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Study of the Performances of Nano-Case Treatment Cutting Tools on Carbon Steel Work Material during Turning Operation

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Abstract: The degree of holding temperature and time play a major role in nano-case treatment of cutting tools which immensely contributed to its performance during machining operation. The objective of this research work is to carryout comparative study of performance of nano-case treatment tools developed using low and medium carbon steel as work piece. Turning operation was carried out under two different categories with specific work piece on universal lathe machine using HSS cutting tools 100 mm x 12mm x 12mm that has been nano-case treated under varying conditions of temperatures and timeof 800,850, 900, 950°C and 60, 90, 120 mins respectively.

The turning parameters used in evaluating this experiment were cutting speed of 270, 380 and 560mm/min, feed rate of 0.15, 0.20 and 0.25 mm/min, depth of cut of 2mm, work piece diameter of 25mm and rake angle of 7° each at three levels. The results of comparative study of their performances revealed that the timespent in the machining of low carbon steel material at a minimum temperature and time of800°C, 60 mins were1.50, 2.17 mins while at maximum temperature and time of 950°C , 120 mins were 1.19, 2.02 mins. It was also observed that at a corresponding constant speed of 270,380 and 560mm/min at higher temperature and time, a relative increased in the length of cut were observed.Critical observation of the result showed that at higher case hardening temperature and time (950°C/120mins), the HSS cutting tool gave a better performance as lesser time was consumed during the turning operation.

INTRODUCTION

High-hardness materials include various hardened alloy steels, case-hardened steels, super alloys, nitridesteels; hard-chrome coated steels, and heat-treated powder metallurgical parts. Hardened steel such as AISI 52100 steel for bearing applications, 16MnCr5 for automotive gears and shaftswere early recognized by the automotive industry for transmission components [1].

Manufacturing cost can be significantly reduced if turning operation is adopted to the production of complex intricate parts. Most of theUS industries now exploited the advantages of hard turning for an annual gain of up to $6 billion[2].A qualitative comparison of the capabilities of hard turning and grinding processes in terms of work- piece quality, process flexibility, dimension and shape accuracy, etc. has been made.[3]

In the previous years, many studies have been carried out to explore different facets of the hard turning of alloy steel. Ramesh *et al.* [4]examined the differences in structure and properties of white layers formed during machining of hardened AISI 52100 steel (62 HRC) at different cutting speeds. Their results indicated that the grain sizes of white layers formed were considerably smaller than the grain sizes of the bulk. They also observed that white layers generated at higher machining speeds are coarser than those generated at lower speeds. Umbrello *et al.* [5] determined residual stresses distribution and optimal cutting conditions during hard turning of AISI 52100 bearing steel using the hybrid model based on the artificial neural networks (ANNs) and finite element method (FEM).

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The material developments for the cutting tool, one of the most critical elements in metal cutting, have always been characterized by an increase in wear resistance to machine harder, tougher, or chemically reactive materials [6].

The forces acting on the tool are important aspect of machining. Knowledge of the cutting forces is needed for the estimation of power requirements, the adequately rigid design of machine tool elements, tool-holders, and fixtures, for vibration free operations [7-8]. Sutter et al. [9] studied the effects of the cutting speed and depth of cut on the temperature profile of the chip during an orthogonal machining of 42 CrMo 4 steel using standard carbide tools TiCN coated, it was observed that temperature at the chip increases with the increase in both cutting speed and the depth of cut. Abukhshim et al. [10] assessed the magnitude of heat flow during turning operation of AISI 4140 high strength alloy steel using Finite element analysis [FEA]. Maximum temperature at the tool-chip was observed to increase with cutting speed. They further highlighted that the non-linearity is attributed to the heat fraction flowing into the tool [19].

Sutter and Ranc [11] measured the temperature during machining of two steels i.e. C15 and 42CrMo4 for a range of cutting speed around 15–65 m/s. The researchers remarked thatthe increase in cutting speed from 10 to 65 m/s maximizes the temperature at the chip continuously [12]. List et al. [12] studied interface cutting temperature and its relation with the crater wear mechanism. Mechanical and thermal parameters were noticed to be influenced with tool rake face [13]. Carburized cutting tool(HSS) always show higher value in resistance to wear and lower wear rate which is always caused as a result of increase in carbon content in the core and surface region of the metal phases [14]. The martensite precipitated during the quenching with oil medium always introduced dislocation during the transformation of the materials [15-16]. Reports abound on the cases of treatment of cutting tools from the literature; however, no work has been reported on the operational performances of case-hardened HSS cutting tool.[17]. Owing to this scarcity, the aim of the research is to carry out the study of the performances of nano-case treated cutting tool on carbon steel work material during turning operation [18-20].

METHODOLOGY

The experimental studies of comparative performance evaluation of cutting tools were carried out on a universal lathe machine- HuichonInc Korea-Model-6515, 1.5 m, The dimensions of the cutting tools are 100 mm x 12 mm x 12 mm. Its back rake angle is 7^o. The cutting tools used were nano-case treated tools of varying holding time of 60, 90 and 120 mins and varying temperature of 800, 850, 900and 950 ^{o}C while the work material (low and medium mild steel) were selected for this experiment. The work piece' physical and mechanical properties were conducted prior turning operation. The chemical composition of the case-hardened was analyzed using standard laboratory procedures[21].

Theory and Experimental Procedure

The cuttings undergo constant heating derived from the shear deformation energy and friction, which cause a high temperature at the tool/chip interface. The high temperature at the tool rake face is a principal wear factor in turning operations.The turning operation is carried on an universal lathe machine- Highlighted in Table 1 are parameters such as length of cut, cutting speed, spindle speed and feed rate for low carbon mild steel and medium carbon steel.

Table 1: Parameters for turning operation

Parameters	Low carbon steel	Medium carbon steel
Length of cut	50mm	50mm
Cutting speed	29.85mm/min	21.20 mm/min
Spindle speed	380rev/min	270 rev/min
Feed rate	19mm/min	13.50m/min
Depth of cut	2mm	2mm
Diameter	25mm	25mm

Experimental Design

The influence of the independent parameters such as case hardening temperature [C_{ht}] case hardening time [C_{hti}] on the time of cut for low carbon steel and medium carbon steel are investigated. The C_{ht} were varied from 800 to 950°C, in step of 50°C while the C_{hti} are varied between 60 and 120 min. The effect of the independent parameters is investigated on the time of cut for both low carbon steel and medium carbon steel. Secondly, the influence of varying temperature from 800 to 950°C and speed (270-560 rpm) were assessed on the length of cut for medium carbon steel results shown in Table 2 below.

Experimental Results and Discussion.

Table 2: Resultsfor low and medium carbon steel

CASE HARDENING TEMP. (°C) At 120 mins	SPEED (mm/min)	LENGHT (mm)	CASE HARDENING TIME (min)	TIME OF CUT(min) Low carbon steel	TIME OF CUT(min) Medium carbon steel
800	270	25.70	60	1.50	2.17
	380	35.60	90	1.47	2.20
	560	40.00	120	1.49	2.14
850	270	26.50	60	1.50	2.12
	380	35.50	90	1.44	2.10
	560	49.00	120	1.50	2.04
900	270	28.30	60	1.49	2.08
	380	38.05	90	1.38	2.09
	560	55.05	120	1.20	2.08
950	270	29.50	60	1.22	2.05
	380	38.55	90	1.24	2.03
	560	57.00	120	1.19	2.02

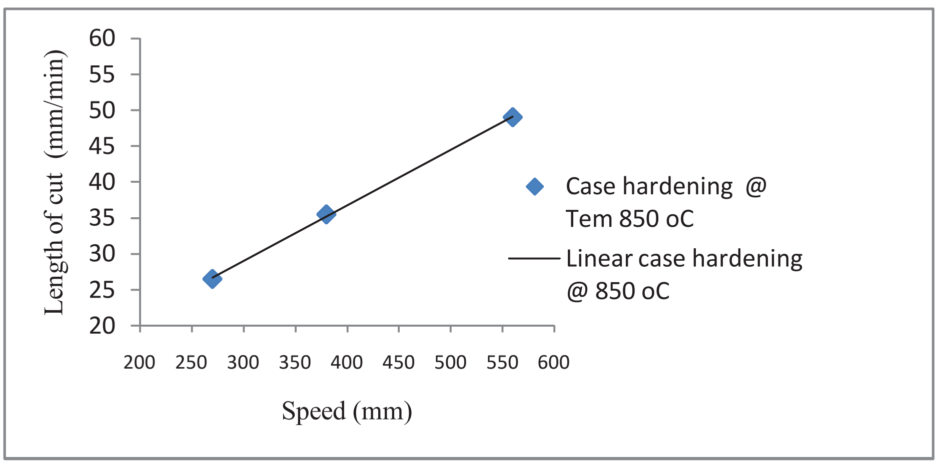

Figure 1: Variation of length of cut with speed for medium carbon steel at 850°C

The variation in length of cut versus speed for the low and medium carbon steel for HSS case hardened at 800°C and 850°C is as shown in Figure 1. It can be deduced from the results that the length of cut of the work piece increases as the spindle speed of the cutting tool increases for tools case hardened at 800°C, 850°C and 900°C. for cutting tool case hardened at 850 °C and 950 °C, the corresponding length of cut were 40.05mm and 49.00m

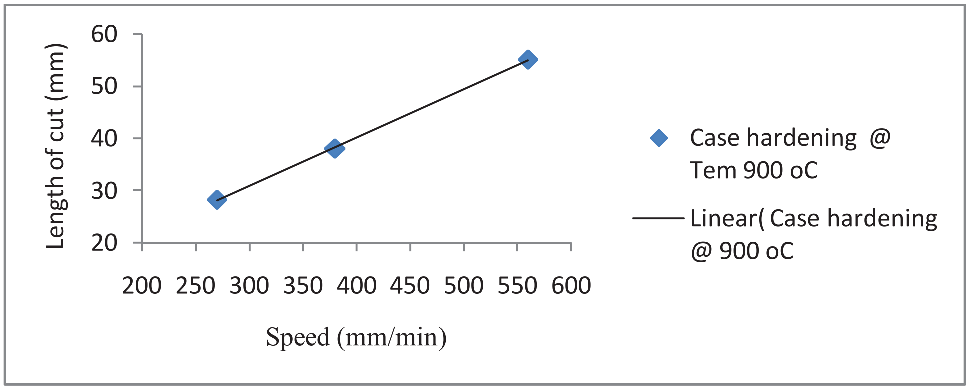

Figure 2: Variation of length of cut with speed for medium carbon steel at 900°C

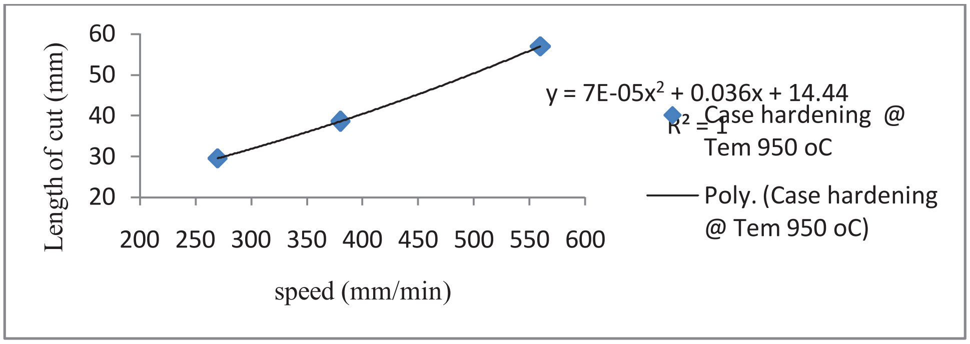

Figure 3: Variation of length of cut with speed for medium carbon steel at 950°C

Variation of length of cut with speed for medium carbon steel at 800, 900 and 950°C were represented in Figure 2 and 3

The result in Fig 2 showed an increase in length of cut of about 55.05mm when the case hardening temperature was increased as well as the spindle speed. Considering the cutting tool case hardened at 800°C, 850°C, 900°C and 950°C with a corresponding constant speed of 270, 380 and 560mm/min, a relative increased in the length of cut were observed. This can be tagged to relative increase in the evenly distribution of the diffused carbon on the surface and in the core of the cutting tool. However in Figure 3at 950°C, and at a speed of 560mm/min, the length of cut increases rapidly to about 55.00mm. This is as a result of high volume of fractions carbide concentration which could have been responsible for higher surface hardness of the cutting tool.

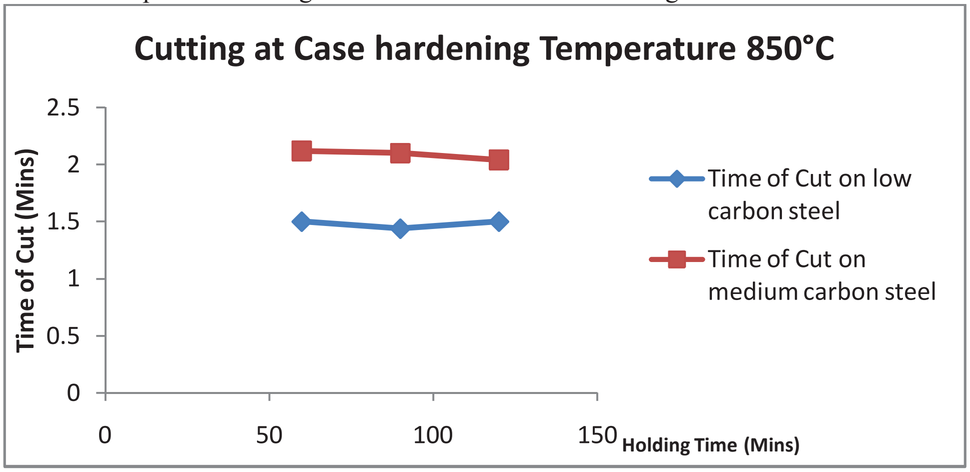

Figure 4: Variation of time of cut and holding time on low and medium mild steel

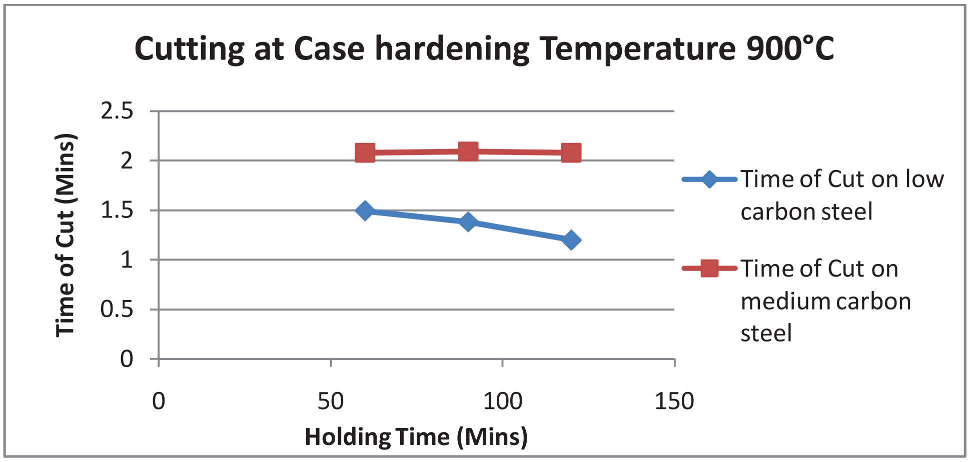

Figure 5: Variation of time of cut and holding time on low and medium carbon steel

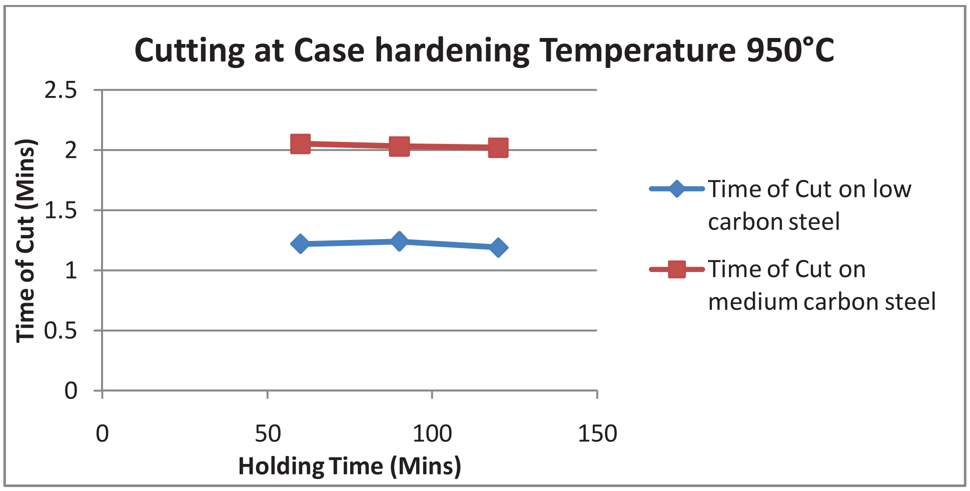

Figure 6: Variation of time of cut and holding time on low and medium carbon steel

Figures 4 to6 represent variation of time of cut and holding time at different case hardening temperature of cutting tools. The comparative study of the performances of HSS case hardened cutting tools on the two work piece(low and medium) mild steel material revealed that the time spent in the machining of low carbon steel material at a temperature of 800°C is less compared to the time spent on the medium carbon steel.Critical observation of the result also showed that at higher case hardening temperature and time (950°C/120mins), the HSS cutting tool gave a better performance as less time was consumed during the turning operation.

CONCLUSION

The comparative study of case hardened HSS cutting tool were experimented on a universal Lathe machine as seen from the experimental procedure. The case hardened HSS tool at higher temperature and time gave the maximum length of cut and minimum time consumption. At a reduced case hardening temperature more time is spent and less work is done.In conclusion, at higher case hardening temperature and holding time for a HSS cutting tool, better performance is achieved in the turning operation of low carbon steel compared to medium carbon steel.

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