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Effect of HSS and Tungsten Carbide Tools on Surface Roughness of Aluminium Alloy during Turning Operation

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Abstract This paper presents investigation of the effects of cutting tool on the surface roughness during the turning of locally sourced aluminum alloy using High speed steel and Tungsten carbide as cutting tools. The cutting speed, feed rate and depth of cut were conditions selected for the study. The aluminium alloy used as workpiece was locally sourced and the chemical analysis was carried out on the alloy to determine its elemental composition. Experiments were carried out at intervals of 10 minutes cutting time for seven different cutting speeds (*Vc*) of 300-600m/min. feed rates (*f*) of 0.2, 0.4 and 0.6mm/rev and a constant depth of cut (*d*) of 1.0mm. The results obtained showed that the surface roughness of the aluminum alloy can be improved upon with higher cutting speed and lower feed rate. Surface roughness value of 1.98 µm was obtained at cutting speed of 600 m/min and feed rate of 0.2 mm/rev as compared with surface roughness value of 2.19 µm at 600 m/rev and feed rate of 0.6 mm/rev.

Keywords: *cutting tool, surface roughness, feed rate and depth of cut*

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1. Introduction

Several types of tools used for cutting are present in the world today, each serving different purposes and applications. There are several factors that manufacturers of cutting tools have to take into consideration when manufacturing cutting tools so as to ensure that the working life of the cutting tool is optimized [1]. The turning process productivity is mostly influenced by tool chatter which results from the interaction of turning operations in the radial and feed directions, leading to irregular thickness distribution in the cutting edge region. The vibrations amplitude may grow exponentially until they become as large as chip thickness in an unstable process [2]. This unstable vibration provides larger cutting forces, capable of destroying machines and causing tool breakage, wearing of tools, dimensional errors and unacceptable surface finish [3]. Surface roughness is one of mechanical design important aspect, as it can influence the mechanical parts performance like heat generation, corrosion and wear resistance, creep life and fatigue strength [4]. During operation of turning different factors such as workpiece materials and feed rate, cutting tool, spindle speed, , depth of cut, coolant, tool nose radius, tool edge angles and tool construction affects surface finish and vibration. As a result, it is important to provide an adequate relationship between tool life and cutting conditions, tool material and workpiece properties and tool geometrical parameters that are hard because of the machining process complexity such as strains, very high train-rates and temperatures, and lack of suitability of data [5]. Also, the optimum cutting conditions can lead to the minimization of cost/production time or costs and the enhancement of surface finish [6]. In present days, cutting conditions optimization for the purpose of vibration reduction and minimization of surface roughness experienced during machining operation has been the major subjects investigated by many researchers in the world [7]. Sasimurugan and Palanikumar [8] studied the effect of cutting parameters on the surface roughness of aluminium alloy 2024A,, it was observed that feed rate has the greatest impact on the surface roughness. Manna and Bhattacharya [9] conducted an experiment on Al/SiC MMC machinability and observed that at low depth of cut, feed rate and high speed a better surface finishing was achieved. Narayana and Chenata [10] during the turning of 2024A aluminium alloy utilized Taguchi method in conducting a study on the effect of parameters of cutting on the surface roughness. Analysis of variance shows that feed rate has the highest impact on the surface roughness and the next parameter is cutting speed and the effect of depth of cut and nose radius was not very significant. In this study, effect of high speed steel (HSS) and tungsten carbide tools on the surface roughness of aluminium alloy during turning operation werebe investigated.

2. Materials and Experimental Method

2.1. Materials

Aluminium alloy which is copper and silicon based with the following percentage composition by weight (Al-84.1, Cu-3.46, Si-8.72, Mg-0.44, Zn-0.93, Fe-0.89, Mn-1.42 and Ni-0.13) was used as workpiece material. The aluminium alloy was sourced from Tudun - Wada material market in Kaduna, Kaduna State of Nigeria. An optical emission spectrometer (SHMADZU, PDA 7000 was used to analysis the chemical composition of the aluminum alloy. High speed steel and tungsten carbide were used as the cutting tools.

2.2. Experimental Method

The experiment was performed on a manual lathe (Muller and Passan, MC20 type and model number NMC 820531 AE39) with maximum power of 9.0 kW and centre height of 260 mm as shown in Figure 1.

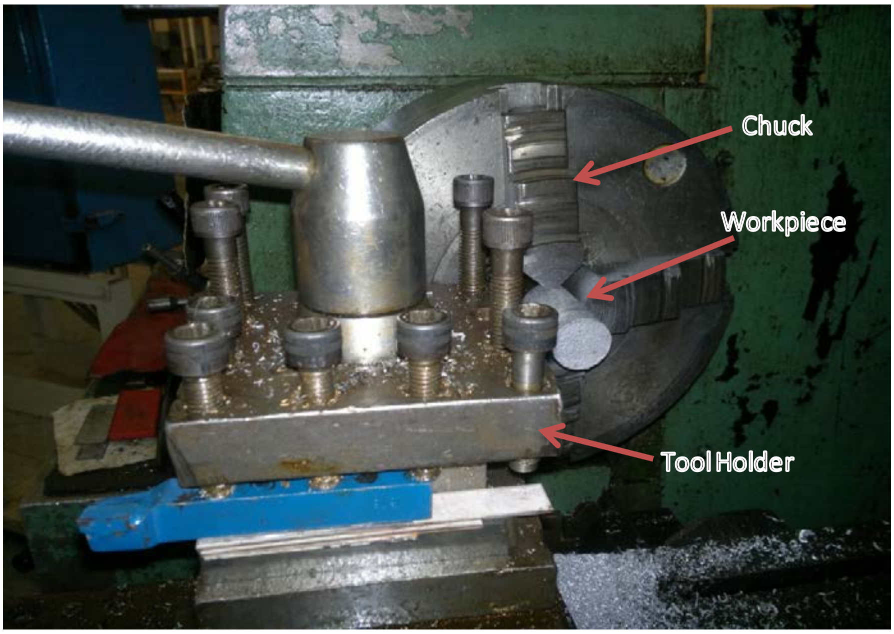

Figure 1. Experimental set up

Table 1. Machining cutting conditions (Experiment 1)

S/N	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)
1	300	0.2	1.0
2	350	0.2	1.0
3	400	0.2	1.0
4	450	0.2	1.0
5	500	0.2	1.0
6	550	0.2	1.0
7	600	0.2	1.0

Table 2. Machining cutting conditions (Experiment 2)

S/N	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)
1	300	0.4	1.0
2	350	0.4	1.0
3	400	0.4	1.0
4	450	0.4	1.0
5	500	0.4	1.0
6	550	0.4	1.0
7	600	0.4	1.0

All experiments were conducted under conditions of dryness using aluminum alloy (A03330) as workpiece material with size of 60 mm length and 30 mm diameter using HSS and tungsten carbide tools each having a nose radius of 0.5 mm. Series of experiments in turning aluminum alloy with the two cutting tools were carried out to study the tool effect on the workpiece surface roughness with cutting speed, feed rate and depth of cut as input parameters as shown in Table 1, Table 2 and Table 3.

For every machining cutting condition, the machine was stopped and tool replaced with new one. Each turning was done for a period of ten minutes and maintaining a constant depth of cut before measuring the surface roughness of the workpiece. The surface roughness measurement was carried out at the Defence Industries Corporation of Nigeria (DICON) Kaduna using a surface roughness tester (SR- 16 surface roughness tester - model number 1510090001). The surface roughness values were calculated by finding the average of three roughness values which were obtained along the length of workpiece from three different points of machined (workpiece) surface.

Table 3. Machining cutting conditions (Experiment 3)

S/N	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)
1	300	0.6	1.0
2	350	0.6	1.0
3	400	0.6	1.0
4	450	0.6	1.0
5	500	0.6	1.0
6	550	0.6	1.0
7	600	0.6	1.0

3. Results and Discussion

The results obtained for surface roughness with high speed steel tool (H) and tungsten carbide tool (T) at different speeds for the three feed rates and constant depth of cut of 1.0 mm are shown in Table 4, Table 5 and Table 6.

Table 4. Results of surface roughness values obtained for Experiment 1

				Surface Roughness (µm)	
S/N	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)	H	T
1	300	0.2	1.0	1.20	2.81
2	350	0.2	1.0	0.99	2.57
3	400	0.2	1.0	1.02	2.35
4	450	0.2	1.0	0.93	2.44
5	500	0.2	1.0	0.87	2.23
6	550	0.2	1.0	0.72	2.03
7	600	0.2	1.0	0.61	1.98

The results obtained for experiment 1, shows that the surface roughness values were in the range of 0.61- 1.20 µm for HSS tool and 1.98-2.81µm for tungsten carbide tool. The surface roughness values for the two cutting tools were observed to be decreasing as the cutting speed increases. However, HSS tool show lower values of surface roughness compared with the tungsten carbide tool

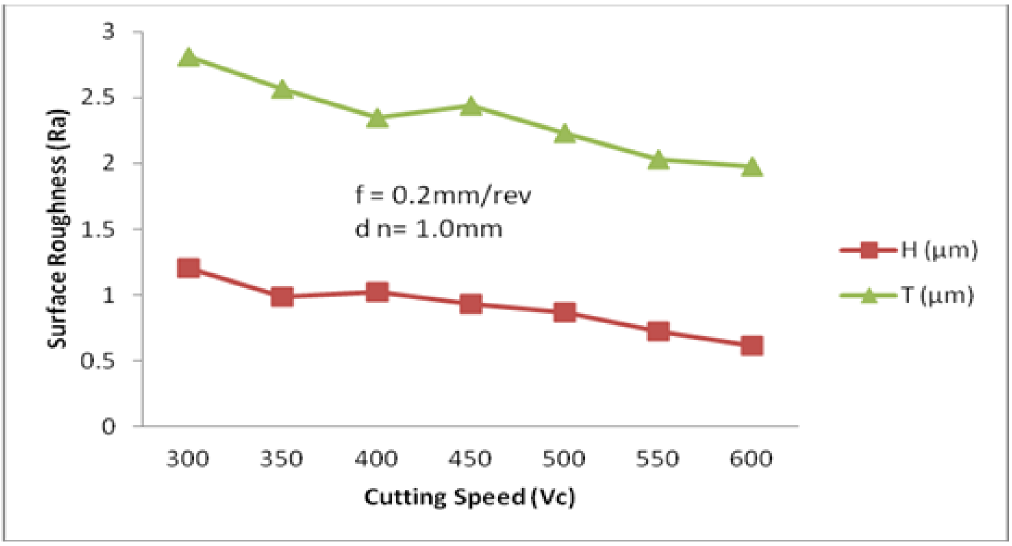

Figure 2. Surface roughness against cutting speed at feed rate of 0.2 mm/rev

Figure 2 depicts the surface roughness against the various cutting speeds at feed rate of 0.2 mm/rev and depth of cut of 1.0 m during turning of aluminium alloy with high speed steel and tungsten carbide tools. It was observed that for both cutting tools, similar pattern for surface roughness was obtained under the same turning conditions. However, the surface roughness of the tungsten carbide cutting tool gradually decreases when the cutting speed increased to 450 m/min and then decreases again from the 500 m/min until it finally reaches minimum value as the cutting speed increases to the maximum of 600m/min. The high speed steel (H) cutting tool also display similar behaviour as its surface roughness values gradually decreases when the speed increased to 500 m/min. Minimum surface roughness value was attained when the cutting speed increases to 600 m/min.

The results obtained from experiment 2 as tabulated in Table 5, show the surface roughness values to be in the range of 0.73- 1.56µm for high speed steel (H) and 2.20-3.52µm for tungsten carbide tool. Similar pattern of results were observed for experiment 2 when compared with experiment 1. However, the surface roughness values for the two cutting tools were higher in experiment 2 which used feed rate of 0.4 mm/rev as compared with experiment 1 which used 0.2 mm/rev feed rate.

Table 5. Results of surface roughness values obtained for Experiment 2

				Surface Roughness (µm)	
S/N	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)	H (µm)	T (µm)
1	300	0.4	1.0	1.56	3.52
2	350	0.4	1.0	1.43	2.96
3	400	0.4	1.0	1.21	2.62
4	450	0.4	1.0	1.17	2.70
5	500	0.4	1.0	0.90	2.56
6	550	0.4	1.0	0.87	2.39
7	600	0.4	1.0	0.73	2.20

Figure 3 indicates a sudden decrease in the surface roughness of tungsten carbide tool for cutting speed of 550 m/min and a feed rate of 0.40 mm/rev and the minimum surface roughness value was obtained at cutting speed of 600 m/min. Similar behaviour was observed for the values of surface roughness when HSS tool was used under the same cutting conditions.

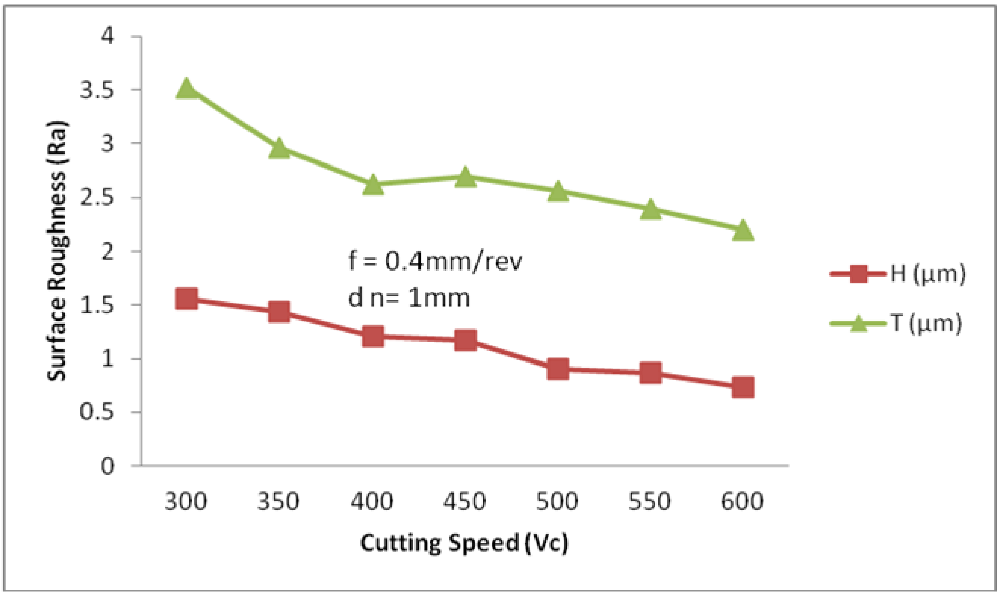

Figure 3. Surface roughness against cutting speed at 0.4mm/rev feed rate

Table 6 show the results obtained for experiment 3. It is observed that surface roughness values decreases as cutting speed increases as reported in the first two experiments

Table 6. Results of surface roughness values obtained for Experiment 3

				Surface Roughness (µm)	
S/N	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)	H (µm)	T (µm)
1	300	0.6	1.0	1.60	3.61
2	350	0.6	1.0	1.47	3.18
3	400	0.6	1.0	1.28	2.67
4	450	0.6	1.0	1.01	2.60
5	500	0.6	1.0	0.96	2.58
6	550	0.6	1.0	0.89	2.33
7	600	0.6	1.0	0.78	2.19

Figure 4 shows the surface roughness against the various cutting speed at a feed rate of 0.6mm/rev and constant depth of cut of 1.0 mm using the two cutting tools. The pattern of surface roughness values obtained is similar to the previous two experiments. The difference observed was that, when using the tungsten carbide tool, as the cutting speed increased from 300 m/min to 600 m/min there was consistent constant decrease in the surface roughness. But for HSS tool, the decreased was not consistent.

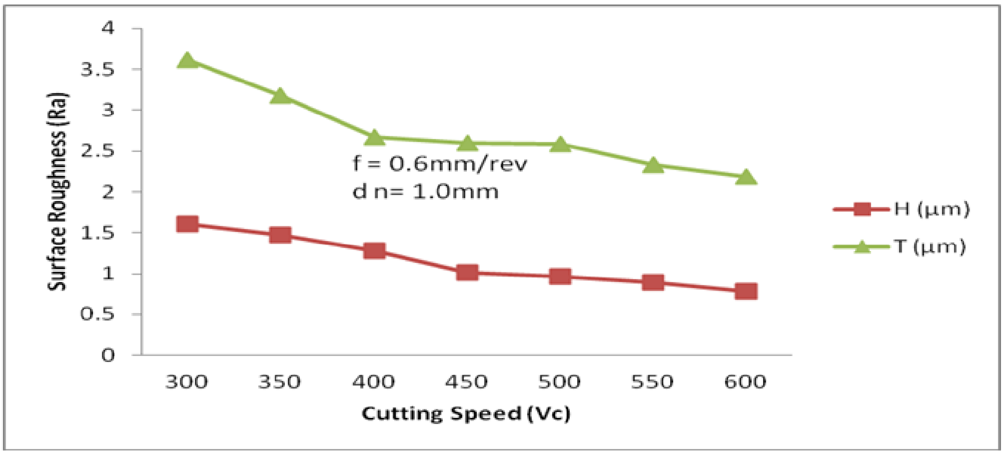

Figure 4. Surface roughness against cutting speed at 0.6mm/rev feed rate

4. Conclusion

In this study, the following conclusions can be drawn from the experimental results

1. The effect of cutting tools and cutting parameters indicates that a significant difference exist among cutting tools. HSS and tungsten carbide tools under similar conditions of cutting conditions gave different surface roughness values. However, feed rate and cutting speed are the two cutting parameters that significantly affect

surface roughness. For constant feed rate and depth of cut, it was observed that better surface roughness was obtained with increase in cutting speed.

2. The surface roughness values obtained with HSS tools are less than tungsten carbide tool under the same cutting conditions. Hence, it can be deduced that surface roughness value is tool material type dependent.

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