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APPLICATION AND DETERMINATION OF THE EFFECTS OF VEGETABLE OIL-BASED CUTTING FLUIDS IN THE MACHINING PROCESSES- A REVIEW

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Abstract :

Machining is an essential part of the manufacturing and production process. Manufacturers and producers are trying to put maximum effort to optimize all machining parameters and to make the machining process environment-friendly. Cutting fluids play an important role in the process of machining by reducing the production time, cost, and energy. The use of cutting fluids reduces heat generation, tool wear, surface roughness of machined workpiece. Since most of the oil-based and petroleum-based cutting fluids harm the environment and health effects on operators, so now industrial processes are using vegetable oil-based cutting fluids as an alternative. In this research, at first, the importance of cutting fluids during cutting has been presented, then the performance of vegetable oil-based cutting fluids used during the machining processes are discussed. Finally, some issues related to the use of vegetable oil-based cutting fluids are illustrated followed by suggestions for the future work and conclusions. Results reveal that the use of vegetable-based cutting fluids is beneficial in machining.

Keywords: Machining, Vegetable oil-based cutting fluids (VOCFs).

1.Introduction

During the machining process, friction between the work piece-cutting tool and cutting tool-chip interfaces causes high temperature on the cutting tool. The effect of this generated heat decreases tool life, increases surface roughness and decreases the dimensional sensitiveness of work material. A lot of heat is generated while machining material which is difficult to cut.

In order to protect the cutting tool from the generated heat either coated cutting tools or cutting fluids are used. Cutting fluids prevent tool wear by reducing friction at the work-tool interface, preventing heat generation and removal of wear particles [1]. Eg. cutting fluids - water, air, oil-water emulsions, mineral oil, vegetable-based oils, etc.

Consumption of cutting fluids as lubricants are gaining popularity because it not only contributes to increasing productivity but also helps in improving the quality of manufacturing operations [2]. Earlier most of the cutting fluids were mineral oil-based. Though cutting fluids are advantageous in machining, they also have negative effects. They cause environmental pollution and also have negative effects on workers' health. Around 80-85 % of workers have skin-related diseases while working with cutting fluids [3-7].

To overcome these negative effects, researches have been made to use biodegradable cutting fluids. This opened the opportunity to use VOCFs as they are biodegradable and environment friendly [1,8]

2.Some research works with the application of VOCFs in machining

From the work of Harikrishnan[9], during turning operation of EN-19 steel on lathe machine, machining with coconut oil-based cutting fluid with 20% and 30% oil concentration had a better surface finish than mineral oil-based cutting fluid. Desired properties like viscosity, pH value of coconut oil at different concentrations were calculated experimentally. The outcome of the experiment was cutting fluid with 10% and 20% oil concentration showed a lesser value of temperature at tool work interface. Overall machining with cutting fluid with 20% oil concentration performed well as compared to other varieties. They concluded that reduction in surface roughness and tool wear was combined effects of both viscosity and thermal conductivity. The viscosity increases with an increase in oil content in emulsion thereby increasing the lubrication but thermal conductivity is decreased. Thermal conductivity is enhanced with the increase of water content in an emulsion.

Sujan Debnath et.al. [10] investigated the cutting fluids and cooling techniques in machining which could be environment friendly. They concluded that machining with VOCFs is environmentally friendly and could reduce the ecological and health problems caused by conventional cutting fluids and application methods.

Xavior and Adithan[11] experimentally performed turning of AISI 304 austenitic stainless steel with carbide tool using three different types of cutting fluids (coconut oil, emulsion, and a neat cutting oil-immiscible with water). Critical input parameters were cutting speed, depth of cut, feed rate, and types of cutting fluids. The results indicated that coconut oil performed better than the other two cutting fluids in reducing the tool wear and improving the surface finish.

Table 1. Source: Xavior and Adithan[11]

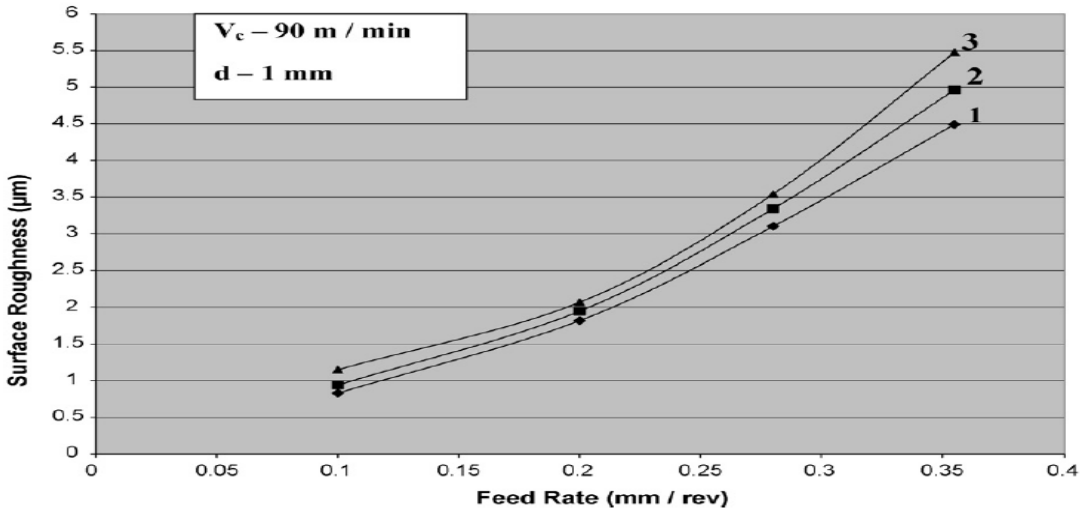

Fig. – Feed rate vs. surface roughness. (1) Coconut oil, (2) soluble oil and (3) straight cutting oil.

Critical parameters and their levels

S. no.	Machining parameter	Unit	Level 1	Level 2	Level 3
1	Cutting speed, V_c	m/min	38.95	61.35	97.38
2	Depth of cut, *d*	mm	0.5	1.0	1.2
3	Feed rate, *f*	mm/rev	0.2	0.25	0.28
4	Type of cutting fluid, D	–	Coconut oil	Soluble oil	Straight cutting oil

Fig1. Source: Xavior and Adithan[11]

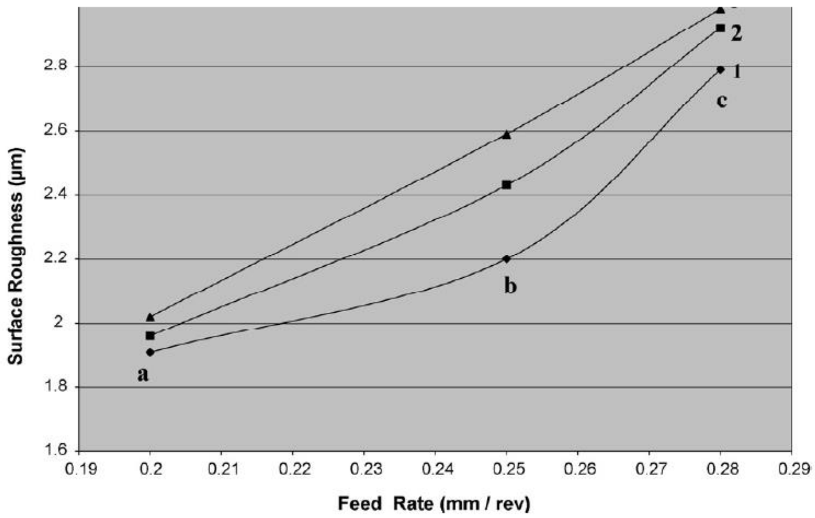

Fig. – Feed rate vs. surface roughness. (1) Coconut oil, (2) soluble oil, (3) straight cutting oil; depth of cut (*d*): 0.5 mm [constant]; cutting speed (V_c): 38.95 m/min, 61.35 m/min and 97.38 m/min at the three points a, b and c, respectively.

Fig 2.Source: Xavior and Adithan[11]

Ojolo et al. (2008)[12], investigated the effect of some vegetable oils (coconut oil, palm kernel oil, groundnut oil, and shear butter oil) on cutting force during cylindrical turning of mild steel, copper, and aluminum using tungsten carbide tool. Machining parameters were spindle speeds of 250, 330, 450, and 550 rpm, constant feed rate of 0.15 mm/rev, and 2 mm depth of cut. The results indicated that bio-oils were suitable for metalworking fluids, but the effects of the bio-oils on cutting force were material-dependent. The highest reduction in cutting force was exhibited by Groundnut oil when aluminum was turned at a speed of 8.25 m/min and feeds of 0.10, 0.15, and 0.20 mm/rev, respectively. Palm kernel oil had the best result for turning copper at feed lower than 0.15 mm/rev. But at higher feeds, groundnut oil had the best result for copper. Cutting force was highest in coconut oil followed by shear butter oil. They concluded that groundnut and palm kernel oils performed well in reducing cutting force during the cylindrical turning of the workpieces.

Lawal et al. [13] performed turning of AISI 4340 steel with coated carbide tools and investigated the effect of vegetable and mineral oil-in-water emulsion cutting fluids. The turning process was performed on a center lathe rated with 7.5 kW and a spindle speed of 3250 rpm. was chosen to maintain order to ensure the required stiffness of chuck/workpiece/cutting force was ensured by maintaining a ratio of cylindrical turning length to the initial diameter of the workpiece at four by choosing a round bar of AISI 4340 steel alloy with 90 mm diameter and 360 mm length. Design of experiment using the full factorial method was used in the process of cutting fluid formulation. The response parameters were surface roughness and cutting force in turning AISI 4340 steel with coated carbide using the Taguchi method. Taguchi method with four factors and three levels experimental design (L27) was adopted. Minitab-14 statistical analysis software was used in the analysis of the S/N (dB) ratio and ANOVA. ANOVA results depicted that cutting speed (64.64%) and feed rate (32.19%) have a significant influence on the surface roughness and depth of cut (33.1%) and type of cutting fluids (51.1%) have significant influence on the cutting force.

Table 2. Source : Lawal et al. [13]

Process parameters and their levels.

Factor	Unit	Level 1	Level 2	Level 3
Cutting speed	m/min	160	200	250
Feed rate	mm/rev	0.18	0.24	0.32
Depth of cut	mm	1.0	1.75	3.0
Type of cutting fluids	mm^2/s	2.97(PKO)	1.04(CSO)	0.87(MO)

PKO (palm kernel oil), CSO (cottonseed oil) and MO (mineral oil) based cutting fluids.

Table 3.Anova analysis for surface roughness. Source : Lawal et al. [13]

Factor	DF	SS	MS	F	P
Cutting speed (m/min)	2	14.026	0.779222	53.53435	0.644636
Feed (mm/rev)	2	7.004	0.389111	26.73282	0.321905
DOC (mm)	2	0.067	0.003722	0.255725	0.003079
Type of cutting fluid (mm^2/s)	2	0.399	0.022167	1.522901	0.018338
Error	18	0.262	0.014556		0.012042
Total	26	21.758			

In order to achieve proper cooling and lubricate ability of fluids, various research works have been conducted in the recent years, some of which are summarised in Table 4.

Table 4. Summary of some of the research works showing application of VOCFs in machining processes.

Machining process	Workpiece material	Tool material	Type of cutting fluids	Investigation	Author(s)
Turning	*AISI 304 steel*	*Carbide*	Coconut oil, emulsion and neat cutting oil immiscible in water	Tool wear and surface roughness	Xavior and Adithan [11]
Turning	Mild steel, aluminum and copper	Tungsten carbide	Groundnut, coconut, palm kernel and shear butter oils	Cutting force	Ojolo et al. [12]
Turning	AISI 4340 steel	Coated carbide	Palm kernel and cottonseed oilin-water emulsions and mineral oil emulsion	Cutting force and surface roughness	Lawal et al. [13]
Turning	Mild steel, brass and aluminum	HSS	Palm kernel oil	Cutting force	Ojolo and Ohunakin [14]
Turning	AISI 1040 steel	Cemented carbide	SAE – 40 and coconut oil	Temperature,flank wear and surface roughness	Krishna et al. [15]
Turning	AISI 9310 steel	Uncoated carbide	Vegetable oil (type not specified)	Temperature, chip formation, tool wear and surface roughness	Khan et al. [16]
Drilling	AISI 316L steel	HSS tool	Rape seed oil and mineral oil	Tool life, cutting force and chip formation	Belluco and De Chiffre [17]
Drilling	Titanium alloys	Ti-6Al-4 V Carbide coated with AlTiN	Palm kernel oil and synthetic ester	Thrust force, torque and temperature	Rahim and Sasahara [18]
Drilling	AISI 304 steel	HSS-E	Sunflower oil and mineral oil	Surface roughness and thrust force	Kuram et al. [19]
Milling	AISI 304 steel	HM90 APKT, 100304PDR IC908	Canola oil and sunflower oil	Tool wear and cutting force	Kuram et al. [20]
Milling	AISI 420 steel	Carbide-TiAIN and AIT	Palm kernel oil	Cutting force, tool life and surface roughness	Sharif et al. [21]
Grinding	100Cr6 steel	CBN	Mineral oil, rape seed oil, palm kernel oil, animal oil and cooking oil	Workpiece roughness, ecological and cost assessment	Hermmann et al. [22]

3.Difficulties related to the application of VOCFs

Physical and chemical properties(like viscosity, relative density, thermal conductivity, etc) of vegetable oil are to be checked. Oil is generally insoluble in water. To obtain a stable emulsion, surfactant and additives are to be used. There are some cases where the application of vegetable-based or mineral-based cutting fluids may harm the process. Machining with ceramic tools is an example of such a case because here application of cutting fluid may promote thermal shock causing the breakage of the tool. Hence dry machining is recommended in such cases.

4.Suggestions for the Future Work

The following works are suggested to be carried out in future.

1.Similar studies can be made for types of vegetable oil according to the physical and chemical properties of the oil.

2.The studies can also be performed by varying the machining parameters and responses.

3.Similar studies can be performed by varying the workpiece material and using different grades of metal alloys.

4.Similar studies can be performed by varying the mechanical properties of the work material and applying to the different heat-treatment process.

5.Similar studies can be made by inclusion of nano particles in the vegetable oil and varying the type and size of the nano particle.

6.Similar studies can be made by varying the type of tool and tool specification used for machines.

7.Similar studies can be made by varying the oil-water ratio.

8.Similar studies can be made by varying the type of additives and surfactants used.

5.Conclusion

Present analysis helps us to draw the following conclusions :

1)VOCF is an environmental and user-friendly fluid because it is biodegradable and due to which it has the ability to replace non-biodegradable and toxic cutting fluids.

2)The VOCFs have the ability the reduce the interface temperature and offer competitive performance with that of conventional soluble oil.

3)The tool wear was reduced and tool life was increased with the use of VOCFs.

4)Surface roughness can be reduced under certain machining parameters with the use of VOCFs.

5)Cutting forces required are low while machining with VOCFs as compared to the conventional soluble oils.

6)Oil and water ratio has a significant influence on machining parameters.

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