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EXPERIMENTAL INVESTIGATION OF TOOL WEAR AND SURFACE ROUGHNESS BY THE INFLUENCE OF VARIOUS CUTTING FLUIDS IN TURNING OPERATION

***Sakthi Vadivel K, Sivaraj C and Vigneshwaran K**

Department of Mechanical Engineering, Builders Engineering College, Nathakadaiyur, Tamil Nadu- 638108, India

ABSTRACT

The main objective of this work is to understand how the tool wear and surface roughness are influenced by various cutting fluids and machining parameters in turning EN8 SAE/AISI 1040 steel. Cutting fluids should be chosen by acidic nature test and viscosity test. It should have proper lubricity and act as a coolant. Vegetable oils like groundnut, coconut, and sunflower are considered to check their properties. Among these oils, groundnut and coconut oils were selected based on their properties. Experimental studies on the performances of both newly developed environmentally friendly vegetable-based cutting fluids (coconut oil and ground nut oil) and commercial cutting fluids in turning processes were reported. Performances of cutting fluids were compared with respect to surface roughness, cutting and feed forces and tool wear during longitudinal turning ofEN8 SAE/AISI 1040 steel. Experimental results were also compared with dry cutting conditions. Based on the results, the best-cutting fluid was selected.

Keywords: *Surface Roughness; Cutting Fluid; Groundnut oil; Coconut Oil; Turning Process*

1. Introduction

Lathe is the father of all machine tools. It is an essential machine tool, probably the most important one of all. The lathe was the first machine tool. The lathe is a particular machine tool in which the work is held and rotated against a suitable cutting tool to produce a surface of revolution in any material. Uses the cutting forces in a turning process of EN 8 steel to estimate the tool wear effect. The tool wear effect is obtained by monitoring the variation in the cutting forces. This study aims to develop an online monitoring system. Identifying one or more criteria to quantify and identify rapid tool wear efficiently can determine when to change the tool [1].

Experimental and analytic methods are still the main ways to investigate different cutting tool wear types. Numerous developments in numerical methods and simulations associated with the existence of more powerful computers make possible tool wear studies using FEM. The primary purpose of this work is to present a new approach to predicting tool wear progression during the cutting operation. In particular, an energy approach linking the tool wear volume with the energy dissipated by friction is used. In addition, the interaction between residual stresses induced by cutting and the variation of tool geometry due to wear's mechanisms is investigated. To carry out this study, the experimental measurements of the wear of the tool, particularly the lost volume during the cut are presented. Numerical simulation of orthogonal cutting operation using the commercial FEM code ABAQUS/Explicit is employed [2]. Tool wear will be analysed for all materials like natural fibre-reinforced composites metals, aluminium alloys, and steels [3, 4 &5].

Experimental studies on the performances of both new developed environmental friendly vegetable based cutting fluids (refined sunflower and canola oils), including different percentages of extreme pressure (EP) additive and two commercial cutting fluids (semi-synthetic and mineral cutting fluids) in turning processes, were reported in this work. Performances of cutting fluids were compared with respect to surface roughness, cutting and feed forces and tool wear during longitudinal turning of AISI 304L. Experimental results were also compared with dry cutting conditions. The results indicated that 8% of EP included canola based cutting fluid performed better than the rest [6]. Based on studies of the physical characteristics of wear processes, the conclusion could be drawn that the cutting distance must be considered not only in abrasive and adhesive processes but also in thermally activated diffusion and oxidation processes. Consequently, it can be proposed that a mathematical model of the rate of flank wear is an autonomous non-linear differential equation that considers the wear-accelerating effect of both the

**Corresponding Author - E- mail: ksakthivadivel@gmail.com*

technological parameters of cutting and the temperature developing on the tool flank can be applied. Furthermore, this model may be used to calculate the tool life and the Taylor formula related to any arbitrarily chosen failure criteria [7].

High-pressure coolant (HPC) delivery is an emerging technology that delivers a high-pressure fluid to the tool and machined material. The high fluid pressure allows a better penetration of the fluid into the tool–workpiece and tool–chip contact regions, thus providing a better cooling effect and decreasing tool wear through lubrication of the contact areas. The main objective of this work is to understand how the tool wear mechanisms are influenced by fluid pressure, flow rate and direction of application in finish turning of AISI 1045 steel using coated carbide tools. The main finding was that when cutting fluid was applied to the tool rake face, the adhesion between chip and tool was very strong, causing the removal of tool particles and large crater wear when the adhered chip material was removed from the tool by the chip flow [8]. Thermal analysis of the materials was measured for thermal stability [9, 10]. The increasing attention to the environmental and health impacts of industrial activities by governmental regulations and by the growing awareness level in the society is forcing industrialists to reduce the use of mineral oil-based metalworking fluids as cutting fluid. In this review, the applicability of vegetable oil-based metalworking fluids in the machining of ferrous metals has been undertaken. It has been reported in various literature that metalworking fluids, which are vegetable oil-based, could be an environmentally friendly mode of machining with similar performance obtained using mineral oil-based metalworking fluids [11,12 &13].

2. Experimentation

Experiments were carried out on a turning lathe. Using a tool holder, a high-speed steel turning tool was clamped in a lathe tool dynamometer. An EN8 steel workpiece of 100mm length was held in a three-jaw chuck for the experimentation. Tool height and tool overhang was set to the required level with the help of gauges. Initially, a rough turning pass was made to eliminate the run out of the workpiece.

2.1. Planning of Experiment

A scientific approach to planning experiments must be incorporated to experiment most effectively. Statistical design of experiment is the process of planning the experiments so that the appropriate data could be collected, which may be analyzed by statistical method resulting in valid conclusions. Planning of experiments was employed to fulfil the following requirements:

i. To get the data uniformity distributed over the whole range of controllable factors to be investigated.
ii. To reduce the total number of experiments
iii. To establish a relationship between different input variables and the output accurately in the selected range of investigation

2.2. Experimental Procedure

The experiments were made on the lathe using a bar turning process under both dry and wet conditions. The range of cutting conditions (cutting speed, feed, and depth of cut using various cutting fluids as a coolant) is required to measure the three force components F_x, F_y and F_z and surface roughness. A total of twelve experiments were carried out, all with the same basic configuration and the HSS tool were replaced after performing a single test. The feed is kept the same in all experiments.

Work material: The EN 8 steel was chosen for the present investigation with a diameter of 25mm and 100 mm in length. The composition of EN8 steel is presented in Table 1.

Table 1 Composition of EN8 Steel

Element	Comosition (%)
Carbon	0.36 – 0.44
Silicon	0.10 – 0.44
Managense	0.60 – 1.0
Sulphur	0.050

Tool material: The tool material used should be capable of high speed machining with both dry and wet cutting conditions. In present investigation HSS tool were used for performing the experiments.

2.3. Cutting Tool

The cutting tool used in the present work is as shown Figure 1.

Fig. 1 Cutting Tool

The geometric dimensions of the cutting tool used are Tool length: 45 mm, Tool width: 9.5 mm, and Nose radius: 0.4 mm

2.4. Coolants used

The coolants that are used for the turning process are

i. Groundnut oil
ii. Coconut oil
iii. Normal coolant

The machining operation is also done in dry condition (without coolant used).

2.5. Experimentation Methodology

The different experimental conditions used for the present study are presented in Table 2.

Table 2 Experimental Conditions

Tool Material	Work Piece Material	Condition
High Speed Steel	EN 8 Steel	Dry Condition
		Coconut Oil as a Coolant
		Groundnut Oil as a Coolant
		Normal Coolant

A lathe was used for the turning experiment. Figure 2 shows the schematic diagram of the machine and equipment setup. The dynamometer is mounted on a tool post with the help of a holder specially designed for this experimental work. Then the actual experiments were carried out with the different input cutting conditions and coolants for different experiments for constant feed rate. The experiments carried out are summarized as:

i. Experiment is carried out on lathe machine using Mild Steel as workpiece and commercial available HSS Tool of triangular shape.
ii. Machining is done by using various cutting fluids.
iii. Machining is done with different sets of cutting speed and depth of cut.
iv. Measuring the cutting forces with a dynamometer.
v. Measuring the Surface Roughness of the workpiece using handy surf.
vi. Measuring the viscosity of various coolants using a redwood viscometer.

Fig. 2 Machining Setup

The cutting force value (F_x, F_y, F_z) displayed in the lathe tool dynamometer while turning are shown. The observed values are in "kgf".

Surface roughness, often shortened to roughness, is a component of surface texture. The deviations quantify it in the direction of the normal vector of a real surface from its ideal form. The dynamometer used to measure the surface roughness values is shown in Figure 3.

Fig. 3 Dynamometer Setup

3. Results and Discussion

3.1. Viscosity Test Results

Viscosity is a property arising from collisions between neighbouring particles in a fluid that is moving at different velocities. When the fluid is forced through a tube, the particles which compose the fluid generally move more quickly near the tube's axis and more slowly near its walls. Therefore, some stress (such as a pressure difference between the two ends of the tube), is needed to overcome the friction between particle layers to keep the fluid moving. For the same velocity pattern, the stress required is proportional to the fluid's viscosity.

The variation of viscosity of coconut oil with respect to temperature before and after machining operation is shown in Figure 5.

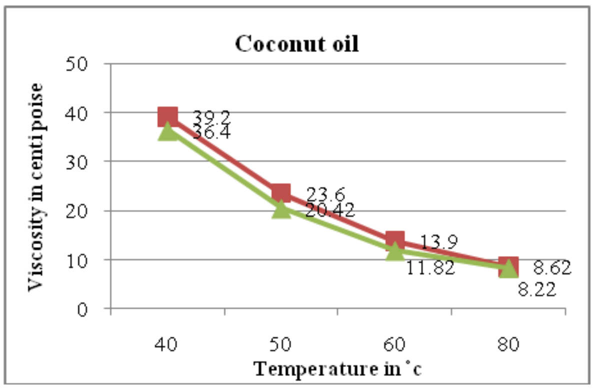

Fig. 5 Viscosity vs Temperature (Coconut Oil)

The variation of viscosity of Groundnut oil with respect to temperature before and after machining operation is shown in Figure 6.

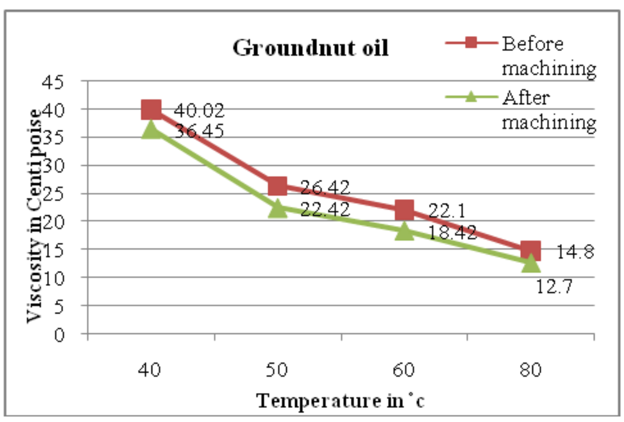

Fig. 6 Viscosity vs Temperature (Groundnut Oil)

The variation of viscosity of normal coolant with respect to temperature before and after machining operation is shown in Figure 7.

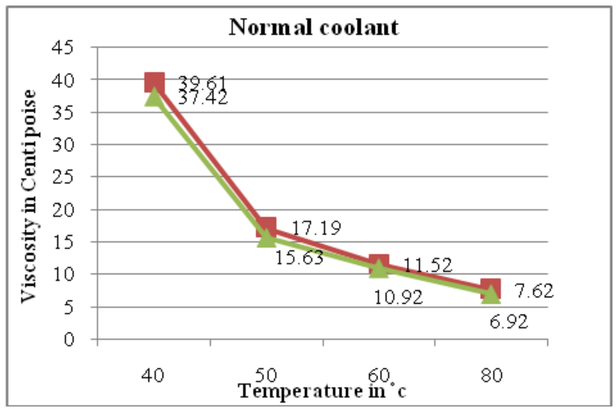

Fig. 7 Viscosity vs Temperature (Normal Coolant)

3.2. Cutting Force with Various Cutting Fluids

The cutting forces acting on the component (dry condition) in x, y, z directions are shown in Table 3.

Table 3 Cutting Force in Dry Condition

S. No	Speed (rpm)	Depth of Cut (mm)	Feed (mm/min)	Fx (Kgf)	Fy (Kgf)	Fz (KgF)	Surface Roughness (μm)
1	303	1	38.66	0.14	285	0.10	36
2	202	1	22.49	0.10	193	0.04	29
3	135	1	16.57	0.14	163	0.07	23

The cutting forces acting on the component (coconut oil) in x, y, z directions is shown in Table 4.

Table 4 Cutting Force with Coconut Oil

S. No	Speed (rpm)	Depth of Cut (mm)	Feed (mm/min)	Fx (Kgf)	Fy (Kgf)	Fz (Kgf)	Surface Roughness (μm)
1	303	1	38.66	0.14	182	0.10	18
2	202	1	22.49	0.10	166	0.09	10
3	135	1	16.57	0.14	155	0.07	12

The cutting forces acting on the component (Groundnut oil) in x, y, z directions is shown in Table 5.

Table 5 Cutting Force with Groundnut Oil

S. No	Speed (rpm)	Depth of Cut (mm)	Feed (mm/min)	Fx (Kgf)	Fy (Kgf)	Fz (Kgf)	Surface Roughness (µm)
1	303	1	38.66	0.23	259	0.13	16
2	202	1	22.49	0.10	230	0.09	6
3	135	1	16.57	0.14	235	0.07	8

The cutting forces acting on the component (normal coolant) in x, y, z directions is shown in Table 6.

Table 6 Cutting Force with Normal Coolant

Speed (rpm)	Depth of Cut (mm)	Feed (mm/min)	Fx (KgF)	Fy (KgF)	Fz (KgF)	Surface Roughness (µm)
303	1	38.66	0.16	238	0.19	8
202	1	22.49	0.17	246	0.09	19
135	1	16.57	0.14	247	0.08	12

3.3. Surface Roughness

The surface roughness of the workpiece can be calculated using the dial gauge. It has two scales; when the dial gauge sensor is pushed upwards, the dial's needle on the dial moves clockwise and when sensor is moved downwards away from the dial, the needle on the dial gauge moves in the anticlockwise direction.

The surface roughness variation with respect to various cutting fluids by varying the speeds is shown in Figures 8, 9, 10 &11.

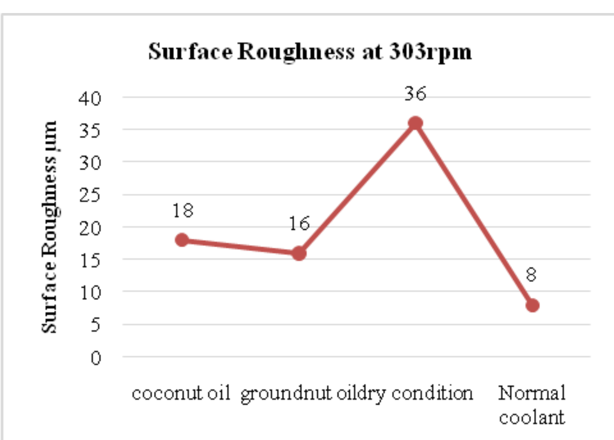

Fig. 8 Surface Roughness at 303 rpm

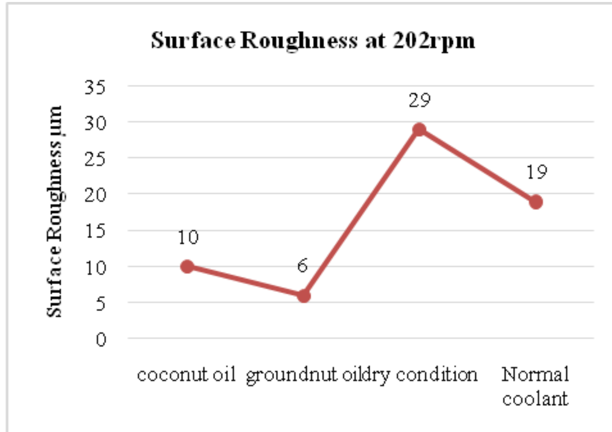

Fig. 9 Surface Roughness at 202 rpm

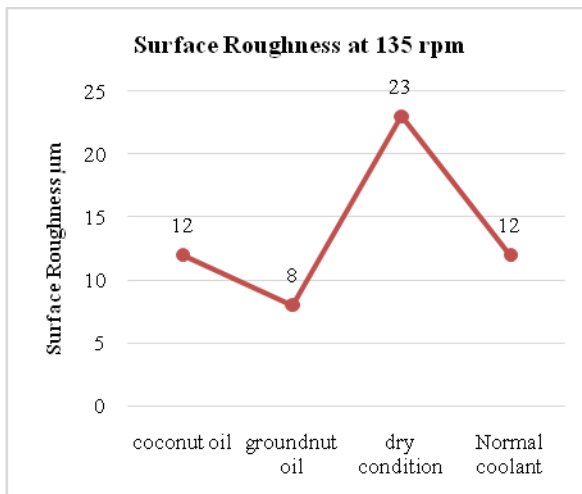

Fig. 10 Surface Roughness at 135 rpm

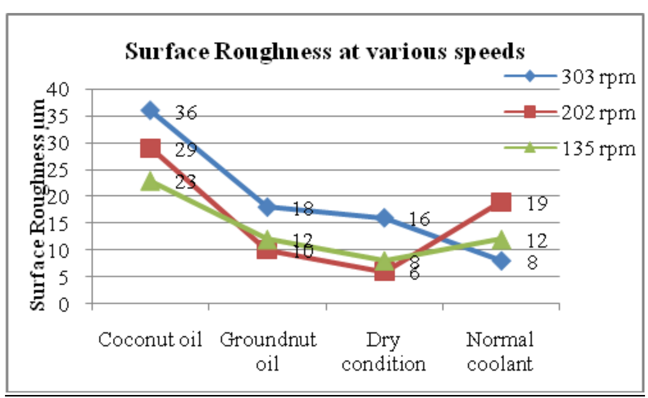

Fig. 11 Surface Roughness at Various Speeds

3.4. Tool Wear

In the proposed experiment, tool wear is measured by the loss of tool material in weight. Table 7 shows the tool wear by weight loss in various machining conditions like a change of coolant oil, speed, feed and constant depth of cut.

Table 7 Tool Wear By Weight Loss

S. No.	Tool Name	Cutting Fluids	Speed in rpm	Before Machining	After Machining
1	A1	Coconut Oil	303	38.292	38.257
2	A2		202	31.494	31.458
3	A3		135	30.186	30.160
4	B1	Ground nut Oil	303	37.067	37.036
5	B2		202	32.103	32.079
6	B3		135	33.569	33.542
7	C1	Dry Condition	135	32.344	32.317
8	C2		202	34.054	34.030
9	C3		303	30.134	30.115
10	D1	Normal Coolant	303	36.588	36.557
11	D2		202	35.381	35.361
12	D3		135	30.706	30.680

In order to check the validity of the results, various graphs are plotted between cutting speed and weight loss in grams.

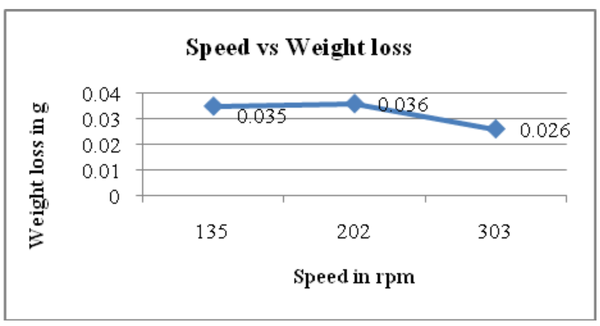

Fig. 12 Wear Analysis by the influence of Coconut Oil

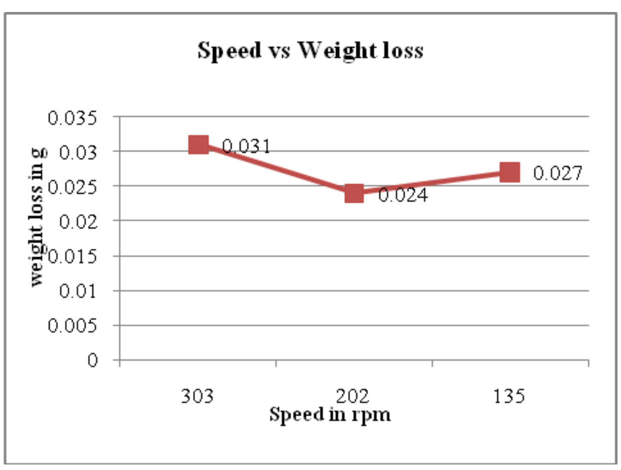

Fig. 13 Wear Analysis by the influence of Groundnut Oil

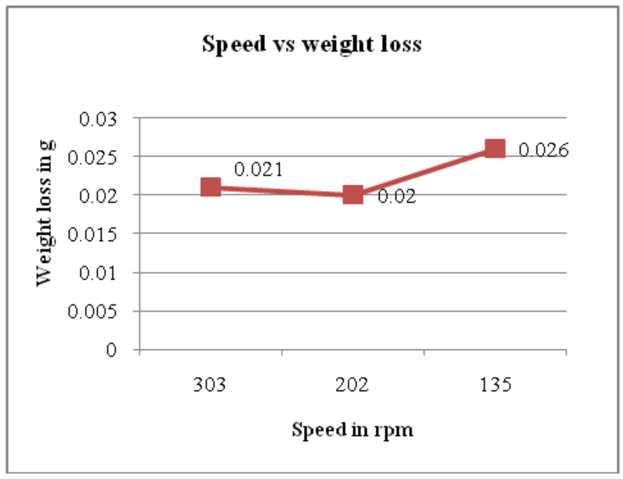

Fig. 14 Wear Analysis by Normal Coolant

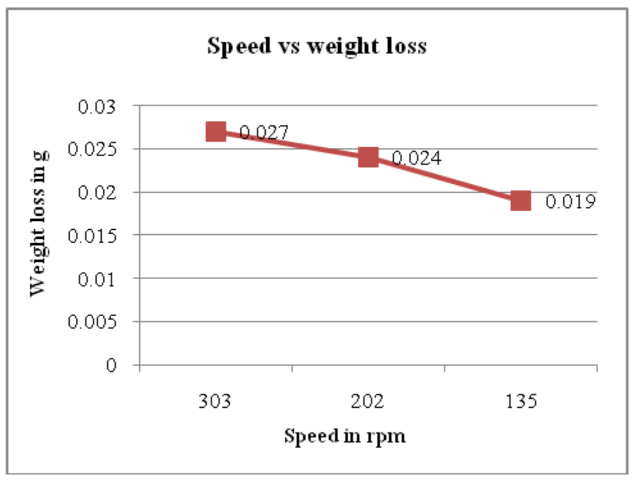

Fig. 15 Wear analysis by Dry Machining

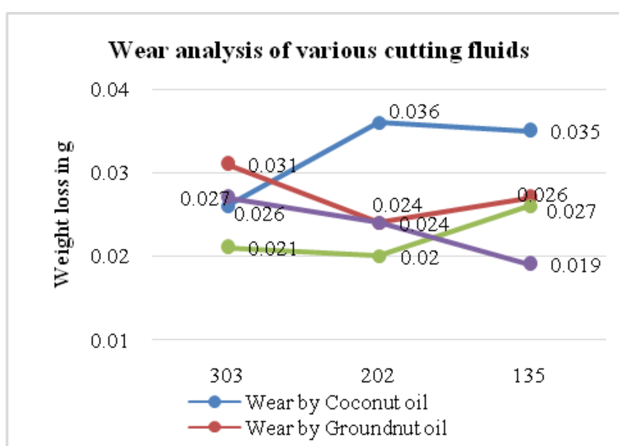

Fig. 16 Wear analysis of various cutting fluids

The graphs shown in the figures 12, 13, 14, 15 & 16 justify the best cutting speed and wear on the tool has been thoroughly understood for further analysis. Thus the tool wear is less at normal coolant and groundnut as well. The wear loss of 0.02g is the minimum, and 0.027g is the maximum in the dry condition. The wear loss of 0.024g is minimum, and 0.031 is maximum in groundnut oil.

4. Conclusions

Thus, the results concluded that the tool wear has significantly less value at the cutting speed of 202 rpm compared to the 303 rpm and 135 rpm. From the tool wear graph, we found that the groundnut oil has better results when compared to Normal coolant. Since Eco-friendly fluids are used, the operator had not found any difficulty while machining operation and disposing of the cutting fluids. The viscosity graph shows that eco-friendly cutting fluids have more viscosity than conventional cutting fluids. The reusability of cutting fluids has been increased, reducing the cost of cutting fluid. Especially Groundnut oil has high viscosity than other cutting fluids.

The best surface finish is obtained from the groundnut oil with an average surface finish value of 6 µm at the cutting speed of 202 rpm and 22.4 mm /min. The groundnut oil's surface roughness value is much less than the normal coolant in all cutting speeds, feeds, and depth of cuts. Therefore, groundnut oil is more efficient than other cutting fluids and can be implemented in industries.

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