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Investigation on Effects of Cutting Speed and Depth of Cut on Surface Roughness of AISI 1040 Steel during Turning Operation

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Abstract: *In this study, experiments are conducted to compare the surface finish quality of medium carbon Steel during tuning operation with uncoated carbide tools using dry cutting and Vegetable base cutting fluid. A series of experiments was carried out by varying the turning parameters like cutting speed (200rpm, 300rpm, and 400rpm) and depth of cut (0.5mm, 0.75mm, 1mm) at constant feed rate 0.45mm/rev. The experiments was carried out on AISI 1040 carbon steel using center lathe (XL400 model) turning machine. The results shows that surface roughness of workpiece decreases with increase cutting speed while it increases with increasing depth of cut, indicating that surface finish is improved by increasing the cutting speeds and lower depth of cut under different cutting condition. It was also observed from the results that the use of vegetable oil gives better surface finish when compared with dry cutting. In addition, castor and moringa cutting oil was found to have greater influence on surface roughness than dry cutting at varying cutting parameter. The least average Surface roughness was obtained at 0.5 mm depth of cut with moringa oil as compare to castor and dry*

Keywords: Turning, Dry Cutting, Vegetable Oil, and Temperature

INTRODUCTION

Machining processes require a large part of metal cutting operation and the objective of metal cutting is to obtain a finished product with desired, shape, size and good surface finish with precise metal removal from the workpiece. Turning operation is considered as one of the most important of these processes due to the various shapes that can be produced by it.

In turning, many parameters like cutting speed, depth of cut, feed rate, cutting tool geometry, cutting temperatures and cutting conditions that affect cutting performance measures, such as, cutting temperature, tool life, cutting force, surface roughness of the machined surface are frequently considered for experimental studies.

The most vital issues in machining operations are minimizing cost of machining and producing the desired quality of the machined parts for sustainable manufacturing. Surface roughness is considered important indicator that specifies products quality due to its influence on mechanical properties of the produced parts as fatigue life and wear resistance (Murat Sarıkaya, et al., 2013). During cutting process most of the cutting energy transforms to heat because of the plastic deformation in shear zone, in addition to the frictional dissipation energy generated at the tool-chip interface and at the interface between tool and workpiece, this heat distributes among tool, workpiece and chip. Temperature at the tool-chip contact affects the seizure and the sliding conditions at this interface (Haider M, et al., 2013). High temperature is not desired because it leads to increase tool wear and as a sequence produces high surface roughness and reduces tool life. Therefore, an investigation on the effect of cutting parameters on workpiece surface quality has been adopted in this study. The effects of cutting parameters on surface roughness of workpiece materials were investigated by several researchers on under different cutting condition: Ipilakyaa, T. D. et al., (2019) examines the effect of cutting parameters (speed, feed rate and depth of cut) on the surface roughness of stainless steel and proposes a model equation that defines the relationship between surface roughness and the cutting parameters. The specimen was turned on a manual lathe machine (Harrison M300) under different levels of constraints and the surface roughness was measured using an SRT-6223 Digital Surface Profile Gauge Roughness Tester. Results of the study indicate significant improvement in surface finish of stainless steel at higher cutting speeds, lower feed rates and lower depths of cut. Paul (2014) also investigated the effect of cutting speed, feed and depth of cut on the surface finish, tool wear and cutting force in dry turning of hardened alloy steel, AISI 4340 using the Taguchi design of experiments. From the result it was observed that tool wear and feed rate had significant influence as compared to depth of cut. Optimal conditions were obtained at cutting speed (140 m/min), feed (0.125 mm/rev), and depth of cut (0.8 mm). Zulaili M. and Zainal S. (2020), Investigate the effect of machining parameters such as depth of cut, cutting speed and feed rate on the surface roughness. A full factorial experimental design was employed in the study and. The results showed that low feed rates and high spindle speed reduced surface roughness of workpiece material during operations. Sujan Debnath et al (2015), Study the effect of cutting conditions and various cutting fluid levels on surface roughness and tool wear. The experiments were carried out on CNC turning machine and the work material was mild steel. Taguchi orthogonal design array was employed to minimize the number of experiment while ANOVA was chosen to determine the influence of cutting parameters on the response's values. The results showed that feed rate has the highest effect with (34.3%) on surface roughness. Cutting speed with (43.1%) and depth of cut with (35.8%) were the dominant factors influencing tool wear. Thamizhmanii *et al.*, (2007), studied surface roughness and tool wear in machining AISI 8620 steels by turning process with ceramic cutting tools. Cutting speed, feed rate and depth of cut were selected as cutting parameters in this study to deterine their influence on surface roughness and tool wear. The experiments had been performed under dry cutting condition and the results showed that surface roughness decreases when cutting speed increases, while tool wear increases with increase each of cutting parameters. Haider and Roaa (2017) study the effect of cutting speed and feed rate on surface roughness and tool temperature by prediction mathematical models. The experiments were conducted on AISI 1045 carbon steel that has wide range of applications by using CNC turning machine under dry cutting condition.

The results shows that surface roughness decreases with increasing cutting speed while it increases with increasing feed rate, also it has been noticed that the temperature of cutting tool increases with increasing both cutting speed and feed rate. Therefore, this experimental study focus on the effect of machining parameters on the surface quality of the machined surfaces during turning operation on AISI 1040 Steel under dry cutting and by using castor and moringa oil as cutting fluid to test the surface roughness and cutting tool temperature.

MATERIALS AND METHODS

2.1 Materials

In this study, the effect of process parameters on AISI 1040 workpiece surface quality finish was investigated using XL400 universal center lathe machine. The experimental studies were carried out in the laboratory workshop of Mechanical Engineering Department, Nigeria Defense Academy (NDA) Kaduna state.

Fig. 1 Machine Setup

Workpiece of 40mmx150mm in dimension was placed into the jaw chuck and the jaws were tightened by chuck key until the jaw started to grip the work piece. Uncoated carbide insert tool was tightly clamped in the tool holder for machining the workpiece. Experimental investigations are undertaken for turning of AISI 1040 steel material under different machining environments.

2.2 Measurements Average Surface Roughness and Temperature

The average surface roughness of the workpiece was measured using a CVR-135 surface roughness tester as shown in Fig. 2b. During the experiment, the mean of three randomly measured values was chosen along the samples machined at different levels of cutting speed and depth of cut selected at constant feed rate.

(Fig. 2) a. Surface Roughness Tester b. Infrared Thermometer

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Workpiece surface temperature was measured using an infrared thermometer as shown in Fig.2b. The thermometer was carefully placed at a distance of 5cm from the tool-workpiece interface.

2.3 Chemical Composition of Workpiece Material.

The sample material was a medium carbon steel AISI 1040 source from Ajaokuta steel company kogi state, Nigeria. Chemical composition steel materials are presented in Table-1

Table-1 Chemical composition AISI 1040 steel workpiece material

C	S	P	Cr	Si	Mn	Mo	Fe
0.3572	0.0453	0.0527	0.1170	0.1894	0.7374	0.1169	98.3841

2.4 Experimental Details

In this study AISI1040 steel specimens of 40mm diameter and 150 mm length were used as workpiece on a turning machine using carbide tools without cutting fluid and using some selected vegetable oil as cutting fluid. The experiments were carried out with the following specific procedures using castor seed oil and moringa seed oil as the cutting fluid and dry machining. Turning operations of AISI1040 medium carbon steel at varying cutting speed (200, 300, 400rpm) at constant feed rate of 0.5mm/rev and depth of cut of 1mm. In the second set of experiments the depth of cut were varied at (0.5, 0.75 and 1 mm) while cutting speed was fixed at (400rpm.) and the feed at (0.5 mm/rev). The experiments were repeated under dry machining and the use of cutting fluid. Parameters such as workpiece material, length, diameter, and tool nose radius remain constant. Table-1 shows the cutting conditions under consideration as experiments were performed varying the cutting speed, and depth of cut at different levels. During turning operation, the surface temperature was measured using the infra-red thermometer as the temperature value is read off a digital display. The surface roughness was obtained using the surface roughness tester.

Table-2 Experimental Details Used for Machining Operation

Process Parameter	Description
Workpiece Material	AISI 1040
Machining Environment	Dry, Flood
Cutting Fluid	Castor, Moringa oil
Cutting Tool	Uncoated Carbide tool
Cutting Speed(rpm)	200, 300, 400
Feed(mm/rev)	0.45
Depth of Cut(mm)	0.5, 0.75, 1.

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RESULTS AND DISCUSSION

3.1 Evaluation of Machining Experiments

Tables 3-5 show the effects of varying cutting speed and depth of cut at constant feed on surface roughness and temperature. In each experimental case, surface roughness and surface temperature of AISI 1040 workpiece were measured under dry and vegetable oils (castor oil and moringa oil) as the cutting fluid during the turning operation of AISI 1040 steel.

Table-3 Effect of varying cutting speed on surface roughness at constant feed rate of 0.5mm/rev and depth of cut at 1mm

Cutting speed (rpm)	Surface Roughness(µm)		
	Dry	Castor oil	Moringa oil
200	3.43	2.26	2.14
300	2.98	2.16	2.06
400	2.52	2.11	1.98

Table-4 Effect of varying depth of cut on surface roughness at constant feed rate of 0.5 mm/rev and speed of 400rpm

Depth of cut (mm)	Surface Roughness(µm)		
	Dry	Castor oil	Moringa oil
0.5	3.72	2.13	2.24
0.75	3.85	2.31	2.35
1	4.02	2.51	2.63

Table-5 Effect of Cutting Speed on Cutting Tool Temperature at constant depth of cut of 1mm and feed rate of 0.5mm/rev

Cutting speed (rpm)	Temperature(^{0}C)		
	Dry	Castor oil	Moringa oil
0.5	57	38.3	40.7
0.75	60	45	47
1	65	49	48.5

3.2 Effect of Cutting Speed on Surface Roughness

Effect of cutting speed on the workpiece surface finish value at constant feed rate and depth of cut are presented in Fig. 3.

Results as presented shows the changing trend of the surface roughness of workpiece with varying cutting speed at constant depth of cut of 1mm and feed rate of 0.5mm/rev.

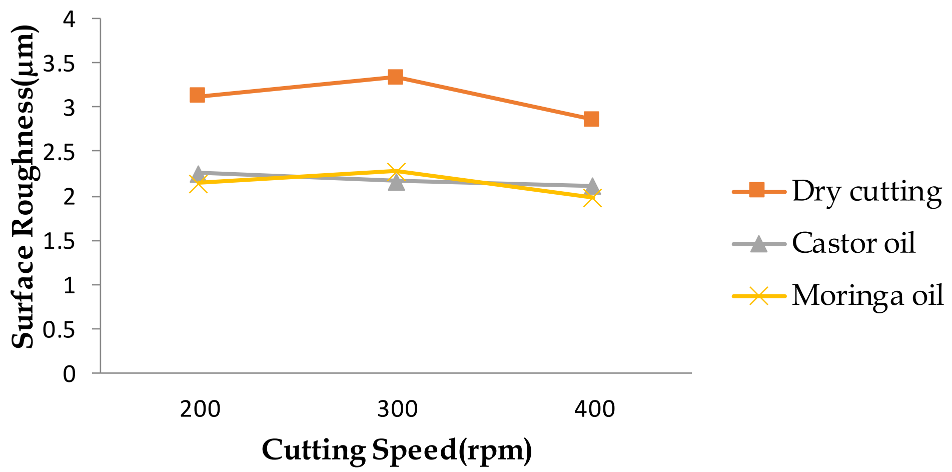

Fig. 3 Effect of cutting speed on surface roughness at 1mm depth of cut and 0.5mm/rev feed

The result as presented in Fig. 3 shows a gradual decrease of surface roughness with increase in cutting speed for using dry cutting and cutting fluid. Also, the results indicated that vegetable cutting fluid performed better as there is a significant decrease in surface roughness for all cases under investigation, compared to dry cutting. This is due to the reduction in the tool temperature through the application of cutting fluid into the cutting interface which reduces friction between the tool face and the chip which reduces the size of the built-up edge, thereby decreasing workpiece surface finish (Vishal *et al.*, 2008).

3.2. Effect of Depth of Cut on Surface Roughness

Fig. 5 shows the variation depths of cut at constant feed rate and cutting speed on workpiece surface finish under different cutting environments.

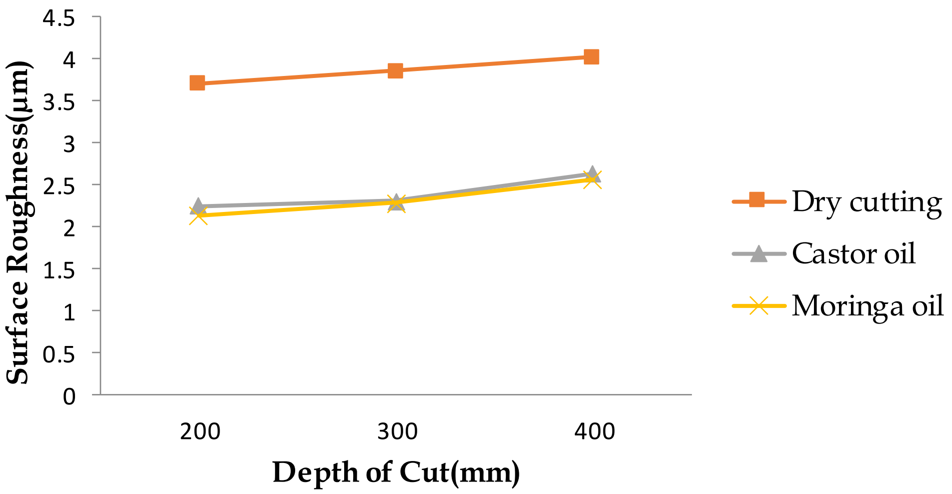

Fig. 4 Effect of depth of cut on surface roughness at 400rpm cutting speed and 0.5mm/rev feed rate

Results as presented in Fig. 4 shown that surface roughness increased with increase in depth of cut under different cutting environment investigated.

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Increase in surface roughness with increase in varying depth of cut may be due to increase in machine vibration due to the increase in cutting forces at higher depths of cut which increase the amount of material in contact with the tool and these forces cause vibration leading to a higher surface roughness (Musonda E, et al., 2014). Surface roughness of dry cutting increased slightly from 3.7 to 4.2µm between depths of cut 0.5–1mm. Vegetable oil produced a significant decrease in surface roughness from 2.31 casstor and 2.28µm, moringa to about 3.85 as compared to dry cutting at 0.75mm depth of cut. Between 0.5, 0.75 and 1.0 mm indicate that surface roughness increases with increasing depth of cut for all vegetable oil samples and dry cutting. The least average Surface roughness was obtained at 0.5 mm depth of cut with moringa oil as compare to castor and dry cutting.

3.3 Variation of Cutting speed on surface Temperature

Fig. 5 shows the effects of varying cutting speed on workpiece surface temperature at constant feed and depth of cut. Surface temperature of AISI 1040 workpiece were measured under dry and vegetable oils (castor oil and moringa oil) as the cutting fluid during the turning operation of AISI 1040 steel.

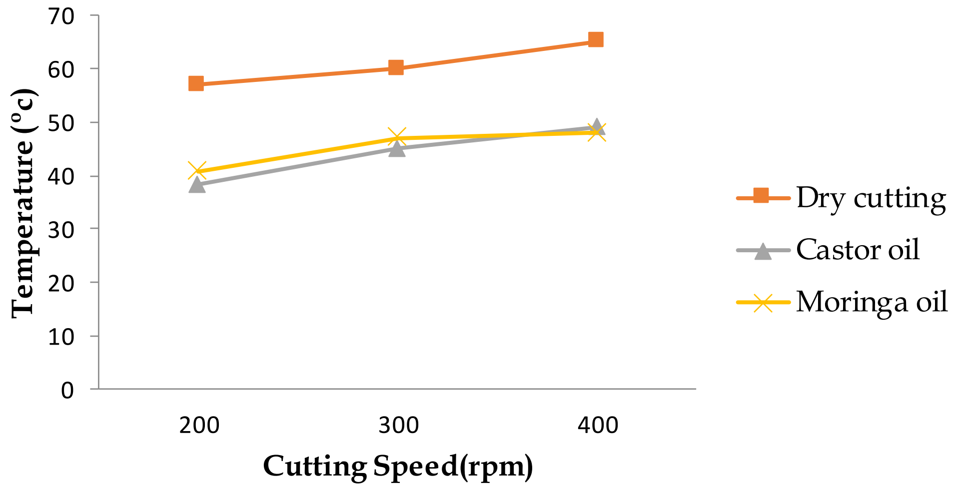

Fig. 5: Effect of cutting speed on surface temperature of AISI 1040 steel of at constant feed rate of 0.5rev/mm and depth of cut of 1mm

Results as shown in Fig 6, indicate the influence of cutting speed on surface temperature of workpiece, it is observed that the temperature variations with speed indicate that temperature increased gradually with an increase in cutting speed. This result is due to a larger amount of material to be removed leading to increase frictional area between tool and workpiece, thereby the generated heat will increase with increase in speed (Moganapriya C. et al., 2018).

CONTRIBUTION TO KNOWLEDGE

This study has shown the viability of locally sourced vegetable oil as machining lubricants for medium carbon steel. Castor oil and moringa seed oil were studied experimentally in the turning operation of AISI 1040 steel under varying spindle speed, feed rate and depth of cut and compared with the dry cutting fluid. The properties of vegetable oils which enhance their performance in machining operations include the presence of fatty acids, surface active agents such as stearic acid and halogens such as chlorine, which help to reduce surface energy and increase its properties as lubricant.

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CONCLUSION

In this study the effect of various cutting parameter on surface roughness at different cutting environment, in turning AISI 1040 steel. Surface roughness was measured for all of the machined specimens and the effect of varying cutting speed and depth of cut on surface roughness and temperature was investigated. It has been seen from the results that workpiece surface temperature increases with increasing cutting speed and depth of cut while surface roughness decreases as cutting speed increases. In addition, castor and moringa cutting oil was found to have greater influence on surface roughness than dry cutting at varying cutting parameter. Considering the various cutting conditions in this experiment, it can be concluded that cutting speed, feed rate, and depth of cut have a significant influence on the temperature and surface finish of the workpiece.

CONFLICT OF INTEREST

There is no conflict of interest for this research work.

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