Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 8; April-June, 2015 pp. 87-91

http://www.krishisanskriti.org/jmsme.html

Vegetable Oil Based Cutting Fluids–Green and Sustainable Machining - II

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Abstract—*"Vegetable Oil Based Cutting Fluids – Green and Sustainable Machining – I" mainly emphasis on evaluation of Surface Roughness of turned Aluminium (AA1050) workpiece using Vegetable Oils (Edible oil/Neat category i.e. Sunflower and Coconut oil) and Mineral oil (Water soluble emulsion 20:1)in which vegetable oil performed well in comparison with conventional oil. A comparative study of turning experiments, between VBCFs and MBCFs, neat or straight Soyabean oil (Edible Category) and Castor oil (Non Edible Category), was conducted using the same machining parameter. Vegetable oils used on the principle of Minimum Quantity Lubrication (MQL) that is oil dropped between the cutting tool and workpiece interface directly. The results shown in this paper indicates that Vegetable oils especially non edible have potential to replace the mineral oils.*

Keywords: *Aluminium AA1050, Vegetable oil Based Cutting Fluids (VBCFs), Mineral oil Based Cutting Fluid (MBCFs), Minimum Quantity Lubrication (MQL), Surface roughness (Ra).*

1. INTRODUCTION

In the recent years, the researchers focused on the use of Vegetable oil Based Cutting Fluids (VBCFs) as a potential alternative for the Mineral oil Based Cutting Fluids (MBCFs). VBCFs came in the trend because MBCFs has some major disadvantages and harmful effect on the both workers as well as environment.

The major negative effect with mineral, synthetic and semi-synthetic CFs is linked with surface water and groundwater contamination, air pollution, soil contamination, and agricultural product and food contaminations. They cause serious health problems such as lung cancer, respiratory disease, dermatological and genetic disease [1].

To overcome these effects, vegetable oils are highly attractive substitutes for petroleum-based oils. MQL (Minimum Quantity Lubrication) minimize the use of cutting fluids because in MQL cutting fluid dropped on the point of contact of tool and surface with a flow rate of 50-500ml\hr [2].

In past few years, on different machining operations (like turning, milling, drilling, grinding) under different machining parameters, such as, spindle speed, depth of cut, feed rate etc. are used to evaluate the surface finish with different vegetable oils, such as, soyabean, sunflower, coconut, palm, cottonseed, canola, sesame, neem, castor, jatropha, rapeseed oil etc. vegetable oils used as an emulsified type i.e. water in oil and some additives.

Here are few examples in which it is proved that vegetable oils could be a potential replacement of mineral oil CFs in the turning operation. Sunflower oil and canola oil were used for turning of AISI 304L [3]. Sulfonate castor oil, crude soyabean oil and refined sunflower oil were used for turning [4]. Sunflower oil and rapeseed oil were used for turning of SS316L [5]. Mustard oil was applied while performing turning on a lathe machine [6]. During the turning of AISI 4340 steel, palm kernel and cottonseed oil were used [7]. Palm oil was applied during the turning of ductile cast iron FCD 700 [8]. Coconut oil gave better surface finish at higher speed during hard turning.

In the above given examples, the results of surface finish obtained shows that the performance of vegetable oil was better than the conventional oil. Because of this reason, my research focused on the evaluation of comparative study between the surface finish obtained from neat vegetable oil and conventional oil under same machining parameters.

2. MATERIALS AND METHODOLOGY

In this experimental study, machining process was conducted using a SIEMENS MTAB FLEXTURN CNC turning machine maximum speed of 4000 rpm and 415V AC drive motor. The workpiece material used was Aluminium alloy (AA1050) cylindrical rod. This study included 39 pieces of cylindrical aluminium specimens with a 60 mm length and 30 mm diameter.

Table 1: Chemical Composition of AA1050 (Wt %)

Mn	Fe	Cu	Mg
0.05	0.40	0.05	0.05
Si	Zn	Ti	Al
0.25	0.07	0.05	99.08

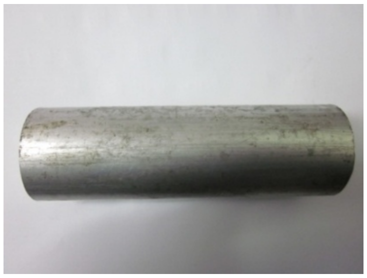


Fig. 1: Aluminium Specimen

The cutting tool inserts used were tungsten carbide single point cutting tool. The machining experimental setup is shown in Fig. 1.

Fig. 2: Schematic experimental turning setup

Machining performance was assessed based on the surface roughness of the machined surfaces. Surface roughness was chosen as output parameters for evaluation using the two vegetable oil-based cutting fluids and mineral oil-based cutting fluids. VBCFs, was used as minimum quantity lubrication (MQL) i.e. at tool-workpiece interface. An overhead system was used to drop the vegetable oil-based cutting fluids between the tool-workpiece interfaces.

The mineral oil-based cutting fluid was applied using conventional (flood) method. The mineral oil-based cutting fluids, water to oil ratio of 20:1. The new cutting fluid i.e. VBCFs (Soyabean and Castor) used neat and straight with their inherent properties. Soyabean oil from the edible oil category and Castor oil is from non edible oil category.

Table 2: Physico-Chemical Properties of Vegetable oils and Mineral oil

Properties	Soyabean	Castor	Mineral(WS)
Kinematic viscosity at 40°C	32.93	220.6	29.55
Kinematic viscosity at 100°C	08.08	19.72	5.38
Viscosity index	219	220	116
Flash point (0°C)	240	252	150
Pour point (0°C)	-09.00	-27.00	-09.00

The surface roughness of the workpiece was measured at three different points along the length of the cut bar using stylus type surface roughness tester MITUTOYO (SURFTEST SJ - 210) Fig. 2. During the turning operations, all cutting experiments were stopped after every 35 mm machining length, in order to measure surface roughness (Ra).

Fig. 3: Surf Test (MITUTOYO SJ-210)

Some Specification of surface roughness tester are: Working Principle is Root Mean Square value, Measuring Force – 4mN, Stylus Profile – Tip Radius: 5µm, Tip Angle: 90^0, Testing Range – 360^0µm (-200µm to +160µm).

Types of cutting fluid, spindle speed, depth of cut and feed rate are considered as longitudinal turning parameters. The range of turning parameters are selected as recommended from the machine manufacturer. Three sets of cutting parameters were employed during the machining process.

The work pieces machined with varying spindle speed i.e. 1200-2000 rpm, with varying feed rate of 110-150 mm/min and depth of cut between 0.1-0.5 mm. The process of turning has been done in the following three cases:

- Varying Spindle Speed while keeping the Depth of Cut and Feed Rate constant.
- Varying Feed Rate and keeping the Spindle Speed and Depth of Cut constant.
- Varying Depth of Cut while keeping the Spindle Speed and Feed Rate constant.

3. RESULTS AND DISCUSSIONS

In order to evaluate the machining process performance, surface roughness were compared under various cutting conditions to conventional oil and vegetable oil-based cutting fluids. In an effort to specify performances of CFs, root mean square value of the surface roughness for each CFs was analyzed. In most of the cutting conditions, values of surface roughness obtained from the vegetable oil based cutting fluid machined samples are better, equivalent or nearer to the results obtained from the samples machined by conventional cutting oil.

Various chips produced in turning: (a) tightly curled chip; (b) chip hits workpiece and breaks; (c) continuous chips moving away from the workpiece; (d) chip hits tool shank and breaks off; and (e) discontinuous chips.

A. All the results are described in the below given tables (3-5) (Soyabean oil/Edible oil).

Table 3: "Ra" Values for Varying Spindle Speed

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1200	0.2	120	0.82
2.	1400	0.2	120	0.60
3.	1600	0.2	120	0.48
4.	1800	0.2	120	0.54
5.	2000	0.2	120	0.57

Table 4: "Ra" Values for Varying Depth of Cut

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1600	0.1	120	0.85
2.	1600	0.2	120	0.48
3.	1600	0.3	120	0.78
4.	1600	0.4	120	0.78
5.	1600	0.5	120	0.81

Table 5: "Ra" Values for Varying Feed Rate

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1600	0.2	110	0.71
2.	1600	0.2	120	0.48
3.	1600	0.2	130	0.60
4.	1600	0.2	140	0.74
5.	1600	0.2	150	0.87

B. All the results are described in the below given tables (6-8) (Castor oil/Non Edible oil).

Table 6: "Ra" Values for Varying Spindle Speed

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1200	0.2	120	0.77
2.	1400	0.2	120	0.51
3.	1600	0.2	120	0.41
4.	1800	0.2	120	0.43
5.	2000	0.2	120	0.45

Table 7: "Ra" Values for Varying Depth of Cut

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1600	0.1	120	0.54
2.	1600	0.2	120	0.41
3.	1600	0.3	120	0.58
4.	1600	0.4	120	0.50
5.	1600	0.5	120	0.55

Table 8: "Ra" Values for Varying Feed Rate

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1600	0.2	110	0.47
2.	1600	0.2	120	0.41
3.	1600	0.2	130	0.54
4.	1600	0.2	140	0.65
5.	1600	0.2	150	0.78

C. All the results are described in the below given tables (9-11) (Mineral oil/Water Soluble).

Table 9: "Ra" Values for Varying Spindle Speed

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1200	0.2	120	0.45
2.	1400	0.2	120	0.58
3.	1600	0.2	120	0.45
4.	1800	0.2	120	0.44
5.	2000	0.2	120	0.52

Table 10: "Ra" Values for Varying Depth of Cut

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1600	0.1	120	0.42
2.	1600	0.2	120	0.45
3.	1600	0.3	120	0.49
4.	1600	0.4	120	0.59
5.	1600	0.5	120	0.58

Table 11: "Ra" Values for Varying Feed Rate

S. No.	Spindle Speed (N) (Rev./min)	Depth of Cut (d) (mm)	Feed Rate (V) (mm/min)	Ra Value (µm)
1.	1600	0.2	110	0.41
2.	1600	0.2	120	0.45

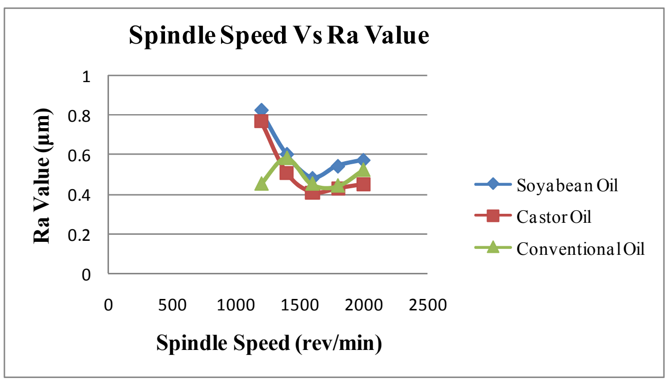
3.	1600	0.2	130	0.54
4.	1600	0.2	140	0.62
5.	1600	0.2	150	0.65

3.1 Comparison of Surface Roughness (Ra) values

- "Ra" values in Green color are better or equivalent than the Red colored values.
- "Ra" values in Blue color are nearer to the Red colored values. Differences between the values are 0.02µm-0.08µm.
- Castor oil gave maximum values i.e. 9/15 better than the Conventional oil.
- In VBCFs, Maximum better or nearest "Ra" value with respect to Conventional has achieved by Castor oil (Non Edible oil).
- The best VBCFs machining performance of Aluminium achieved by Castor oil at spindle speed = 1600 rpm, depth of cut = 0.2 mm, and feed rate = 120 mm/min i.e. 0.41µm.

Table 12: "Ra" Values for Varying Spindle Speed

S. No.	Conditions N-d-V	Soyabean Ra (µm)	Castor Ra (µm)	Mineral Ra (µm)
1.	1200-0.2-120	0.82	0.77	0.45
2.	1400-0.2-120	0.60	0.51	0.58
3.	1600-0.2-120	0.48	0.41	0.45
4.	1800-0.2-120	0.54	0.43	0.44
5.	2000-0.2-120	0.57	0.45	0.52

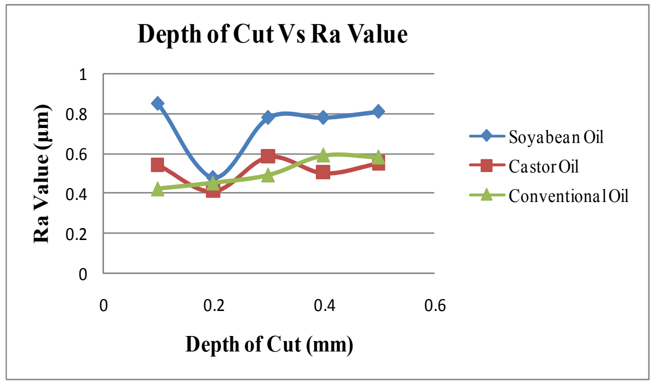


Graph 1: Comparison of Spindle Speed Vs Ra Value

In Graph 1; at lower spindle speed, surface finish is low but surface finish increasing with the increase of spindle speed. Maximum values lying between the 0.4µm to 0.6µm.

Table 13:"Ra" Values for Varying Depth of Cut

S. No.	Conditions N-d-V	Soyabean Ra (µm)	Castor Ra (µm)	Mineral Ra (µm)
1.	1600-0.1-120	0.85	0.54	0.42
2.	1600-0.2-120	0.48	0.41	0.45
3.	1600-0.3-120	0.78	0.58	0.49
4.	1600-0.4-120	0.78	0.50	0.59
5.	1600-0.5-120	0.81	0.55	0.58

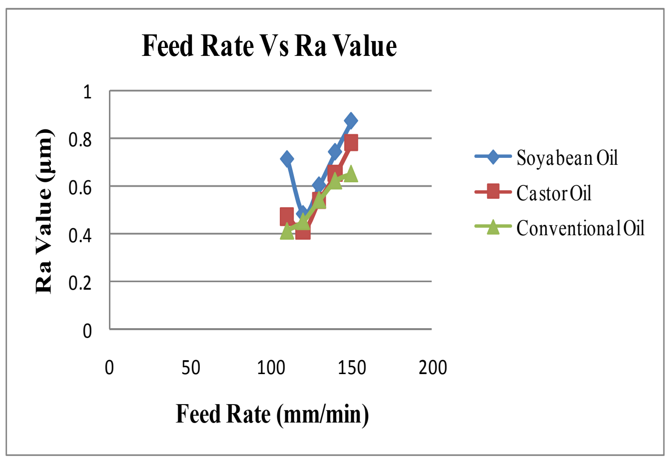


Graph 2: Comparison of Depth of Cut Vs Ra Value

In Graph 2; surface finish of soyabean is far away from the castor and conventional. Castor and conventional are almost same values between the 0.4µm to 0.6µm. Best value achieved by castor oil i.e. 0.41µm at (N=1600rpm, d=0.2mm and V=120mm/min).

Table 14: "Ra" Values for Varying Feed Rate

S. No.	Conditions N-d-V	Soyabean Ra (µm)	Castor Ra (µm)	Mineral Ra (µm)
1.	1600-0.2-110	0.71	0.47	0.41
2.	1600-0.2-120	0.48	0.41	0.45
3.	1600-0.2-130	0.60	0.54	0.54
4.	1600-0.2-140	0.74	0.65	0.62
5.	1600-0.2-150	0.87	0.78	0.65



Graph 3: Comparison of Feed Rate Vs Ra Value

In Graph 3; at low feed rate surface finish was good, but with the increase of feed rate surface finish is decreasing continuously. Surface roughness value varying between 0.4µm to 0.8µm. Best value achieved by conventional oil i.e. 0.41µm at (N=1600rpm, d=0.2mm and V=110mm/min).

4. CONCLUSIONS

In VBCFs, Maximum better or nearest "Ra" value with respect to Conventional has achieved by Castor oil (non edible oil). So we can say that from the above results those vegetable oil based cutting fluids which are non edible may be a better alternative for the replacement of Conventional oil in turning operations.

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