EVALUATION OF NEEM SEED OIL AS A CUTTING FLUID IN ORTHOGONAL MACHINING OF ALUMINUM MANGANESE ALLOY (AL-MN) IN TURNING OPERATION

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ABSTRACT

Neem seed oil was investigated in order to determine its suitability as a cutting fluid. So, the neem seed oil was used as a cutting fluid to machine aluminum manganese alloy 3003 in a centre lathe machine under the following machining (turning) conditions: Spindle Speed (V) was 250, 355 and 500 rpm respectively; depth of cut (d) was 0.5mm, 1.0mm and 1.5mm respectively; the feed rate (f) was 1.05mm/rev, 1.52mm/rev and 2.10mm/rev respectively. Carbide tool insert grade SNMG 120408-QM H13A was used. The results of the neem seed oil in terms of the surface rough, tool wear were compared with that of the soluble oil and 'dry' machining. Based on the obtained results, the neem oil reduced the surface roughness by 39% and 22% when compared to soluble oil and dry machining respectively. The soluble oil reduced the flank tool wear by 24% compared to dry turning. In fact the lowest surface roughness was obtained when the V = 500 rpm, f = 1.05 rev/mm and d = 0.5mm in comparison with soluble oil and dry machining. It has been established from the results that the neem seed oil gave the lowest flank wear at spindle speed of 250rpm, feed rate of 1.05mm/rev and depth of cut of 0.5mm as compared to dry and soluble oil machining. The neem seed oil reduced the flank wear by about 72% and 56% as compared to dry turning and soluble oil cutting respectively, while the soluble oil reduced the flank wear by 36% as compared to dry turning. Therefore, the neem seed oil is not only suitable for cutting fluid, but it is more effective as a cutting fluid than the soluble oil as a cutting fluid.

Keywords: Neem Seed oil, Soluble oil, aluminum manganese alloy, surface roughness, flank wear.

INTRODUCTION

In machining process, one of the most significant technical requirements of customer is the surface finish (surface quality). A reasonably good surface finish is desired to improve the tribological properties, fatigue strength, corrosion resistance and aesthetic appeal of the product. The challenge of modern machining industries is focused mainly on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact [1].

Al-3XXX wrought alloys are widely used for architectural applications, cooking utensils, bodies of beverage cans, packaging, chemical equipment, pressure vessels, and heat exchangers [2-7]. These products are usually used in sheet form. Both the hot and cold rolling that are used in aluminium alloy sheet production result in a high level of enhanced surface shear deformation. These alloys tend to be used when moderate strength combined with high ductility, good weldability, good formability, and excellent corrosion resistance are required. In sheet form, the strength is achieved by application of various degrees of strain hardening, and in some cases by intermediate annealing [8-10]. The 3003 alloy is one of the most popular alloys in this group, which has good formability, very good resistance to corrosion, and good weldability [2]. That is why Al-Mn 3003 alloy was used for this study.

Development of new cutting tool material and the availability of machine tools with high rotational speeds have made it possible to increase material removal rate. But at a high cutting speed, tool wear occurs more intensively and causes frequent changes in the tool. Consequently, resulting to high tool cost or production cost. Tool changing with time increases machine idle time and reduces the productivity of machining [11]. Therefore, cutting fluids are used to eliminate or reduce this negative effect on the cutting tool and surface finish. But, because of the negative effect of cutting fluids, especially the liquid fluids on the environment and the human being (machinist), more focus on the use of environmental friendly cutting fluids such as the bio and gaseous cutting fluids. Vegetable oil is one the bio-cutting fluids used nowadays. Vegetable oils with high oleic content have been the prime factor to replace conventional mineral oil-based lubricating oils and synthetic esters [12].

Furthermore, vegetable oils lubricants are biodegradable and non-toxic, unlike conventional mineral-based oils [13]. They have low volatility due to high molecular weight of the triglyceride molecule and have a narrow range of viscosity changes with temperature. Polar ester groups are able to adhere to metal surfaces and therefore, posses' good boundary lubrication properties. In addition, vegetable oils have high solubilizing power for polar contaminants and additive molecules [14]. As the demand for vegetable oils for food has increased in recent years, it is impossible to justify the use of these oils for cutting fluid, hence, the present focus on production and utilization of oil from non-edible oil seeds (neem seed oil) [14].

The neem tree (Azadirachta indica Juss.) is a native to tropical and semi-tropical regions with origin in Europe and later domesticated in Asia. It is extensively found in India and Indonesia [15].

It is also ubiquitous in Northern Nigeria, and fairly found in Western Nigeria, where it is popularly referred to as Dogon Yaro. It is a tree in the mahogany family with broad dark stem and widely spread branches. It grows above 20m and produces evergreen leaves with white fragrant flowers and fruits. It is also drought resistant. All parts of neem tree (the leaves, twigs, and oil from the nuts) are used both industrially and medicinally. Neem oil is generally light to dark brown, bitter and has a rather strong odour that is said to combine the odours of peanut and garlic [16].

Northern part of Nigeria has great potential for production of bio-lubricants from non-edible oil seeds. The country is endowed with species of tree born non-edible oil such as neem seed oil. The non-edible oils currently being available in Nigeria are karanja oil, Neem oil, Rice bran oil, Rapeseed oil, castor oil, linseed oil and Mahua oil. Non-edibles seeds grow on their own, but nowadays stress are given for cultivation of these trees which not only provides us with vegetation, but it also provides employment to tribal, poor people. Finally they provide us with different products which are superior to mineral oils for being biodegradable, cheaper and eco-friendly. Non-edible oil seeds mainly contain lipid protein, protein portion and carbohydrates [17].

In view of the above and couple the fact that there is little or no research on the development of neem seed oil into metalworking fluids led to this research.

Furthermore, the chemical based coolants used nowadays are harmful to the operator and environment compared to the environmental friendly coolants, one of which is the neem seed oil.

MATERIALS AND METHODS

Materials

The materials used in this research work were: Al-Mn 3003 alloy used as the workpiece, neem seed oil and soluble oil used as the cutting fluids in this study. The chemical composition of the Al-Mn alloy 3003 is presented in table 3.1

Equipment

The equipment used in this study are: Centre Lathe Machine model XL 400, Uncoated Carbide Inserts Tool SNMG 120408-QM H13A (ISO designation) were clamped onto a tool holder for turning operation. Surface roughness tester ISR-16 type, and a digital vernier caliper were used to measure the surface roughness and the tool wear values respectively.

Experimental Procedures

The experiments were performed in the workshop of mechanical engineering department, Nigerian Defence Academy, Kaduna, Nigeria. The neem seed oil and the souluble oil were used as the cutting fluids. The experimental set up is presented in Fig. 3.1.The fatty acid profile and the Physicochemical Analysis of Neem seed oil are given in Table 3.2 and 3.3.

The work piece was first and foremost faced and a centre hole drilled and it was then supported by the tailstock centre. Thereafter, it was turned to a 1mm depth to remove all the rusted and/or harden surface prior to the actual turning operation. This was done in order to minimize any effect of inhomogeneity on the experimental results.

After turning, the surface roughness of the work piece was measured using a surface roughness tester ISR 16 shown in Figure 3.2. ISO 4287 standard was followed during the measurements. These measurements were repeated three times, on three different points on the work piece and the average values of the readings were recorded.

The flank wears were measured with a digital vernier caliper shown in Figure 3.3. The flank wear was measured from the distance between the top of the cutting edge and the bottom of the area where flank wear occurs. The carbide turning tool was replaced when the width of the flank wear area reached the predefined limit of 0.76mm. The duration of machining was 8mins for each experiment. The flank wear measurements were repeated three times, the average values of the readings were taken.

Table 3.1: Chemical composition of aluminum-manganese alloy 3003 (workpiece)

Chemical composition Wt%	Al	Ca	Ti	Cr	Mn	Fe	Cu	Te	Hf
	93.4%	0.1%	0.79%	0.94%	2.03%	1.52%	0.06%	0.92%	0.1%

Source: National Geosciences Research Laboratory (NGRL), Kaduna.

Table 3.2 Fatty Acid Profile of Neem Seed Oil

Fatty acid	% composition
Unsaturated fractions	
Oleic acid (C18:1)	56.98
Linoleic acid (C18:2)	3.69
Linolenic acid (C18:3)	0.28
Erucic acid (C22:1)	0.09
Palmitoleic acid (C16:1)	1.88
Saturated fractions	
Palmitic acid (C16:0)	15.55
Stearic acid (C18:0)	21.11
Arachidic acid (C20:0)	0.18
Behenic acid (C22:0)	0.11
Lignoceric acid (C24:0)	0.71
Total	100%

Source: National Research Institute for Chemical Technology, Zaria

Table 3.3 Physicochemical Analysis of Neem Seed Oil

Properties	Values
Density (kg/m^3) at 25ºC	0.889
Viscosity (mm^2/s)	36.67
Saponification value (mg KOH/g)	210.0
Iodine value (g I2/100 g)	36.54
Acid value (mg KOH/g)	2.88
Free fatty acid (% w/w)	5.11
Peroxide value (meqo$_2$/kg)	10.20
Cetane number	58
Higher heating value (mJ/Kg)	40.27

Source: National Research Institute for Chemical Technology, Zaria

Fig. 3.1 Experimental Set Up

Fig. 3.2 Surface Roughness Tester ISR16

Fig. 3.3 Digital Vernier Caliper

RESULTS AND DISCUSSION

Results

Surface Roughness

The results of the effect of spindle speed on the surface roughness under the following conditions: spindle speed (N) = 250 - 500rpm, feed rate (f) = 1.52mm/rev, depth of cut (d) = 1.0mm are presented in Table 4.1.

Table 4.1: The surface roughness under various spindle speeds.

S/N	Spindle Speed N (rpm)	Average Surface Roughness R_a (μm)		
		Dry	Soluble oil	Neem seed oil
1	250	3.015	2.346	2.150
2	355	2.972	2.212	1.633
3	500	2.806	2.154	1.485
Total Average		**2.931**	**2.237**	**1.756**

The results of the effect of feed rate on the surface roughness under the following conditions: feed rate (f) = 1.05 – 2.10mm/rev, depth of cut (d) = 1.0mm, spindle speed (N) = 355rpm are presented in Table 4.2.

Table 4.2: The surface roughness under various Feed rates

S/N	Feed rate f (mm/rev)	Average Surface Roughness R_a (μm)		
		Dry	Soluble oil	Neem seed oil
1	1.05	2.872	2.668	2.284
2	1.52	3.253	2.867	2.346
3	2.10	3.618	3.024	2.374
Total Average		**3.248**	**2.853**	**2.335**

The results of the effect of depth of cut on the surface roughness under the following conditions: depth of cut (d) = 0.5 – 1.5mm, feed rate (f) = 1.52mm/rev, spindle speed (N) = 355rpm as presented in Table 4.3.

Table 4.3: The surface roughness under various depths of cut

S/N	Depth of cut d (mm)	Average Surface Roughness R_a (μm)		
		Dry	Soluble oil	Neem seed oil
1	0.5	2.759	2.574	2.167
2	1.0	2.983	2.663	2.254
3	1.5	3.034	2.685	2.295
Total Average		**2.925**	**2.641**	**2.239**

Flank Wear

The results of the effect of the spindle speed on flank wear under the following conditions: spindle speed (N) = 250 – 500rpm, feed rate (f) = 1.52mm/rev, depth of cut (d) = 1.0mm as presented in Table 4.4.

Table 4.4: The tool flank wear under various spindle speeds

S/N	Spindle Speed N (rpm)	Flank Wear (mm)		
		Dry	Soluble oil	Neem seed oil
1	250	0.12	0.10	0.04
2	355	0.23	0.16	0.07
3	500	0.40	0.22	0.09
Total Average		**0.25**	**0.16**	**0.07**

The results of the effect of feed rate on the flank wear under the following conditions: feed rate (f) = 1.05 – 2.10mm/rev, spindle speed (N) = 355rpm, depth of cut (d) = 1.0mm are presented in Table 4.5.

Table 4.5: The tool flank wear under various Feed Rates

S/N	Feed Rate N (mm/rev)	Flank Wear (mm)		
		Dry	Soluble oil	Neem seed oil
1	1.05	0.20	0.14	0.09
2	1.52	0.28	0.19	0.11
3	2.10	0.37	0.25	0.18
Total Average		**0.283**	**0.193**	**0.127**

The results of the effect of depth of cut on the flank wear under the following conditions: depth of cut (d) = 0.5 – 1.5mm, feed rate (f) = 1.52mm/rev, spindle speed (N) = 355rpm as presented in Table 4.6.

Table 4.6: The tool flank wear under various depths of cut

S/N	Depth of Cut d (mm)	Flank Wear (mm)		
		Dry	Soluble oil	Neem seed oil
1	0.5	0.48	0.34	0.28
2	1.0	0.54	0.41	0.32
3	1.5	0.61	0.48	0.37
Total Average		**0.543**	**0.410**	**0.323**

DISCUSSION

The effect of speed on the surface roughness

It was observed that the average surface roughness decreases with the increase in spindle speed from 250 to 500rpm. However, the highest surface quality was obtained using neem seed oil as cutting fluid and the lowest surface quality occurred in dry condition. This was followed by the soluble oil cutting fluid. The neem seed oil cutting fluid reduced the surface roughness by 39% and 22% as compared to dry turning and soluble oil cutting fluid respectively. The soluble oil cutting fluid reduced the surface roughness by 24% as compared to dry turning. It was also observed that the deviation of surface roughness is highest in the case of neem seed oil cutting fluid and lowest for dry machining. This was perhaps due to the high lubricating effect of neem seed oil cutting fluid.

The effect of feed rate on the surface roughness

The result (Table 4.2) shows that neem seed oil is the most effective at reducing the surface roughness when compared to the use of soluble oil and dry turning. The average surface roughness increases with increase in feed rate from 1.05 to 2.10mm/rev. Better surface quality was obtained using neem seed oil cutting fluid compared with soluble oil cutting fluid. The neem seed oil cutting fluid reduced the surface roughness by 28% and 18% as compared to dry turning and soluble oil cutting fluid respectively. The soluble oil cutting fluid reduced the surface roughness by 12% as compared to dry turning. It is also observed that deviation of surface roughness is the lowest in case of neem oil based cutting fluid and highest for machining without any cutting fluid (dry).

The effect of depth of cut on the surface roughness

In this case the best surface quality was obtained using neem seed oil cutting fluid when compared to the other two machining conditions. For the two cutting conditions namely dry machining and machining with soluble oil cutting fluid, roughness was linearly increasing with increasing rate of depth of cut, but using neem seed oil as cutting fluid, surface quality slightly reduce with increasing rate of depth of cut. The neem seed oil cutting fluid reduced the surface roughness by 23% and 15% as compared to dry turning and soluble oil cutting fluid respectively. The soluble oil cutting fluid reduced the surface roughness by 10% as compared to dry turning. The application of neem seed oil as cutting fluid gave good surface quality, because of its good lubricating properties.

The effect of Speed on the tool flank wear

Table 4.4 presents the values of the flank wear under various spindle speeds and cutting fluids. It was established that the flank wear increases with an increase in the speed and that the values of wear were almost the same both soluble oil and dry machining at the speed of 250 rpm.

The highest wear rate was obtained under dry turning followed the soluble oil turning. The lowest flank wear was achieved using neem seed oil. The neem seed oil reduced the rate of flank wear by 72% and 56% in comparison with the dry and soluble oil turning. The soluble oil reduced the flank wear by 36% as compared to dry turning. At higher spindle speeds, the material passes away within a short interval of time, which facilitates the machining interface to become an adiabatic system. Increase in temperature softens the cutting tool and causes more tool wear.

The effect of Feed Rate on the tool flank wear

A rise in the feed rate increases the friction between work piece and hikes heat generation which causes greater flank wear. It was seen that in dry machining, the effect of feed rate on flank wear was highest among all. However, with the application of cutting fluid the rate of flank wear was reduced, but the lowest flank wear was obtained using neem seed oil. The neem oil coolant reduced the flank wear by 55% and 34% as compared to dry turning and soluble oil coolant respectively. The soluble oil coolant reduced the flank wear by 32% as compared to dry turning. overall, the results suggested that neem seed oil exhibited comparable performance with soluble oil in terms of flank wear rate. This can be attributed to the ability of neem seed oil in reducing the temperature at the tool-work piece interface thus the flank wear rate was reduced. Neem seed oil has higher viscosity index than soluble oil. The higher viscosity index of neem seed oil can be explained due to the fact that neem seed oil contains palmatic acid ($CH_3(CH_2)_{14}COOH$) which consists of triglyceride structures that provide desirable lubricant and maintain stronger intermolecular interactions with increasing temperature [18]. In addition, the fatty acid in neem seed oil contains a thicker molecular layer of lube oils. These factors could contributed to the better lubricating hence could reduce the tool wear rate.

The influence of the depth of cut on the Tool Flank Wear

The obtained results (table 4.6) here again show the advantage of neem seed oil cutting fluid over the soluble oil cutting fluid and dry turning in term of the tool flank reduction. The neem seed oil greatly reduced the flank wear as compared to the soluble oil. It reduced the flank by 77% and 69% compared to the dry turning and soluble oil turning respectively. The soluble oil only reduced the flank wear by 24% compared to the dry turning.

CONCLUSION AND RECOMMENDATION

Conclusions

In this work, the suitability of neem seed oil as cutting fluid and its effect on surface roughness of aluminum-manganese alloy 3003 and tool wear during were confirmed in terms of selected parameters such as spindle speeds, feed rates, and depths of cut. Therefore, the following conclusions are being drawn:

1. The minimum surface roughness (best surface quality) was obtained using neem seed oil as cutting fluid compared to soluble oil cutting fluid during the turning operation.
2. The least surface roughness was achieved at spindle speed of 500 rpm using neem seed oil. It was the most effective in the reduction of the surface roughness as spindle speed was increased.
3. Neem seed oil had relatively small surface roughness at feed rate of 1.05 mm/rev and depth of cut of 0.5mm, while the highest surface roughness was achieved at feed rate of 2.10 mm/rev and depth of cut 0.5mm using dry turning.
4. Lower flank wear values were obtained with soluble oil and the least flank wear was achieved at spindle speed of 250 rpm. Neem seed oil generated the highest reduction in flank wear when machining Al-Mn alloy at a spindle speed of 250rpm, a feed rate of 1.05 mm/rev and a depth of cut 0.5mm.
5. An increase in the spindle speed decreased the surface roughness value.
6. An increase in the feed rate and depth of cut increased the surface roughness value.
7. An increase in the spindle speed increased the flank wear value.
8. An increase in the feed rate and depth of cut increased the flank wear value.
9. The significant contribution of neem seed oil in the machining of aluminum-manganese alloy 3003 using carbide insert tool has been the high reduction of flank wear which would enable remarkable improvement in tool life and allow the use of higher spindle speeds, feed rates and depths of cut. Such significant reduction was due to its high lubricating property.

Recommendations

In view of the fact that no research is in itself conclusive, the following recommendations are made.

- The study should be extended to cover carbon steel tools, CBN, or other harder materials.
- The future work should focus on the microstructure of the machined Al-Mn alloy and flank wear using scanning electron microscope (SEM) in order to view micro crack and chipping of the work piece and cutting tool.
- The range of the cutting parameter (spindle speed, feed rate and depth of cut) used in the work should be increase for future work.
- CNC machines can be used for the experimentation to have the better control of the process variables and parameters.
- The present developed system can be used for machining processes such as milling and drilling.

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