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EFFECT OF VEGETABLE OILS AS LUBRICATING/COOLING MEDIUM DURING MACHINING PROCESSES ON SURFACE ROUGHNESS

Ibrahem R. A.[1,4], Ali A. S.[2], Shewakh W. M.[3,4]

[1]Engineering college, Beni-Suef University, EGYPT,
[2]Mechanical Engineering Dept., Faculty of Engineering, Suez Canal University, EGYPT
[3]Industrial Education college, Beni-Suef University, EGYPT,
[4]Engineering college, Jizan University, KSA.

ABSTRACT
Using of natural oils in machining process for lubrication/cooling purposes represents an increasing trend nowadays because of their good properties from the environmental point of view, thermal and oxidative stability in comparison with conventional cutting fluids. All of mineral oils have harmful effect on human beings, for that; environmental issues during machining have led to looking for safe and efficient cutting fluids. The objective of this work is to investigate the effect of vegetable oils based emulsion (VOBE) on the surface roughness during turning process of aluminum 6061 alloy in comparison with traditional cutting fluids mineral oils based emulsion (MOBE), that known commercially as (ecool mk-3). Corn, olive and coconut oils were proposed as vegetable oils based emulsion for lubrication/cooling during turning process under different conditions of cutting speed and feed as well as the concentration of oil in lubricating emulsion. Digital Surface Roughness Tester (TR-Y-SRT-6210S) was used for surface roughness (Ra) measurements of the machined aluminum bars. The results show good performance for vegetable based emulsion oils in turning process as lubricant medium compared to dry cutting or using traditional lubricants based on mineral oils. Coconut oil based emulsion shows significant effect on reduction of surface roughness of machined parts as well as good healthy impact.

KEYWORDS
Vegetable oils based emulsion (VOBE), Mineral oils based emulsion (MOBE), Cutting fluids, and Surface roughness.

INTRODUCTION
Machining processes occupy a wide range sector in manufacturing of most components for various industrial products. Turning, milling and drilling operations are the common examples of producing machined parts like; gears, shafts, holes, pockets and so on. Lubrication or cooling process during machining operations represents high impact on the final product properties as well as cutting tool life and consumed power required to perform cutting process. Fine surfaces and low frictional behavior are the first and prime thinking in modern manufacturing process. After the cutting operation, smoother surface represents high priority request for machined parts. The surface finish profile of a

machined workpiece affected by cutting conditions (parameters) like, tool geometry, workpiece material, cooling fluids and other factors. Cooling or lubricating fluids indicate significant effective parameter on chip removal, tool wear, generated temperature as well as surface roughness of machined parts. Lubrications display an important role during the machining process. Improper lubricant will affect the tool life and workpiece quality, [1 - 3]. Conventional cooling fluids generally based on mineral oils that lead to several hazardous effect on the operator's health, during metal working operations, workers are subjected to extra values of mineral oil Aerosol intake which should not exceeds certain amount for the exposure limit, [4 - 7]. Vegetable oils proposed for several industrial applications as an effective alternative for mineral oils; it used as lubricants, additives for some lubricants to enhance its properties, added to solid lubricants, and a lot of other applications.

It was concluded that vegetable oils indicated significant effect on the frictional and wear behavior of polymer composites that were proposed as solid lubricants, [8 - 10]. Oils and oils based emulsion display the most cooling/lubricant medium for machining process. Mineral oils and their emulsions are used in large scale of machining operations but; unfortunately, it causes/contributes in several kinds of diseases for the operators in direct contact with its emissions; for that and other reasons natural/vegetable oils based-emulsions strongly studied for cooling/ lubricant purposes during machining operation. In spite of adding nanoparticles for mineral oils.

It was concluded that various types of mineral oils have their own ill effects on the human health, [11]. Vegetable-based emulsion as good replacer for petroleum -based emulsions in metal working industry was proposed, [12]. It was reported that vegetable oil can be used as a lubricant medium in the turning operation as an effective alternative to other cooling/lubricant liquids for environmental and health aspects, [13]. Vegetable oils have good lubricating ability and have been used to form an emulsion for machining operations.

Vegetable oil-based emulsions were also a part of recent research to produce stable emulsions to use as metalworking fluids and in other applications. Rapeseed oil as good alternative for conventional cutting fluids based on its lubricating capacity compared to that obtained for a usual mineral oil was presented. It was indicated that there is significant effect of vegetable oils on surface integrity and part accuracy in reaming and tapping operations with AISI 316L stainless steel.

Cutting fluid was found to have a significant effect on surface integrity and thickness of the strain hardened layer in the sub-surface, as well as part accuracy. Cutting fluids based on vegetable oils showed better performance than mineral oils. It was concluded that conventional cutting fluid might be replaced with castor oil based-emulsion as it gives better performance for tool life and cutting force, [14 - 18].

The present study investigates the effect of three types of vegetable oils- based emulsion; corn, olive and coconut oil based- emulsion on the surface roughness of aluminum 6061 alloy during turning operation comparing with traditional cutting fluid - synthetic oils-based emulsion- using minimum quantity lubrication technique, as well as the effect of other cutting parameters like cutting speed or feed rates. The present work investigates the influence of vegetable oils based emulsion (VOBE) as cooling medium on the surface roughness after turning process of aluminum 6061 alloy.

EXPERIMENTAL

Materials and Experimental Conditions

Four types of vegetable oils as listed in Table 1 were used as oil-based emulsion in different concentrations for lubrication/cooling purpose during external turning process under different values of speeds and feeds. Conventional cooling oil (eco-cool mk3) was used as oil based emulsion in the same concentrations of natural oils emulsion to compare the effect of using each type of oil on the surface roughness of aluminum bars after turning.

Table 1 Types and concentration of lubricant emulsions.

Oil type	Oil – water ratio		
Corn oil	15 %– 85 %	30 %– 70 %	60 %– 40 %
Olive oil			
Coconut oil			
Ecool-mk3 oil			

Single point cutting tool was used to perform the external turning of aluminum bars by means of center lathe machine. Feed rate and cutting speed were adjusted to be suitable for aluminum as ductile metal as mentioned in Table 2

Table 2 Cutting speed and feed rate conditions.

Speed. rpm	1st feed rate	2nd feed rate	3rd feed rate
60	0.034mm/rev.	0.10 mm/rev.	0.117 mm/rev.
95			
145			

Experiments and Measurements

External turning operation was applied on Aluminum bar with diameter 20 mm for length of 200 mm and constant depth of cut 0.5mm by means of single point high speed steel cutting tool with the following geometry,Table 3.

Table 3 Cutting tool geometry.

Side Relief angle	End Relief angle	Side Rake angle	Back Rake angle	Nose radius (mm)
12°	8°	16°	35°	0.4

Surface roughness Ra in (μm) for finished product (aluminum bars) was measured by means of digital surface tester (TR-Y-SRT-6210S). Surface roughness of each sample was measured after turning at five different positions on its circumference and the average value was recorded. Bar charts were constructed to display the effect of cutting parameters such as cutting speed, feed rate, lubricating emulsion type and quantity on surface roughness of aluminum parts.

RESULTS AND DISCUSSION

Effect of cutting fluids on Surface roughness of Aluminum bars under low cutting speed (60 rpm).

Figures 1 - 3 show the effect of cutting fluid types and concentrations as well as feed rate on surface roughness of aluminum bars. Figure 1 indicates that surface roughness

increases with the increase of feed rate under dry cutting conditions. Besides, it shows slight reduction in roughness under low content (15 %) of all types of oil-based emulsion. Surface roughness remarkably decreased from 5.7 µm for dry cut to 1.7 µm under high feed rate 0.117 mm/rev. by using 15 % mineral oil-based emulsion as lubricant. Under low cutting speed (60 rpm) and with increase of emulsion oil content to 30 % and 60 %, Figs. 2 and 3 respectively, where surface roughness decreased by 25 % to 28 % for different types of oils. Using of corn oil based emulsion in 60 % concentration decreased the roughness of aluminum bar to 1.2 µm for low feed rate cutting. For medium and high feed rates, there is similar behavior for all types of oils, where increase of oil content slightly decreased surface roughness compared to dry cutting. It seems that the presence of chip macro-particles in contact area between cutting tool and work piece surface contributes in increasing roughness under dry cutting that decreased by using of lubricants.

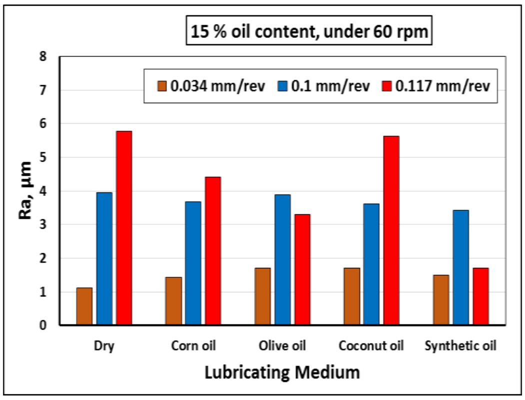

Fig.1 effect of oil type and feed rate on surface roughness of Al. under 60 rpm and 15 % oil content

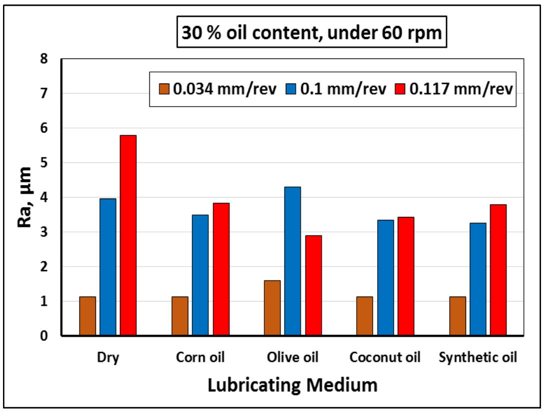

Fig.2 effect of oil type and feed rate on surface roughness of Al. under 60 rpm and 30 % oil content

In comparison with mineral based-oil emulsion there is no significant variation between this type and the other three vegetable oil-based emulsions except emulsion with 30 % coconut oil that shows somewhat reduction in surface roughness with all levels of feed rate. That may be related to the natural properties of coconut oil compared with other types.

Effect of cutting fluids on Surface roughness of Aluminum bars under medium cutting speed (95 rpm)

Increase of cutting speed during machining operations directly affects the surface roughness of machined parts. Figures 4 - 6 shows relatively increase of surface roughness for low and medium feed rate with increase of cutting speed under dry cut. Increase of oil content to 15%, Fig. 4, decreases the surface roughness of aluminum bars, coconut oil-based emulsion result in reduction of roughness from 5.2 mm to 3.2 µm for feed rate 0.1 mm/rev.

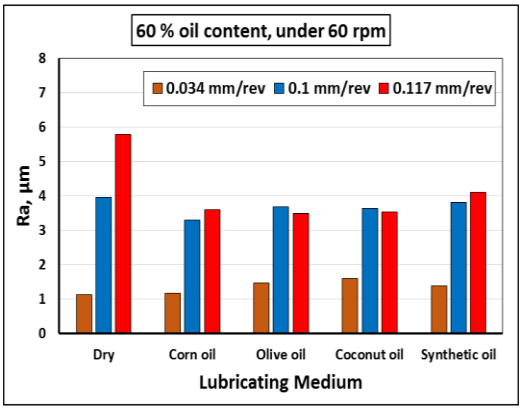

Fig. 3 effect of oil type and feed rate on surface roughness of Al. under 60 rpm and 60 % oil content

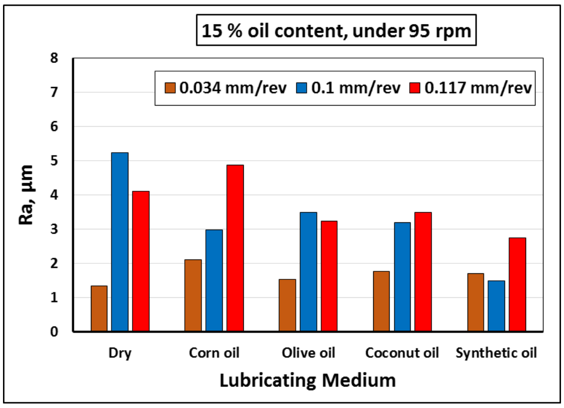

Fig. 4 effect of oil type and feed rate on surface roughness of Al. under 95 rpm and 15 % oil content

For the same oil content and feed rate mineral oil-based emulsion indicate better enhancement for surface roughness of machined aluminum bars to 1.5 µm. Continuous increases of mineral oil content to 30% and 60% lead to unexpected increase in surface roughness for medium and high feed rates. It seems that, the decrease of water content in cooling/lubricant emulsion keeps the cutting temperature high. That may be responsible for the roughness increase. Beside, soft reduction noticed in surface roughness values, Fig. 6, with increase of coconut oil content for medium and high feed rates.

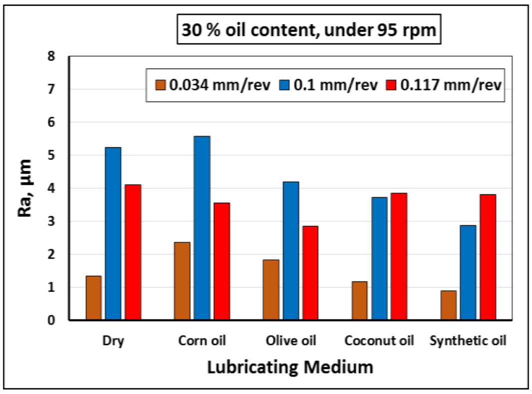

Fig. 5 effect of oil type and feed rate on surface roughness of Al. under 95 rpm and 30 % oil content

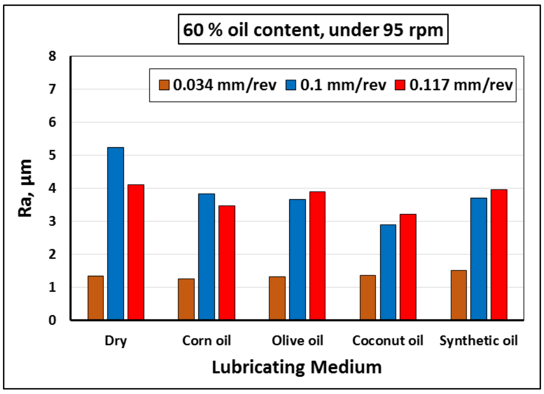

Fig. 6 effect of oil type and feed rate on surface roughness of Al. under 95 rpm and 60 % oil content

Effect of cutting fluids on Surface roughness of Aluminum bars under high cutting speed (145 rpm)

Surface roughness of aluminum bars shows remarkably high values under high cutting speed (145 rpm) especially for dry cutting operations, where it records higher than 6.2 µm for high rate of feed. Figure 7 shows significant reduction in surface roughness to 2 µm by applying vegetable oil-based emulsion of 15% olive oil content under high feed rate. Similar trend for surface roughness noticed for 30% coconut oil based emulsion for high and medium rates of feed as shown in Fig. 8. For all values of feed rate, further increase in oil content in lubricant emulsion to 60% increases surface roughness, Fig. 9, in comparison with emulsions that contain 30% oil content. That behavior may be related to the ability of high content of water in cooling emulsion to absorb and dissipate generated heat at cutting region and consequently surface roughness decreased.

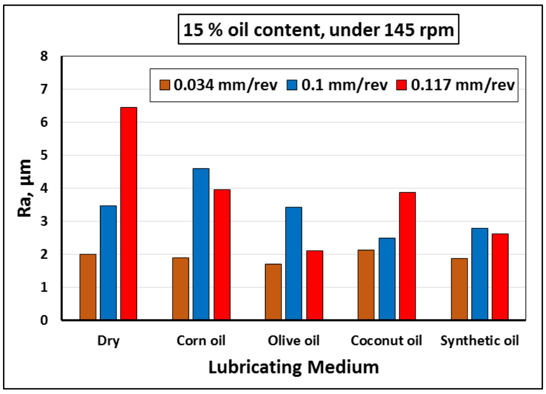

Fig. 7 effect of oil type and feed rate on surface roughness of Al. under 145 rpm and 15 % oil content

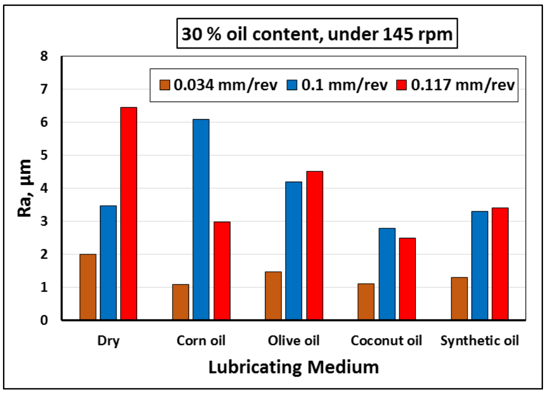

Fig. 8 effect of oil type and feed rate on surface roughness of Al. under 145 rpm and 30 % oil

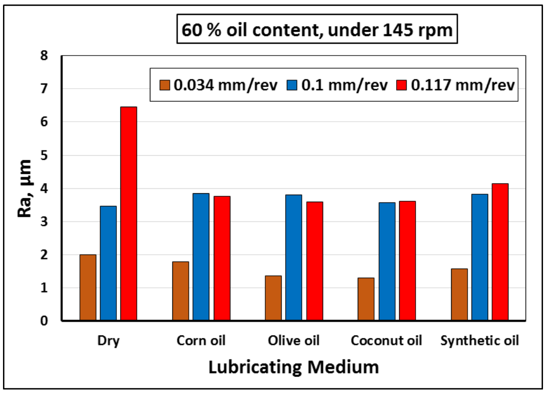

Fig. 9 effect of oil type and feed rate on surface roughness of Al. under 145 rpm and 60 % oil content

CONCLUSIONS

Based on results of experimental work, it can be concluded that:

1. Surface roughness of machined parts significantly influenced by feed rate, cutting speed and lubricant emulsion content.

2. Vegetable oil-based emulsion (VOBE) can be successfully used as lubricant/cooling fluids for turning operations.

3. Coconut oil-based emulsion remarkably decreases the surface roughness of machined aluminum bars.

4. Coconut oil-based emulsion with 30 % oil content shows better enhancement of surface roughness for high cutting speed (145 rpm) and high feed rate (0.117 mm/rev). It is recommended to apply this emulsion as lubricant/cooling medium instead of conventional mineral oil-based emulsion.

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