wear volume, wear resistance and wear rate were carried out using Rotopol –V, impact tester, polisher, grinder and weight scale. It was found from the experiment carried out that cutting tool(sample 5) carburized at holding temperature and time of 800 ^{o}C and 90 minutes has the lowest cutting weight loss, volume and wear rate of 0.002 g, 0.00026 cm^3 and 5.476 X10^{-10} cm^2 with maximum wear resistance of 1.83X10^9. This showed that sample 5 has the best wear properties which undermined the general believe that the sample with highest holding temperature and time should have the highest wear properties. This experiment has further established carburization as one of the heat treatment methods that involved carbon penetration to the depth that improved wear rate and resistance of a material.

Keywords: Carburization, Wear rate, Wear resistance, Cutting tool, High Speed Steel, ASTM A600.

INTRODUCTION

Carburizing is one of the most widely used surface hardening processes which involves diffusing carbon into a low carbon steel alloy to form a high carbon steel surface. Carburizing steel is widely used as a material of automobiles, form implements, machines, gears, springs and high strength wires etc. which are required to have the excellent strength, toughness, hardness and wear resistance, etc. because these parts are generally subjected to high load and impact. Such mechanical properties and wear resistance can be obtained from the carburization and quenching processes. This manufacturing process can be characterized by the key points such as: it is applied to low carbon work-pieces, work-pieces are in contact with high carbon gas, liquid or solid, it produces hard work-piece surface, work-piece cores retain soft [1]. Carburization consist of enrichment of surface layers of low carbon / mild steel (C less than equal to 0.30%) with carbon up to 0.8 % to 1% by this way the good wear and fatigue resistance is superimposed on a tough low carbon steel core. usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at between 0.8 and 1% C. However, surface carbon is often limited to 0.9% because too high a carbon content can result in retained austenite and brittle martensite [2]. There are following types of carburization processes which are solid, gaseous, vacuum, plasma, salt bath carburization

Wear is commonly defined as the undesirable deterioration of a component by the removal of material from its surface. It occurs by displacement and detachment of particles from surface. The mechanical properties of steel are sharply reduced due to wear [3]. The wear of material may be due to the friction of metals against each other, eroding effect of liquid and gaseous media, scratching of solid particles from the surface and other surface phenomena. In laboratory tests, wear are usually determined by weight loss in a material and wear resistance is characterized by the loss in weight per unit area per unit time. There are following principle types of wear as described below. It results when non metallic particles penetrate the metal surface and cause removal of metallic debris. Abrasive wear is a dominant failure mechanism of engineering components. The abrasive wear resistance in general increases with increase in hardness [4].

Adhesive wear or metal to metal wear that is caused due to relative slides or rolling movement of two mating metallic surfaces. If contact pressure are high it cause to permanent plastic deformation of rubbing component. Erosive wear occur as a result of relative movement between metal and liquid or gas. Corrosive wear is the destruction of materials by the action of surrounding medium is called corrosion. Corrosive wear begins at the surface and gradually penetrates into the matrix. Fatigue wear is the removal of particles by cyclic processes comes under the category of fatigue wear. This type of wear predominates in most practical machine component [5]. 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 [7].

Cutting tool materials are high quality steels made to close compositional and physical tolerances. In service, most cutting tools are subjected to extremely high and fluctuating loads. That is, the tool materials must withstand loads for long times without breaking and without undergoing excessive wear or deformation.[8] The knowledge of tool and cutting parameters can stem from either pure experimental analysis or hybrid of experimental and numerical/theoretical analysis. [9]. High Speed Steels are high-performance special steels offering high hardness at temperatures up to 500°C and high wear resistance, is a high carbon tool steel, containing a large dose of tungsten. A typical HSS composition is: 18% tungsten, 4% Chromium, 1% Vanadium, 0.7% carbon and the rest, Iron. HSS tools have a harness of 62-64 Rc. The addition of 5 to 8% cobalt to HSS imparts higher strength and wears resistance [10-12].

MATERIALS AND METHOD

The test was carried out at Standard Organization of Nigeria, Enugu. Twelve Samples carburized HSS tools (0.65% C) treated at 800,850,900 and 950ºC with holding time of 60, 90 and 120 minutes respectively were used with the following equipment; Rotopol –V, Impact tester, polisher, grinder and weight scale. All the Samples were weighed to get the initial weight and grit was fixed at a point for the sample to revolve at a specific time 1200sec/40mins. Weight loss and volume was now taken which was represented in Table 1. The machine, Rotopol -V has provision for carrying out wear resistance and rate on any material. It is simple to use but the surface of the sample to be tested must be parallel to the surface of the rotating disc of the machine. Samples under test were 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 and rate for each sample was measured at particular time 10mins during cutting and the results was represented in Table 2.

RESULTS AND DISCUSSION

Table 1: Results of shown cutting tool weight loss and cutting tools wear volume

EXPERIMENTAL SAMPLE	CARBURISING TEMP (°C)	CARBURISING TIME (mins)	CUTTING TOOL WEIGHT LOSS ($\times 10^{-3}$kg)	CUTTING TOOL WEAR VOLUME ($\times 10^{-5}$ m^3)
1	800	60	0.008	0.00103
2	850	60	0.020	0.00258
3	900	60	0.077	0.00994
4	950	60	0.014	0.00181
5	800	90	0.002	0.00026
6	850	90	0.018	0.00232
7	900	90	0.038	0.00490
8	950	90	0.024	0.00310
9	800	120	0.039	0.00503
10	850	120	0.087	0.01120
11	900	120	0.047	0.00606
12	950	120	0.040	0.00516

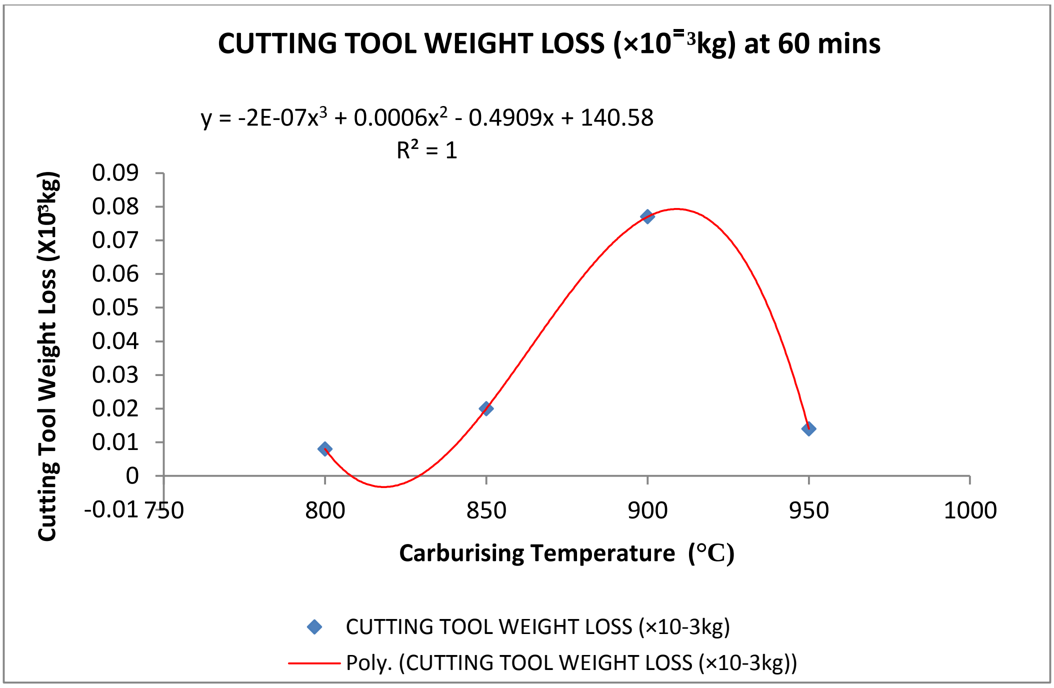

Figure 1: Carburizing temperature dependence of Cutting tool weight loss at 60mins

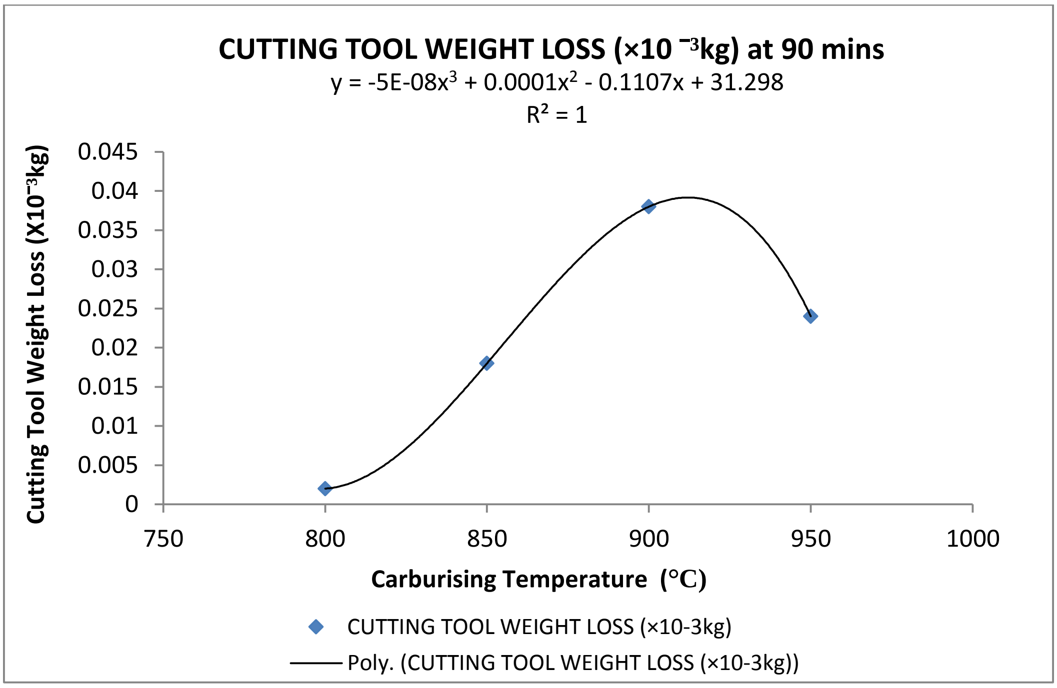

Figure 2: Carburizing temperature dependence of Cutting tool weight loss at 90mins

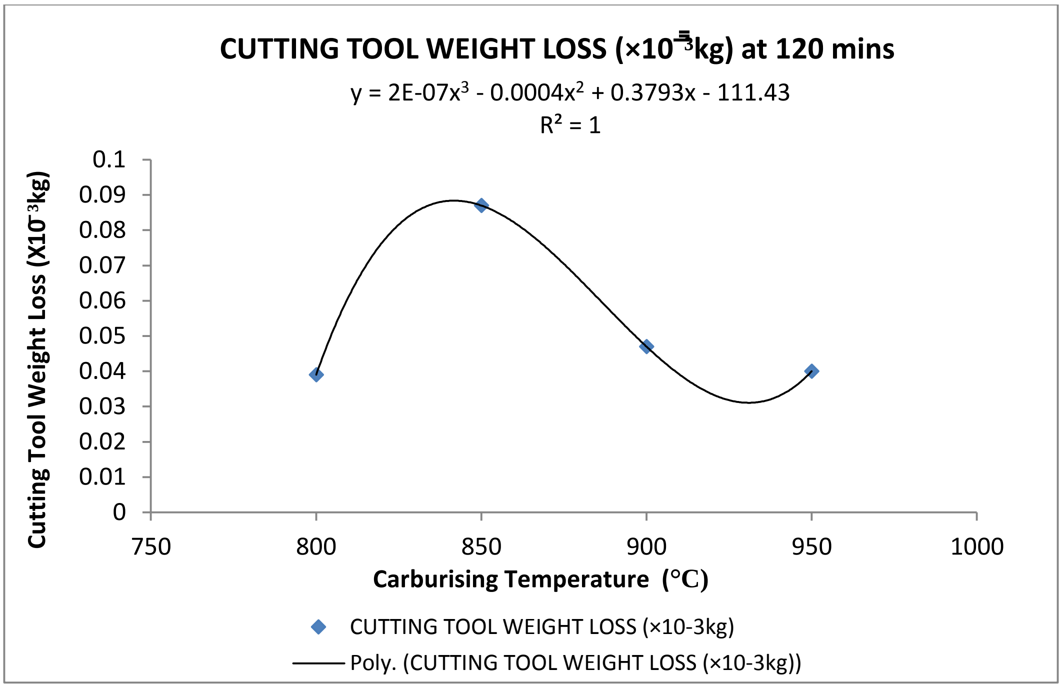

Figure 3: Carburizing temperature dependence of Cutting tool weight loss at 120mins

The quantity of weight loss increases in polynomials trend form as the carburizing temperatures increases when the carbon in the carburizer has not fully saturated to dissipate into the core layer of the tools materials but changes as its getting to holding temperature of 900 ºC in Figures 1 and 2.

Considering Figure 3 it can be observed that high wide range of low in weight loss was experienced aside that the lowest weigh loss was found in Figure 2 for sample 5 of holding temperature and time 800 ºC and 90 minutes.

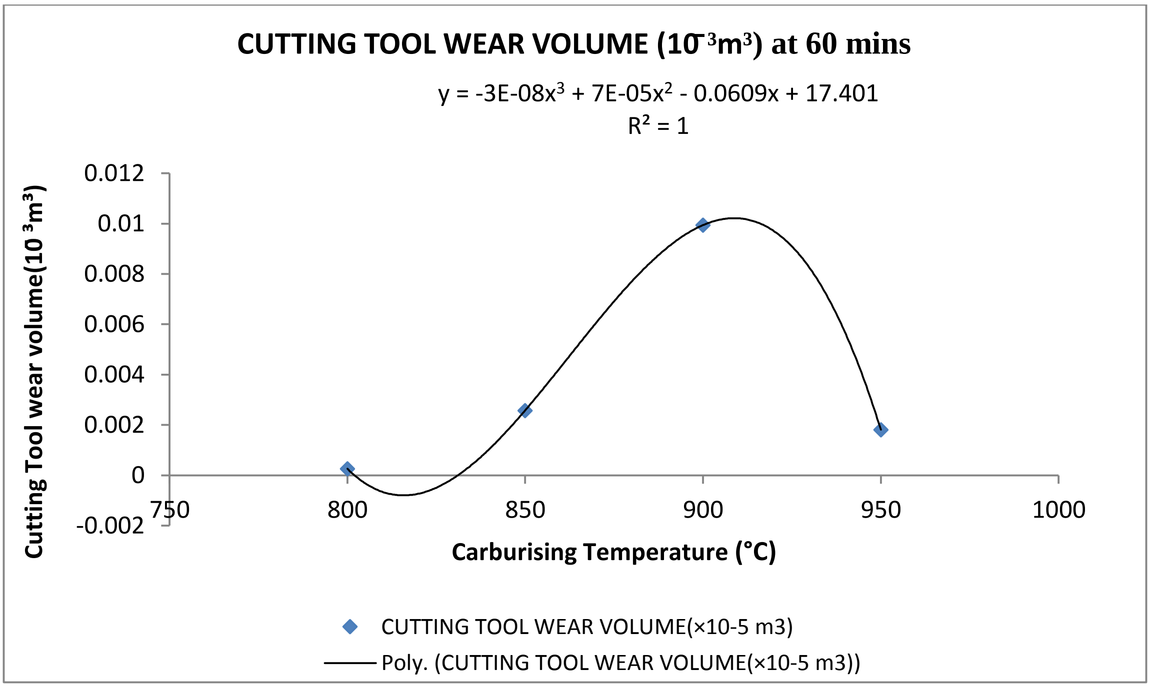

Figure 4: Carburizing temperature dependence of wear volume at 60mins

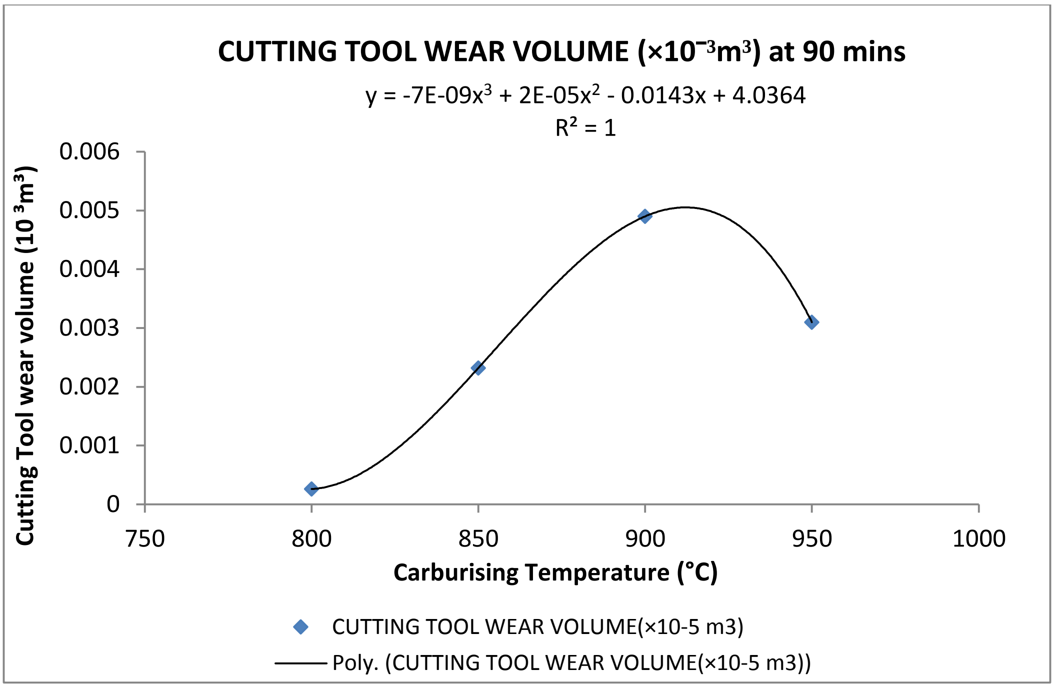

Figure 5: Carburizing temperature dependence of wear volume at 90mins

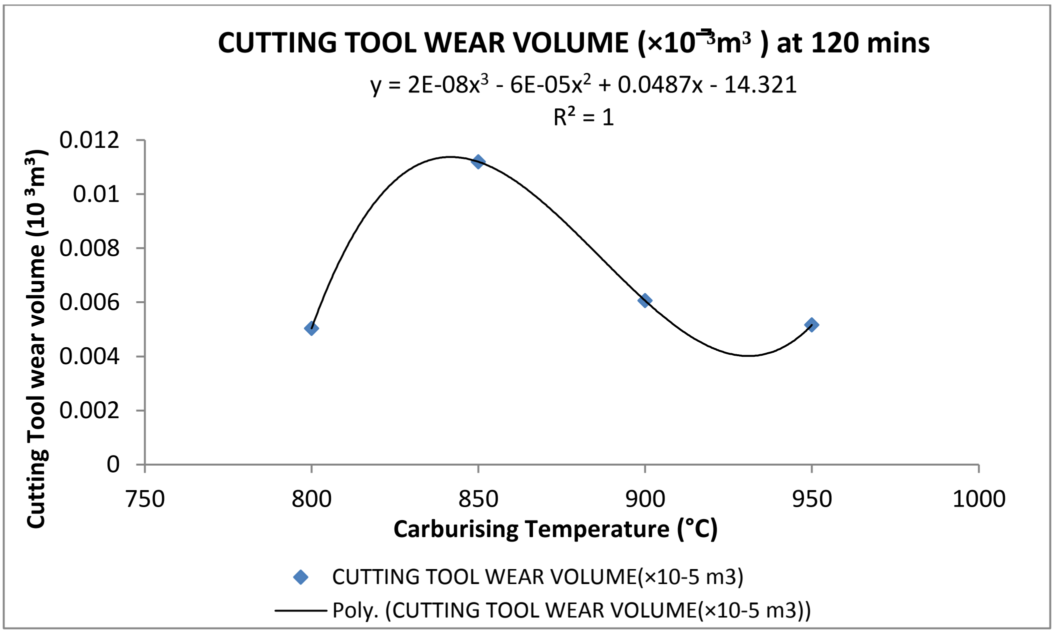

Figure 6: Carburizing temperature dependence of wear volume at 120 mins

The variation in carburizing temperatures with wear volume took the same dimension of weight loss due to the fact that the dependency relationship of wear volume and time in Figures 4 and 5was so significant that its polynomial form of its trend in wear volume increases relatively with time. This might be as a result of rate of carbon dissipation into the surface of the materials. Considering Figure 6, more wide range of low wear volume was realized at the highest holding time of 120 minutes due to the fact that there was more evenly saturated dissipation of concentrated carbon into the surface and core layers of the materials. Despite of this reasons, lowest wear volume was observed in Figure 5 which indicates best wear property compare to others.

Table 3: Result of wear rate and wear resistance of 12 samples of carburized cutting tools.

EXPERIMENTAL SAMPLE	CARBURISING TIME (mins)	CARBURISING TEMP (°C)	CUTTING TOOL WEAR RATE (cm^2)	CUTTING TOOL WEAR RESISTANCE (cm^2)
1	60	800	2.190 X10^{-8}	4.57 X10^{7}
2	60	850	5.476 X10^{-9}	1.83 X10^{8}
3	60	900	2.108 X10^{-8}	4.74X10^{7}
4	60	950	3.833X10^{-8}	2.61 X10^{7}
5	90	800	5.476 X10^{-10}	1.83X10^{8}
6	90	850	4.928X10^{-9}	2.03X10^{8}
7	90	900	1.040 X10^{-8}	9.62 X10^{7}
8	90	950	6.571 X10^{-9}	1.52X10^{8}
9	120	800	1.068 X10^{-8}	9.37 X10^{7}
10	120	850	2.382 X10^{-8}	4.20 X10^{7}
11	120	900	1.287X10^{-8}	7.77 X10^{8}
12	120	950	1.095 X10^{-8}	9.13X10^{8}

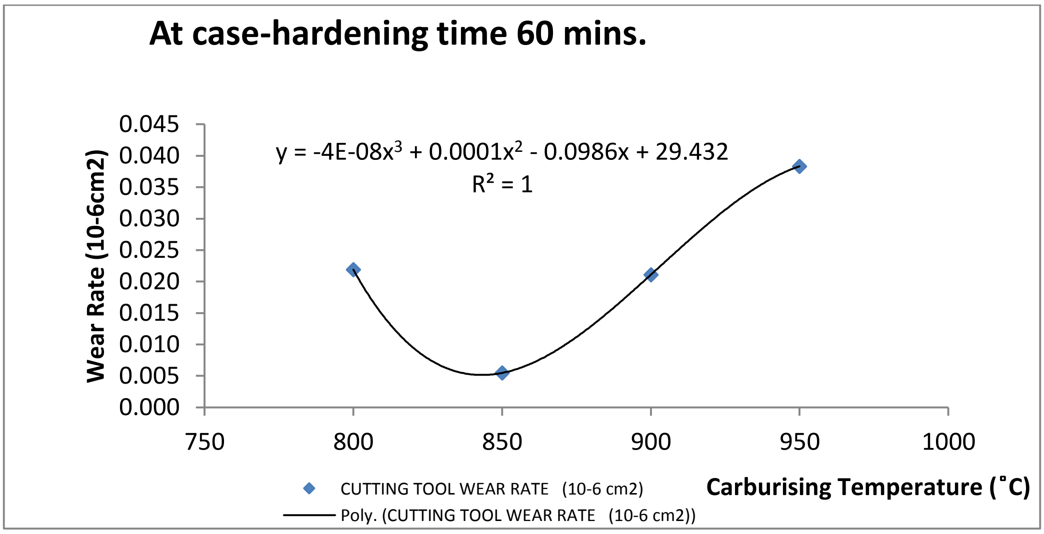

Figure 7: Carburizing temperature dependence of wear rate at 60 minutes

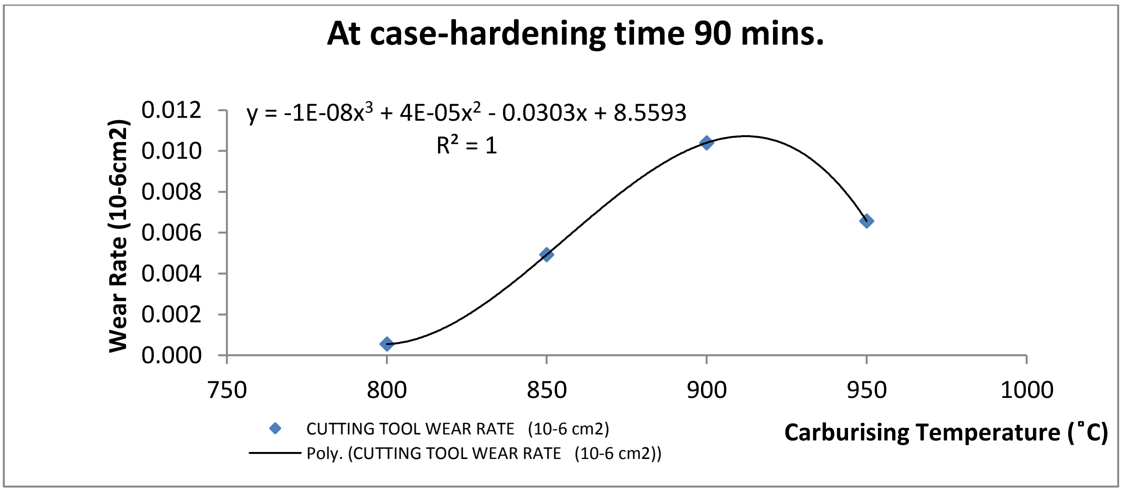

Figure 8: Carburizing temperature dependence of wear rate at 90 minutes

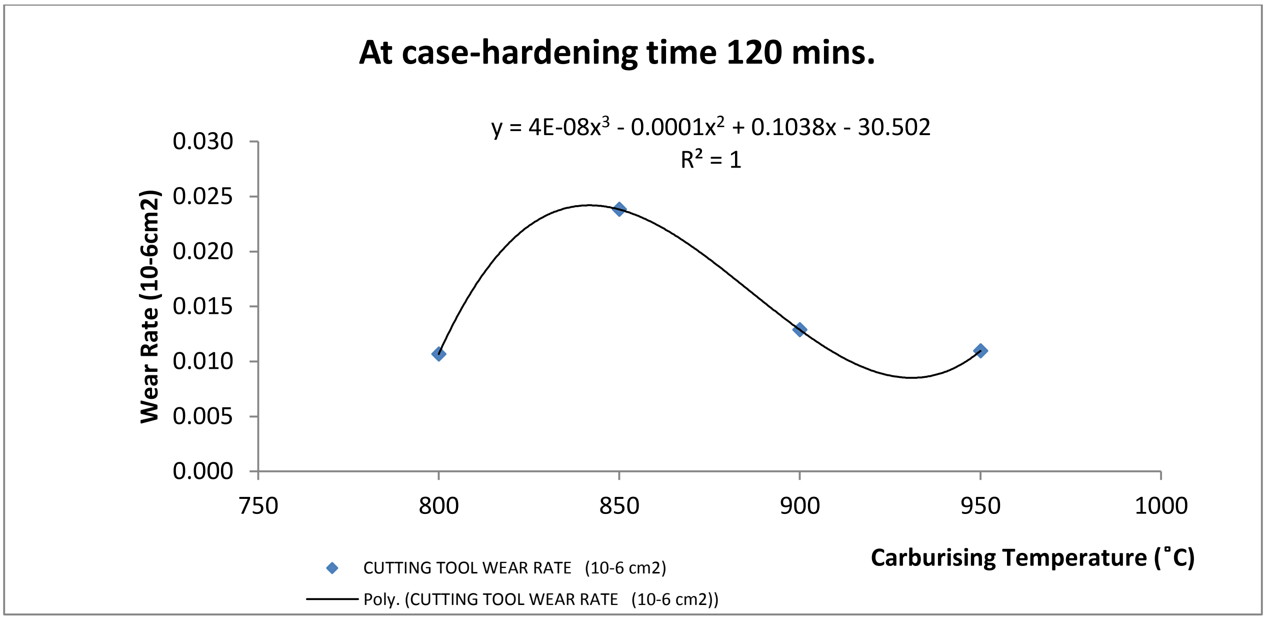

Figure 9: Carburizing temperature dependence of wear rate at 120 minutes

The polynomial trends behavior of the wear rate and carburizing temperature took another new dimension in Figures 7, 8 and 9. The best wide range of low wear rate was found in Figure 8 and 9 which could be as a result of high saturated temperature and time given the carburizer enough strength to dissipate faster into the surfaces of the cutting tools materials.

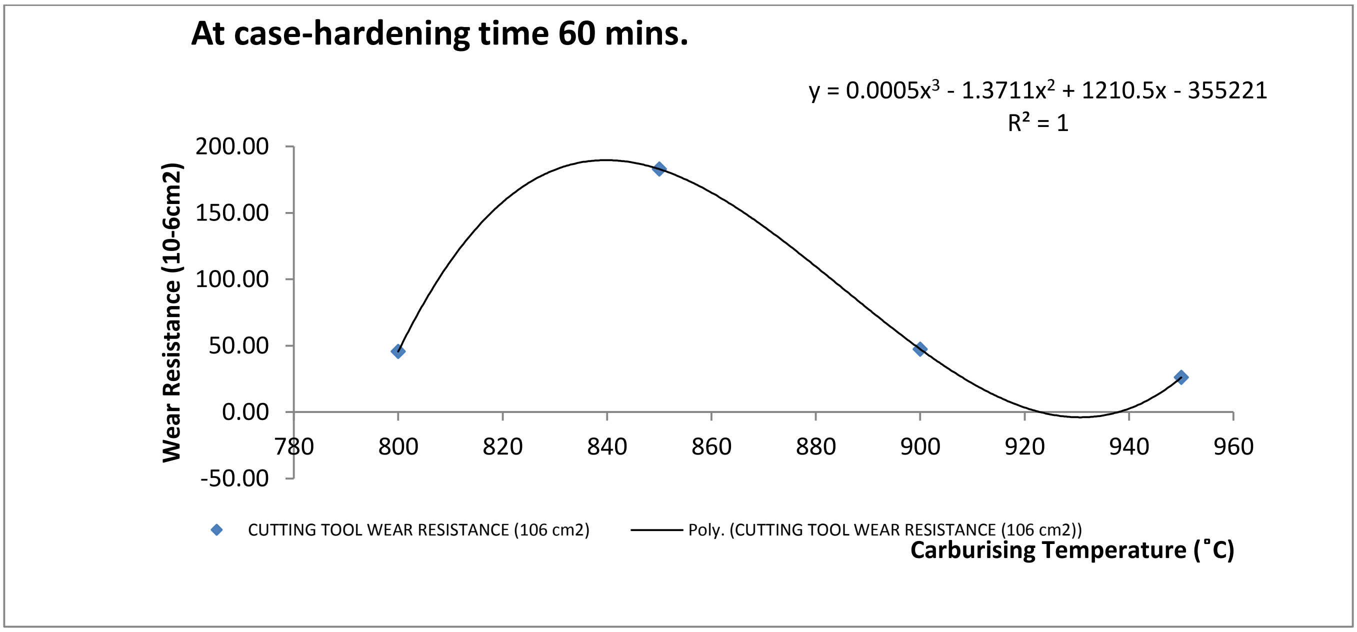

Figure 10: Carburizing temperature dependence of wear resistance at 60 minutes

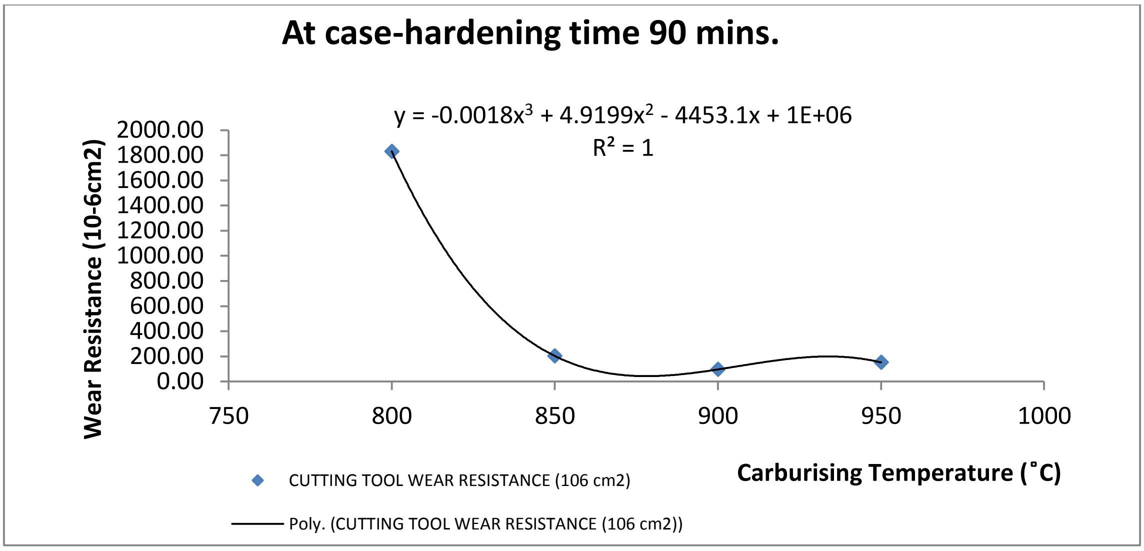

Figure 11: Carburizing temperature dependence of wear resistance at 90 minutes

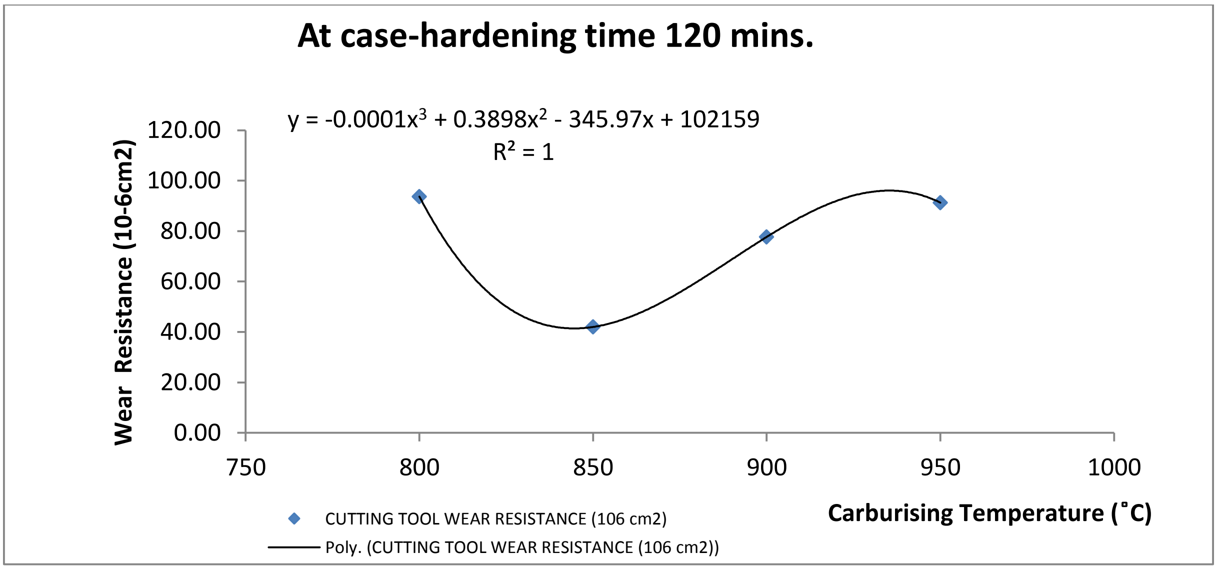

Figure 12: Carburizing temperature dependence of wear resistance at 120 minutes

The behavioural variation of carburizing temperature and wear resistance of the cutting tools were real factors to be considered in checking the mechanical and abrasiveness properties of the tools. There was sharp declination of polynomial trends for wear resistance in Figure 11 which It was found from the experiment that cutting tool(sample 5) carburized at holding temperature and time of 800 ºC and 90 minutes has the highest wear resistance of $1.83X10^9$.

CONCLUSION

The experimental analysis of the wear properties of carburized HSS (ASTM A600) cutting tool carried out in this research work has been able to establish the important of carburization in the context of wear rate and resistance of a cutting tool. It was found that increase in the carburizing temperature and holding time enhances and aids excessive austenite grain growth and penetration of high concentrated carbon into the surface and core layers of the tools. It was observed from the experiment carried out that cutting tool (sample 5) carburized at holding temperature and time of 800 ºC and 90 minutes has the lowest cutting weight loss, volume and wear rate of 0.002 g, 0.00026 cm^3 and 5.476 $X10^{-10}$ cm^2 with maximum wear resistance of $1.83X10^9$. This showed that sample 5 has the best wear properties which undermined the general believe that the sample with highest holding temperature and time should have the highest wear properties. This experiment has further established carburization as one of the heat treatment methods that have impact in variation of wear rate and resistance of a material with carburizing temperature and time as determinant factors for its wear properties.

AKNOWLEDGEMENT

We acknowledge the financial support offered by Covenant University in actualization of this research work for publication.

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