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Evaluation of Surface Finish of Aluminium using Non-edible Vegetable Oils as Cutting Fluid on CNC Milling

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Abstract—*Nowadays cutting fluids are extensively used to boost the quality of metal cutting and machining productivity. At the same time the increasing rate of their usage creates an enormous threat to environment and health of workers dealing with this on daily basis. Therefore, a need is developed to discover harmless and eco-friendly substitutes to conventional mineral oil based cutting fluids. Vegetables oil has established itself as a feasible source of environment friendly metal cutting fluid due to its combined property of biodegradability, renewability, and outstanding lubrication performance. In this journal, the performances of Neem oil, Karanja oil are compared with that of mineral oil-based cutting fluid during machining operation of Aluminium. Using these vegetable oil based cutting fluids under different spindle speed (rev/min), feed rate (mm/min) and depth of cut (mm), surface roughness (Ra) value has been compared with that of mineral oil based cutting fluid. The results of surface roughness obtained during milling of Aluminium with different cutting fluids indicates that the surface roughness of the work pieces using vegetable oil as cutting fluid is having close propinquity with mineral oil.*

Keywords: *Metal Cutting Fluids (MCFs), Vegetable Based Cutting Fluids (VBCFs), Material Removal Rate (MRR), Computer Numeric Control (CNC), Revolution per Minute (RPM)*

1. INTRODUCTION

In different metal cutting processes many cutting fluids are used mainly, straight oils, soluble oils, and synthetic and semi synthetic oils. Bio-based cutting fluids have the possibility to reduce the waste treatment costs because of their intrinsically higher biodegradability and may decrease the industrial health risks related with petroleum-oil-based cutting fluids as they comprise lower toxicity *[1, 2]*. As a result a healthier and cleaner work environment may be achieved, with less smog in the air *[3]*. For this profound reason cutting fluids ensued from vegetable oils are environmental friendly and have a good lubricating ability as compared to others *[4]*. The extensive use of conventional cutting fluids coincides with the industrial revolution in the late eighteenth century *[5]*. In 1868, W.H. Northcott observed that the use of cutting fluids enhanced tool life. In 1883, Taylor used water in machining and observed that cutting speeds could be increased by 30—40 % by using water *[6, 7]*. The focus of all machining operations is to attain lower machining costs by enhancing quality and productivity. If we consider mineral oil as chemical product, the lubricant industry is accountable for around 8.5% increase every year of the worldwide chemical production by weight. They are omnipresent in the machine tool industry, with estimates of consumption in North America exceeding two billion gallons in 2000 *[8]*. Though metal cutting fluids have their own advantages in the machining industry but the waste generated after machining is a major environmental concern for manufacturers as it is very difficult to purify it before waste disposal *[9, 10]*. Experimental study shows that as a source of feasible and renewable source of nontoxic oils, VBCFs are serving a great purpose as a replacement of MCFs *[11]*. The necessity for renewable and biodegradable lubricants became stronger considering environmental pollution and rising rules and regulations over contaminations and labor safety. In the year 2002, US market estimated an average annual hike of 7-10% of environmentally safe lubricants for the upcoming years whereas the requirement was only 2% earlier to this *[12]*. Studies say that approximately 38 million metric tons of lubricants were utilized globally in the year 2005 with a chance of enhanced use of 1.2% over the next year *[13]*. Because of their advantage on production process, the uses of MCFs are increasing drastically in industries. From different surveys it has been found that European Union alone consumes 320000 tons of MCFs per year out of which two third has to be discarded annually. In spite of their extensive use, they create major health and environmental hazards during their life cycle *[14]*. In this paper, an attempt has been made to compare the surface roughness and MRR using conventional and vegetable oil based cutting fluid in CNC milling machine.

2. MATERIAL AND METHODOLOGY

The materials and equipment used in this work incorporated Aluminum alloy specimens with Neem oil, Karanja oil, MTAB CNC Milling Machine of maximum speed of 4000 rpm, Surface Roughness Tester and Vernier Caliper.

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

Machining performance was evaluated based on the surface roughness (Ra, Rz) of the machined surfaces. Surface roughness was preferred as output parameters for evaluation using the two VBCFs and mineral oil-based cutting fluids.

Oils of Neem, Karanja were purchased which are free from dirt particles or contamination. Oils contain all the desired properties which we required and appropriate for the research work. The essential physio-Chemical properties of various vegetable oils which will be use in the experiment are presented in the table 2 given below.

TABLE 2: Chemical Properties of Various Cutting Fluids

Properties	Neem	Karanja	Conventional
Flashpoint (°C)	214	180	150
Viscosity at 40°C	20.5-48.5	4.85	29.55
Specific gravity	0.9137	0.878	0.875

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 (Neem-*Azadirachta indica* and Karanja-*Millettia pinnata)* used neat and straight with their original properties. Both oils are from non-edible category.

The surface roughness of the work piece was measured at three different points along the length of the cut bar using stylus type surface roughness tester.

Fig. 2: Surf Test (MITUTOYO SJ-210)

During the milling operations, all cutting experiments were stopped after every 35 mm machining length, in order to measure surface roughness (Ra).

Some Specification of surface roughness tester are: Working Principle is Root Mean Square value, Measuring Force – 4mN, Stylus Profile – Tip Radius: 5μm, Tip Angle: 900, Testing Range – 3600μm (-200μm to +160μm). Types of cutting fluid, spindle speed, depth of cut and feed rate are considered as milling parameters. The range of milling 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. 1500-3000 rpm, with varying feed of 22-40 mm/min and depth of cut between 0.6-1.5 mm.

3. EXPERIMENTAL PROCEDURE

The experimental procedure is carried out in the following six steps:

STEP 1: The raw material (work piece) is fixed on the work table to begin with the pilot run.

STEP 2: The program is started according to the required result parameters i.e. feed rate, depth of cut, spindle speed.

STEP 3: The material removal will be done with different combination of process parameters.

STEP 4: The machined components are tested for surface roughness by using Surface roughness tester. After that the "Ra" and "Rz" values will be calculated as the output parameter.

STEP 5: Using ANOVA multiple regression analysis will be done on the input and output parameters of the pilot run.

STEP 6: Repeat step 4 and make the final table in order to compare the values of output parameters obtained from different cutting condition and cutting fluids.

4. RESULT & DISCUSSION

In order to evaluate the machining process performances, surface roughness were compared under various cutting conditions to conventional oil and vegetable oil-based cutting fluids. During the machining operation different combinations of cutting parameters are used in turning. These parameters are: a) spindle speed; b) depth of cut; and c) feed rate.

In this section, two non-edible vegetable oils i.e. Neem oil, Karanja oil and one conventional oil i.e. water soluble (ratio of oil and water is 1:20 respectively) are used as cutting fluids on CNC Milling Machine to evaluate the surface roughness of aluminium at various cutting conditions.

The work piece machined with spindle speed between 1500-3000 rpm, feed rate between 22-40 mm/min and depth of cut between 0.6-1.5 mm.

In most of the conditions , values of surface roughness obtained from the non-edible vegetable oil based cutting fluid machined samples are better , equivalent or nearer to the result obtained from the samples machined by conventional cutting oil. All the results are described in the table given below. The Units of Speed, feed and depth of cut are RPM, mm/min and mm respectively.

TABLE 3: (Pilot Run)

MRR AND ROUGHNESS VALUES (RA, RZ) FOR CONVENTIONAL OIL

S.N	Speed	Feed	Doc	MRR	Ra(µm)	Rz(µm)
1	3000	40	1.5	.026	2.016	8.395
2	2700	37	1.4	.018	1.784	8.557
3	2500	36	1.3	.015	1.070	5.515
4	2400	34	1.2	.013	1.001	5.277
5	2100	32	1.1	.024	1.245	5.796
6	2000	30	1	.023	0.946	5.225
7	1800	28	0.9	.008	0.650	3.339
8	1700	26	0.8	.008	0.726	4.321
9	1600	24	0.7	.006	0.582	3.347
10	1500	22	0.6	.004	0.476	2.830

TABLE 4: (Pilot Run)
MRR AND ROUGHNESS VALUES (RA , RZ) FOR NEEM OIL

S.N.	Speed	Feed	Doc	MRR	Ra(µm)	Rz(µm)
1	3000	40	1.5	.024	2.266	9.104
2	2700	37	1.4	.023	1.579	7.484
3	2500	36	1.3	.012	1.191	7.368
4	2400	34	1.2	.017	0.955	5.101
5	2100	32	1.1	.012	0.957	4.875
6	2000	30	1	.010	0.925	4.220
7	1800	28	0.9	.015	1.471	9.572
8	1700	26	0.8	.0008	1.481	7.691
9	1600	24	0.7	.014	1.275	6.919
10	1500	22	0.6	.006	0.901	5.420

TABLE 5: (Pilot Run)
MRR and Roughness Values (RA, RZ) For Karanja Oil

S.N.	Speed	Feed	Doc	MRR	Ra(µm)	Rz(µm)
1	3000	40	1.5	.014	1.116	6.151
2	2700	37	1.4	.015	1.787	8.615
3	2500	36	1.3	.013	1.848	9.49
4	2400	34	1.2	.015	1.592	8.352
5	2100	32	1.1	.004	1.883	8.976
6	2000	30	1	.003	2.767	14.749
7	1800	28	0.9	.010	1.946	9.800
8	1700	26	0.8	.006	1.903	9.967
9	1600	24	0.7	.005	1.820	8.836

After successful completion of the pilot run, final experimentation has been done using multiple regression analysis by ANOVA (Minitab version). Based on the obtained optimal process parameters range final experimentation has been done on the aluminium specimen. The experimental results of final run are mentioned below.

TABLE 6:
MRR AND ROUGHNESS VALUES (RA, RZ) FOR CONVENTIONAL OIL

S.N.	Speed	Feed	Doc	MRR	Ra(µm)	Rz(µm)
1	1500	32	1.1	.0161	1.059	5.382
2	3000	32	0.6	.0544	1.027	5.388
3	2100	22	1.1	.0101	1.316	6.847
4	1500	22	0.6	.0052	1.010	6.836
5	2100	40	0.6	.0029	1.041	5.480
6	2100	32	1.5	.0103	0.801	4.494
7	3000	40	1.1	.0134	1.841	4.390
8	1500	40	1.5	.0250	1.067	5.359
9	3000	22	1.5	.0109	1.692	5.735

TABLE 7: MRR AND ROUGHNESS VALUES (RA, RZ) FOR NEEM OIL

S.N.	Speed	Feed	Doc	MRR	*Ra(µm)*	*Rz(µm)*
1	1500	32	1.1	.0052	1.088	12.574
2	3000	32	0.6	.0056	1.047	5.661
3	2100	22	1.1	.0076	1.004	5.937
4	1500	22	0.6	.0038	1.041	5.480
5	2100	40	0.6	.0039	.993	5.864
6	2100	32	1.5	.0108	1.011	5.719
7	3000	40	1.1	.0116	0.841	5.234
8	1500	40	1.5	.0165	1.094	6.083
9	3000	22	1.5	.0102	1.072	7.672

TABLE 8: MRR AND ROUGHNESS VALUES (RA, RZ) FOR KARANJA OIL

S.N.	Speed	Feed	Doc	MRR	*Ra(µm)*	*Rz(µm)*
1	1500	32	1.1	.0123	0.901	4.873
2	3000	32	0.6	.0066	.876	5.079
3	2100	22	1.1	.0073	.849	4.664
4	1500	22	0.6	.0033	1.134	6.358
5	2100	40	0.6	.0092	0.957	5.825
6	2100	32	1.5	.0117	1.095	5.294
7	3000	40	1.1	.0165	0.844	6.716
8	1500	40	1.5	.0226	1.229	6.813
9	3000	22	1.5	.0129	1.056	5.330

TABLE 9: COMPARATIVE STUDY OF THE SURFACE ROUGHNESS 'RA' VALUES

S.No	Conditions (N-V-d)	Neem oil Ra (µm)	Karanja oil-Ra (µm)	Conventional oil -Ra (µm)
1	1500-32-1.1	1.088	**0.901**	1.059
2	3000-32-0.6	1.047	**0.876**	1.027
3	2100-22-1.1	1.004	**0.849**	1.316
4	1500-22-0.6	1.041	**1.001**	1.010
5	2100-40-0.6	0.993	**0.957**	1.041
6	2100-32-1.5	1.011	1.095	**0.801**
7	3000-40-1.1	**0.841**	0.844	1.841
8	1500-40-1.5	1.094	**1.050**	1.067
9	3000-22-1.5	1.072	**1.056**	1.692
Average Ra value		**1.021**	**0.959**	**1.206**

Comparative Study of the Surface Roughness 'Ra' values in various conditions,

- "Ra" values in bold digits shows the best Ra value for different combinations.
- After close observation it has been found that the Ra value of work pieces using Karanja oil as cutting fluid gives minimum Ra values as compared to other cutting fluids.
- Karanja oil gave optimum values of Ra in seven out of nine readings. The Conventional oil and Neem oil showed almost similar values.
- The average "Ra" value considering all possible combinations of speed, feed and depth of cut shows that the oil with minimum surface roughness is Karanja oil followed by conventional and Neem.
- So, better or nearest "Ra" value with respect to conventional cutting fluid has achieved by Karanja oil.

TABLE 10: Comparative Study of the Surface Roughness 'Rz' Values

S.No	Conditions (N-V-d)	Neem oil Ra (µm)	Karanja oil Ra (µm)	Conventional oil Ra (µm)
1	1500-32-1.1	12.574	**4.873**	5.382
2	3000-32-0.6	5.361	**5.079**	5.388
3	2100-22-1.1	5.937	**4.664**	6.847
4	1500-22-0.6	**5.480**	6.358	6.836
5	2100-40-0.6	5.864	**5.325**	5.480
6	2100-32-1.5	5.719	**4.294**	4.494
7	3000-40-1.1	5.234	6.716	**4.390**
8	1500-40-1.5	6.083	6.813	**5.359**
9	3000-22-1.5	7.672	**5.330**	5.735
Average Rz value		**6.658**	**5.495**	**5.546**

Comparative Study of the Surface Roughness 'Rz' values in various conditions

- "Rz" values in bold digits shows the best Rz value for different combinations.
- The Rz value for Karanja oil shows outstanding results as compared to conventional cutting fluid. Six out of nine values of Karanja Oil is best compared to other values of Neem and Conventional cutting fluid.

- The average "Rz" value taking into account all possible combinations of speed, feed and depth of cut shows that, the oil securing minimum surface roughness is Karanja oil followed by conventional and Neem.

5. CONCLUSION

A comparative experimental study of the machining performance of Non Edible vegetable oil based Cutting Fluids and conventional oil (water soluble) in milling operation of aluminium was performed with Respect to surface roughness.

According to the comparative analysis, the following conclusions may be drawn-

- Non edible Vegetable oils has potential as cutting fluid which may be better alternative for the replacement of conventional oil in turning operation in the near future.
- Experimental research shows that Karanja oil (a vegetable oil based cutting fluid which is Non edible) may be a better alternative for the substitute of conventional oil in milling operation with its inherent properties.

It is concluded that NEEM OIL, KARANJA OIL seem to possess the required properties as a potential cutting fluid.

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