Study of New Vegetable Oil Based Eco-Friendly Cutting Fluid for Machining Operation

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Abstract: ***The purpose of cutting fluids is to provide cooling and reduce the friction between tool and work piece at the shear zone. The work piece is first machined under dry condition. The air surrounding the work piece acts as the cooling agent. Since air has low thermal conductivity it acts as a poor coolant. In wet-machining, cutting work piece is machined by using conventional cutting fluid and veg-cutting fluids in which the basic constituents are taken from the nature. According to the studies 60% companies are spending 20% more amounts on their coolants/lubricants than on cutting tools. Five veg-cutting fluid is selected for Machining. The veg-cutting fluids are applied at a constant flow rate while performing turning operation of work piece under constant cutting conditions. The performance of cutting fluids is evaluated by measuring cutting temperature and surface roughness for each turn. The results are compared under Dry and conventional cutting fluid using Minitab17 and Excel 2010.***

Keywords: Vegetable oils, EN-8, CNC, Turning operation

1. Introduction

The machining processes have an important place in the traditional production industry. In metal cutting process, the condition of the cutting tools plays a significant role in achieving consistent quality and controlling the overall cost of manufacturing. According to the use of cutting fluid the machining process can be divided into Dry machining and Wet machining.

In the case of dry machining it is impossible for perfect machining due to the nature of the work piece materials. During machining, many nonferrous alloys, and especially Aluminum, tend to be adhered to tool edges, giving rise to complex problems like the wrong cutting of the work piece material and leading to a high tool wear. Wet machining application delivers fluid to the cutting tool/work piece interface by means of pipe, hose or nozzle system. Cutting fluids may also be atomized and blown onto the tool/work piece interface via mist application. A fluid's cooling and lubrication properties are critical in decreasing tool wear and extending tool life. Cutting fluids have been used widespread in all machining processes, The aims of cutting fluid applications were determined as cooling and lubrication in metal cutting. In addition, cutting fluids can help to disposal of the chips from hole and control chip formation. As cutting fluid is applied during machining operation, it removes heat by carrying it away from the cutting tool/work-piece interface. This cooling effect prevents the tool from exceeding its critical temperature range beyond which the tool softens and wears rapidly.

In this study vegetable oils is used as the cutting fluid and are compared with conventional oil and dry machining. Vegetable oils perform better than the other oils and the reasons are described as follows:

1) Vegetable oil has good lubricity properties.
2) Vegetable oil has a higher flash point, which reduce smoke formation and fire hazard. Higher flash point value allows using the cutting fluid in high temperature cutting conditions.
3) Vegetable oil molecules are quite homogenous in size but mineral oil molecules vary in size. Consequently, the properties of mineral oil such as viscosity, boiling temperature are more susceptible to variation.
4) Vegetable oil has higher boiling point and greater molecular weight and this result in less loss from vaporization and misting.

2. Literature Review

Kishor Kumar Gajrani *et.al* [1], Studied and focused on review of composition, physio-chemical properties, advantages, applications and practical use of individual vegetable oils as metal working fluid in environmental conscious machining to make the process environmental friendly and less toxic for operators. J.F.G. Oliveira *et.al* [2], Developed an environmental friendly fluid for CBN grinding. The intention was to develop a fluid based on water. The reaction of the grinding wheel with water was checked experimentally at two conditions at normal temperature and at 873K. Marius Winter *et.al* [3], have done a work in order to develop a new ecologically benign metal working fluid in grinding operation to substitute mineral oil based fluids. W.Belluco *et.al* [4], He analyzed the performance of six cutting fluids of which five of them are vegetable based cutting fluids. The tool lift, drilling force and chip tangling are taken as testing parameters. Aldo Braghini Junior *et.al* [5], Investigated the tool wear mechanism for an end milling operation of a precipitation hardened martensitic stainless steel under four different cooling and lubrication conditions.
Emil Kuram *et.al* [6], He used crude and refined sunflower based fluids during drilling. The performances of these cutting fluids are found out by measuring the thrust force and the surface roughness. Harikrishnan k *et.al* [7], the experimental study was carried out on a CNC lathe for turning operation of EN 19 Steel. Cutting speed, feed rate and type of cutting fluid are as selected as process parameters

by keeping constant depth of cut. Surface finish and tool work interface temperature were selected as responses. B.Ozcelik *et.al* [8], He conducted experiment on AISI304L stainless steel with different vegetable oil based cutting fluid at extreme pressure condition. The machining is carried out in a Turning Centre.

3. Experimental Approach

The main objectives of this work are the following:
1) To develop a new ecofriendly cutting fluid based on vegetable oil to replace the existing conventional oil based cutting fluid.
2) To compare between dry machining and wet machining, by measuring various output parameters during the machining at various condition and the experiments are to be conducted in order to find out the best cutting fluid from the selected vegetable oils.

In this work, EN-8 steel is used as the work piece material shown in Figure 1. EN-8 is medium carbon steel usually supplied untreated, EN-8 steel possesses good homogenous metallurgical structures giving consistent machining properties; EN-8 is a very popular grade and is readily machinable in any condition. Chemical composition of EN-8 is shown in Table 1. EN-8 is used in Engine shafts, gears, stressed pins, studs, bolts, keys, connecting rods etc.

Five vegetable oils are selected as cutting fluid for this work, they are: Canola oil, Sesame oil, Sunflower oil, Palm oil and Rice bran oil.

Figure 1: EN-8 steel

The cutting tools used are coated carbide inserts of grade H13A made by SANDVIK Coromant. The inserts used are of CNMG type. The selection of cutting tool is done according to the range of control factors (cutting speed, speed and depth of cut) and the hardness of the material being cut.

Table 1: Chemical composition of EN-8

Component	Percentage
C	0.36-0.44%
Si	0.10-0.40%
Mn	0.60-1%
S	.050 Max,
P	.050 Max

Computer Numeric Controlled (CNC) machines are replacing conventional machines due to their inherent advantages. High accuracy, flexibility, machining of complex components and reduced production time are the main advantages of CNC machines. In the present work the turning process is carried out on a two axis CNC machine. The different sets turning experiments are performed on a two axis CNC lathe. Figure 2 shows the CNC lathe on which the experiment is performed.

Figure 2: CNC lathe

An initial turning and facing is carried out to eliminate the irregularities present on the surface of the work piece prior to heat treatment. The holding length is set to 20mm. Turning length is selected as 20mm The CNC machine is checked for its lubrication level, coolant level, hydraulic/pneumatic systems etc.

Table 2: Combination of speed and feed selected

Trail No.	Speed (mm/min)	Feed (mm/rev)
1	100	0.10
2	100	0.15
3	100	0.20
4	200	0.10
5	200	0.15
6	200	0.20
7	300	0.10
8	300	0.15
9	300	0.20

Combination of feed and speed selected for the study is shown in Table 2, Each combination is machined in 7 cutting condition i.e., Dry condition, machining with conventional oil based cutting fluid, machining with veg-oil based cutting fluids such as Canola oil, Sesame oil, Sunflower oil, Palm oil and Rice bran oil.

The machining program for turning is entered according to the values provided in Table 2; the program entered is checked by a simulation run. The machining program is edited for each experimental run and the values of speed, feed and type of fluid. The depth of cut is fixed as 1mm. After editing, the program is simulated to find out any error in the program. If the simulation shows the correct pattern of operation, actual machining is carried out. Turning is carried out for a 20mm length which is just enough surface area to allow for cutting stabilization and subsequent surface roughness measurement. After machining the work piece is given to the inspection section of surface roughness. The tool-work piece interface temperature is measured using infrared thermometer.

4. Data Collection and Analysis

The machined work piece is inspected for surface roughness after every machining process. The machined surface was measured at three different positions and the average (Ra) values are taken using a Mitutoyo SURFTEST SJ-410 surface roughness meter shown in figure 3, which has diamond stylus tip with accuracy of 0.005µm and resolution of 0.05 µm and having a maximum measuring range of 300µm.

Figure 3: Roughness tester

During machining, the consumed power is largely converted into heat resulting high cutting temperature near the cutting edge of the tool. The amount of heat generated varies with the type of material being machined and machining parameters. The surface temperature or cutting temperature (CT) of the machined samples were measured by using infrared thermometer (make: HTC MTX-2) having temperature range of -30°C to 550°C and with optical resolution technique shown in figure 4.

Figure 4: Infrared thermometer

Table 3: Data collection of canola oil

Trail No.	Speed (rpm)	Feed (mm/rev)	CT (◦C)	Ra (µm)
1	100	0.1	37.5	1.335
2	100	0.15	38.7	2.5
3	100	0.2	50	2.765
4	200	0.1	38.6	1.655
5	200	0.15	41	2.353
6	200	0.2	50.5	2.078
7	300	0.1	46.2	1.223
8	300	0.15	43.3	1.715
9	300	0.2	50.6	2.992

Table 4: Data collection of sesame oil

Trail No.	Speed (rpm)	Feed (mm/rev)	CT (◦C)	Ra (µm)
1	100	0.1	36	0.849
2	100	0.15	37	0.912
3	100	0.2	37.5	1.256
4	200	0.1	38.4	1.233
5	200	0.15	41	1.054
6	200	0.2	40.5	2.232
7	300	0.1	38.2	0.808
8	300	0.15	42.2	1.6
9	300	0.2	47.2	2.065

Table 5: Data collection of sunflower oil

Trail No.	Speed (rpm)	Feed (mm/rev)	CT (◦C)	Ra (µm)
1	100	0.1	33.9	0.534
2	100	0.15	34.2	0.655
3	100	0.2	35.5	1.203
4	200	0.1	37.5	0.674
5	200	0.15	40	0.732
6	200	0.2	41.5	1.222
7	300	0.1	36.8	0.785
8	300	0.15	43	0.999
9	300	0.2	45	0.95

Table 6: Data collection of palm oil

Trail No.	Speed (rpm)	Feed (mm/rev)	CT (◦C)	Ra (µm)
1	100	0.1	38.5	1.421
2	100	0.15	39.6	1.643
3	100	0.2	43	2.252
4	200	0.1	44.4	2.043
5	200	0.15	46	2.2
6	200	0.2	47.5	2.9
7	300	0.1	41	1.98
8	300	0.15	52.3	2.045
9	300	0.2	57.1	2.423

Table 7: Data collection of rice bran oil

Trail No.	Speed (rpm)	Feed (mm/rev)	CT (◦C)	Ra (µm)
1	100	0.1	35	1.711
2	100	0.15	36	1.789
3	100	0.2	38	1.967
4	200	0.1	40	1.023
5	200	0.15	52	1.055
6	200	0.2	54	1.666
7	300	0.1	44.8	1.454
8	300	0.15	47.5	1.987
9	300	0.2	53.3	2.099

Table 8: Data collection of conventional oil

Trail No.	Speed (rpm)	Feed (mm/rev)	CT (◦C)	Ra (µm)
1	100	0.1	38	1.656
2	100	0.15	39	1.886
3	100	0.2	41	2.501
4	200	0.1	38.8	2.099
5	200	0.15	41	2.033
6	200	0.2	59	2.501
7	300	0.1	44	2.508
8	300	0.15	53	2.691
9	300	0.2	54	2.832

Table 9: Data collection of dry machining

Trail No.	Speed (rpm)	Feed (mm/rev)	CT (◦C)	Ra (µm)
1	100	0.1	49.4	3.004
2	100	0.15	52.2	3.212
3	100	0.2	52.8	3.232
4	200	0.1	52.2	3.311
5	200	0.15	53.1	3.612
6	200	0.2	54.1	3.734
7	300	0.1	54.2	2.953
8	300	0.15	55.9	3.203
9	300	0.2	57.6	3.508

Table 3, shows the data collection of canola oil, where we can see that surface roughness (Ra) and interface temperature (CT) increases with increase in feed and speed. Table 4 and 5 shows the data collection of sesame oil and sunflower oil, which also shows the increase in Ra and CT.

Table 6, 7 and 8 shows the data collection of palm oil, rice bran oil and conventional oil respectively. Data collected from dry machining in Table 9 shows highest value of Ra and CT. In Table 5, sunflower oil shows least Ra and CT value.

5. Results and Discussions

The data from experimental study is analyzed and the following graphs were plotted using Minitab17 and Excel 2010.

- Comparison of Ra with respect to speed
- Comparison of Ra with respect to feed
- Comparison of temperature with respect to speed
- Comparison of temperature with respect to feed

5.1 Comparison of Ra with respect to speed

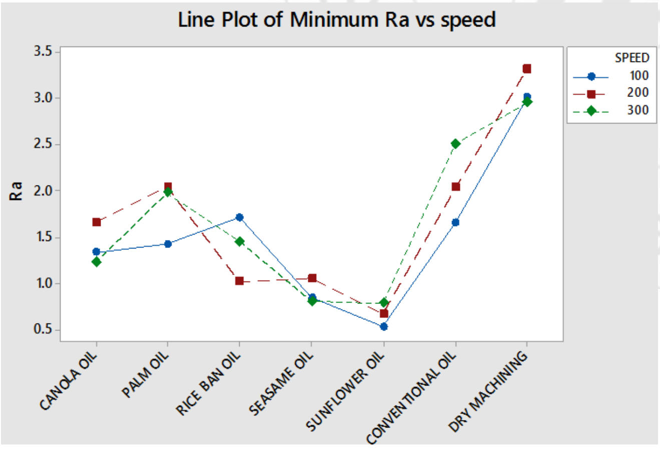

Figure 5: Comparison of Ra w.r.t speed.

Figure 5, shows the comparison result of collected data of five vegetable oils, conventional oil and dry machining with respect to speed. In figure 5, dry machining and conventional oil has highest surface roughness (Ra) value. Canola oil, palm oil, rice bran oil and sesame oil shows medium Ra value but sunflower oil shows the least surface roughness (Ra) value.

5.2 Comparison of Ra with respect to Feed

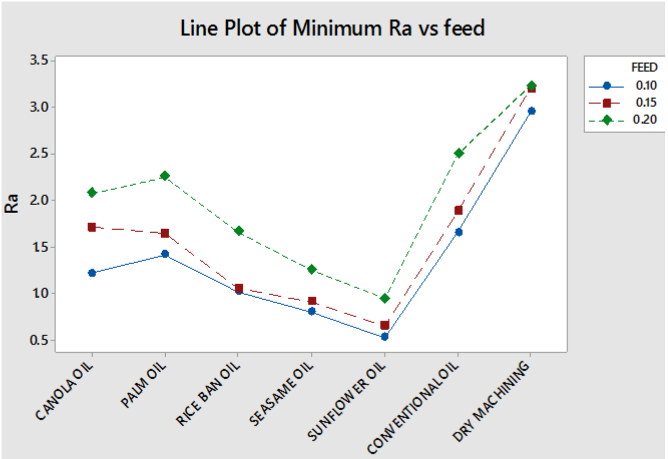

Figure 6: Comparison of Ra w.r.t feed

Figure 6, shows the comparison result of collected data of five vegetable oils, conventional oil and dry machining with respect to feed. In figure 6, dry machining and conventional oil has highest surface roughness (Ra) value. Canola oil, palm oil, rice bran oil and sesame oil shows medium Ra value but sunflower oil shows the least surface roughness (Ra) value.

5.3 Comparison of Temp. with respect to Speed

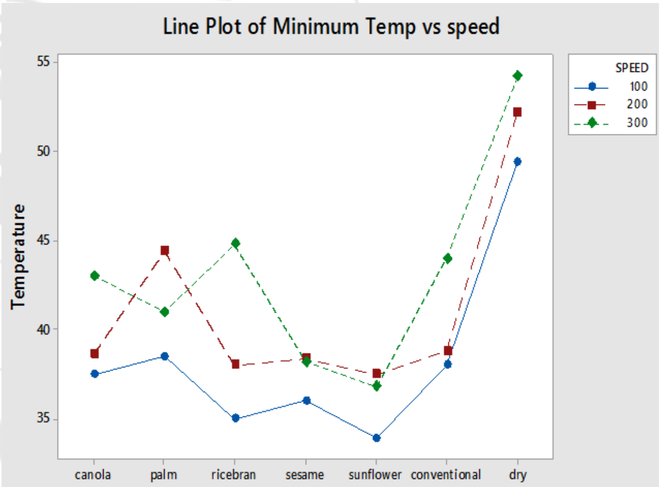

Figure 7: Comparison of temp. w.r.t speed

Figure 7, shows the comparison result of collected data of five vegetable oils, conventional oil and dry machining with respect to speed. In figure 7, dry machining and conventional oil has highest interface temperature. Canola oil, palm oil, rice bran oil and sesame oil shows medium interface temperature (CT) but sunflower oil shows the least interface temperature (CT).

5.4 Comparison of Temp. with respect to Feed

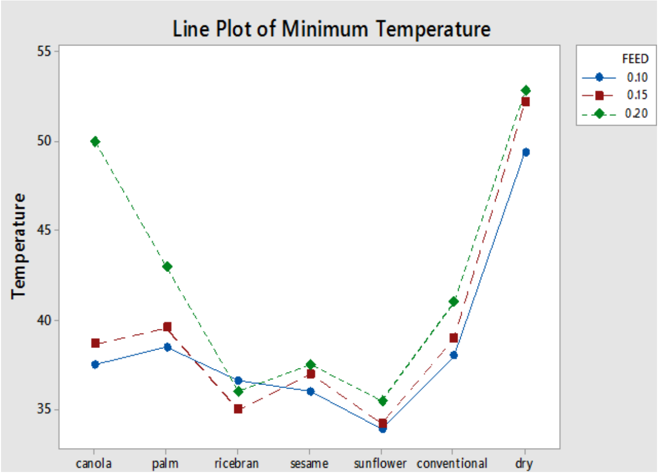

Figure 8: Comparison of temp. w.r.t feed

Figure 8, shows the comparison result of collected data of five vegetable oils, conventional oil and dry machining with respect to feed. In figure 7, dry machining; canola oil and palm oil have highest interface temperature (CT). Conventional oil, rice bran oil and sesame oil shows medium interface temperature (CT) but sunflower oil shows the least interface temperature or cutting temperature (CT).

Primary importance is for surface finish and then for reducing the temperature at tool work interface. A cutting fluid is used by considering these two factors.

Some of the main observations of this work are the following:

- From this study Sunflower oil is the best, considering the two factors i.e. Surface finish and then for reducing the temperature at tool work interface.
- Figure 5 and 6, comparison plot shows sunflower oil has lowest Ra value with respect to speed and feed.
- Figure 7 and 8, comparison plot shows sunflower oil has lowest interface temperature with respect to speed and feed.
- In almost all cutting condition sunflower oil worked superior to dry machining, conventional oil and other veg-cutting fluid in both aspects.

During machining more importance is given for obtaining required surface finish and minimizing the surface temperature in order to reduce the tool wear. Cutting fluids are used in order to improve the surface finish and to reduce the tool wear. Considering these conditions the cutting fluid should help to improve the surface finish and should reduce the temperature at tool work interface. From this study the new and best Veg-oil based cutting fluid is sunflower oil. Sunflower oil shown better performance both in case of improving surface finish as well reduces the temperature at tool wok interface. In almost all condition this fluid performed superior to conventional oil based cutting fluid and other veg-based cutting fluids.

6. Conclusion

The experimental study was carried out on a CNC lathe for turning operation of EN-8 Steel. Cutting speed, feed rate and type of cutting fluid are as selected as process parameters by keeping constant depth of cut. Surface finish and tool work interface temperature were selected as responses. Sixty three experiments were carried out to collect the data for study and required graph were plotted using Minitab17 software and EXCEL 2010, Five veg-oil based cutting fluid were studied and the properties of fluid were compared with each other. The main findings of the work are:

- Experimental study shows that the veg-oil based sunflower oil can perform better than any other fluid.
- The sunflower and sesame oil gave better surface finish than any other veg-oil based cutting fluid.
- The sunflower and sesame oil showed lesser value of temperature at tool work interface.
- The Sunflower oil based cutting fluid can be utilized as a suitable and possible alternative for mineral oil based cutting fluid considering the environmental issues and wastage accumulation.
- So it is evident that conventional oil based cutting fluid can be replaced with veg-oil based cutting fluid.

6.1 Future Scope

- The performance of Veg-oil may change according to the change in work piece and machining process so the work can be extended for different work piece materials and machining processes, which will add to the scope of work in future.
- More number of output responses like cutting force, tool wear and tool life can be considered for study.

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