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PERFORMANCE EVALUATION OF GROUNDNUT OIL AND MELON OIL AS CUTTING FLUIDS IN MACHINING OPERATION

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Abstract: Coolants are used during machining for variety of reasons such as improving tool life, reducing work-piece thermal deformation and surface finish. Traditionally, coolants in machining are based on conventional oil as the base fluid, but because of its non-biodegradability which results in environmental pollution and danger to human health, there is a growing demand for biodegradable material thus opening an avenue for vegetable oils for use as coolants. In this work, groundnut and melon oils were used as coolants during the turning operation of mild steel using carbide cutting tool at different spindle speeds and depths of cut. The cooling ability, surface finish and chip shapes were studied during the machining process. The results showed that the cooling ability of melon oil was better than that of groundnut oil and the surface finish produced by the vegetable oils was better than that of soluble oil with melon giving the best surface finish. Soluble oil extracted heat the most. The chips formed using vegetable oil coolants are more ductile and continuous than those obtained using soluble oil coolant. Vegetable oil coolants were seen to enhance tool life better than the conventional oil and as such can be used as alternative to soluble oil coolants.
Keywords: coolant, machining, groundnut oil, melon oil, operation, cutting, soluble

INTRODUCTION

Machining processes have an important place in the traditional production industry. During machining process, friction between workpiece-cutting tool and cutting tool-chip interfaces causes high temperature on the cutting tool. The effects of this generated heat include decrease in tool life, increase in surface roughness and decrease in the dimensional sensitivity of work material. This is more important when machining materials that are difficult to cut, where more heat would be generated [1]. This brought about the incorporation of coolants in the manufacturing process. The use of coolants permit higher cutting speeds, higher feed rates, greater depths of cut as well as lengthened tool life, decreased surface roughness, increased dimensional accuracy, and reduced power consumption [2, 3]. The development of coolants was traditionally based on mineral oil as a base fluid and this was because of the good technical properties and the reasonable price of mineral oils. However, the Report to the Club of Rome in 1972 and the two oil crises of 1979 and 1983, pointed out that mineral oil is a limited resource [4]. Also, conventional cutting fluids are not eco-friendly due to the several negative impacts they have had on the environment. When in-appropriately discharged, cutting fluids may damage soil and water resources, cause serious environmental impacts and adverse effects on human health [5, 6]. Vegetable oil on the other hand occurs naturally and has the extra advantage of biodegradability. Compared to mineral oil, vegetable oil can even enhance the cutting performance, extend tool life and improve the surface finish [7, 8]. Although, they have many environmental benefits, vegetable oils are more susceptible to degradation by oxidation or hydrolytic reactions.

Cutting lubricants may consist of pure oil, a mixture of two or more oils or a mixture of oil and water [9]. Oils are generally divided into two groups: the fixed oils and the mineral oils. The fixed oils have greater oiliness than the mineral oils, but they are not so stable and tend to become gummy and decompose when heated. In this group are animal and vegetable oils. On the other hand, the mineral oils group is obtained from crude petroleum mined from the oil fields. The most common type of lubricant used for cutting is soluble oil, which when mixed with water, forms a white solution known as "suds" or "slurry". This has better cooling properties than oil, but does not lubricate as much. The oil part of it is generally a mineral oil mixed with a soap solution [10, 11]. The successful application of bio-oils in metal cutting operation has been restricted to few percentages. Vegetable oils provide intrinsically strong and lubricious film and as such possess higher lubricating ability than conventional mineral oil metal working fluid [12, 13]. Biological oil coolant has some superior features compared to the petroleum-based cutting fluids. There are reduced overall volume of fluids due to higher viscosity, minimized health risk to workers and minimized bio-contamination. Ojolo et al [14] studied the effect of vegetable oils on cutting force during cylindrical turning. Their work demonstrated that *the performance of vegetable based coolants is comparable or better than the performance of the traditional petroleum based metal working fluids. This work is aimed at investigating the possibility of using vegetable oil as an alternative coolant to soluble oil when machining mild steel on a lathe machine by determining; the temperature generated at the cutting zone when different oils are used as coolant at different cutting speeds on the workpiece, the effect of oil coolants on the chips formed during machining and the effect of coolants on the surface finish of the workpiece.*

EXPERIMENTAL DETAILS

Mild steel with chemical composition shown in Table1 was used for the experiment. The tool material used was a round half carbide cutting tool soldered on a mild steel holder. The mild steel holder was bored through and tapped at a point very close to cutting edge of the carbide tool before soldering. A thermocouple of 0-600^{0}C was tightly screwed into the tapped hole until the tip of the thermocouple made a direct contact with the carbide tool. Unrefined vegetable oils of groundnut oil and melon oil were used as alternative coolants to the conventional soluble oil during machining. The vegetable oils were obtained from the south-western region of Nigeria, while the mild steel was obtained from Federated Steel Limited, Otta, Ogun State, Nigeria. The major test parameter used to investigate the performance of the vegetable oil as cutting fluid were temperature at cutting zone, spindle speed and chip thickness. Mild steel bar of diameter 35mm and length 120mm was prepared for machining using conventional soluble oil, groundnut oil and melon oil as coolants. During machining, various spindle speeds of 80, 108 and 260 rpm were investigated at depths of cut of 0.4, 0.6, 0.8, 1.0 and 1.2 mm. The temperature of heat generated between the surface of work piece and the carbide tool was captured during turning operation using a 3 channel SD card data lodger thermometer monitor of model number MTM-380SD connected via the thermocouple at a time interval of 5seconds Figure 1. During machining, coolants were applied using dripping method at a constant rate of 0.28cm^3/s. Maximum temperature for each reading was taken and the chips obtained during machining for various speed and depth of cut were observed. The work piece was then removed and labelled against the spindle speed and the specific coolant used. The procedure highlighted above was used for dry cut, conventional soluble oil, groundnut oil and melon oil in order to compare the effectiveness of the coolants. The composition of the base metal was determined using an Atomic Absorption Spectrometer. The tests carried out on the mild steel metal showed the following percentage composition as given in Table 1.

***Table 1:** Chemical Composition of the Mild steel used*

Components	Fe	C	Si	Mn	P	Cr
Composition (wt%)	99.200	0.131	0140	0.347	0.015	0.013
Components	Ni	Cu	Al	Ti	Co	Sn
Composition (wt%)	0.004	0.038	0.004	0.016	0.001	0.001

***Figure 1:** Experimental setup*

RESULTS AND DISCUSSION

The results obtained showed that temperature at the cutting zone increases as the depth of cut and spindle speed increases irrespective of the coolant used Fig. 2 - Fig. 4. The temperature of the dry cut machining was higher at all speeds while soluble oil absorbs heat better than all other coolants at low, medium and high spindle speeds of 80, 108, 260 rpm respectively. At all spindle speeds, melon oil absorbs heat better than groundnut oil but soluble oil absorbs heat the most. At spindle speed of 80rpm, the amounts of heat absorbed by melon and groundnut oils are almost the same as that of soluble oil which indicated that the properties of the vegetable oils are similar to that of soluble oil Fig. 2.

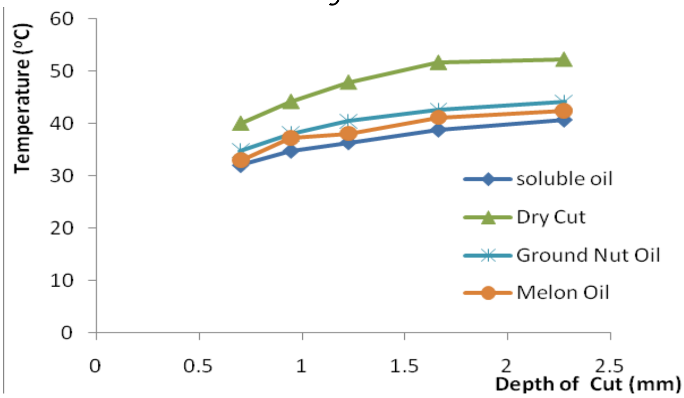


***Figure 2:** Variation of temperature and depth of cut at 80 rpm*

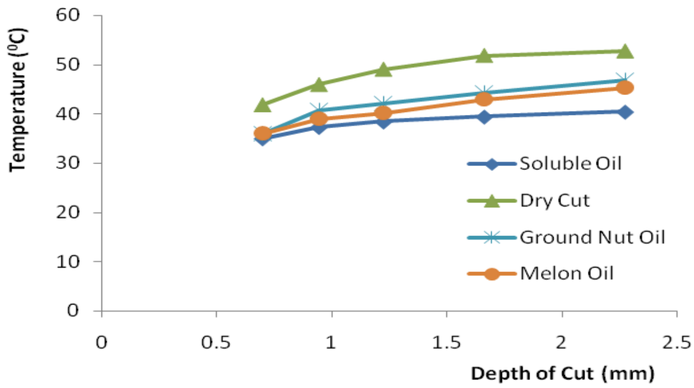


***Figure 3:** Variation of temperature and depth of cut at 108 rpm*

At medium spindle speed of 108rpm and high spindle speed of 260rpm, the amount of heat absorbed by melon and groundnut oils is similar to that of soluble oil at lower depths of cut; but at higher depths of cut, the property of melon and groundnut oil begins to *change and their performance in heat absorption begins to decline as shown in Fig. 3 and Fig. 4 which resulted in high temperature rise.*

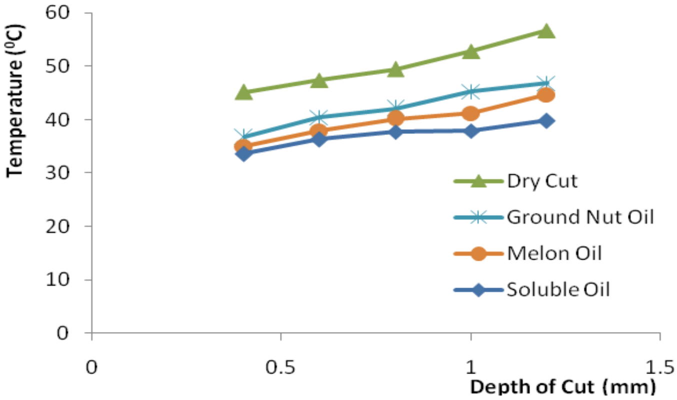
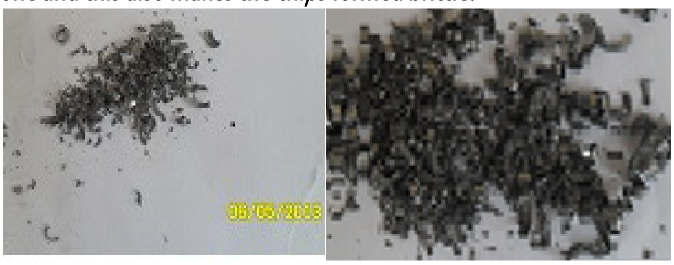
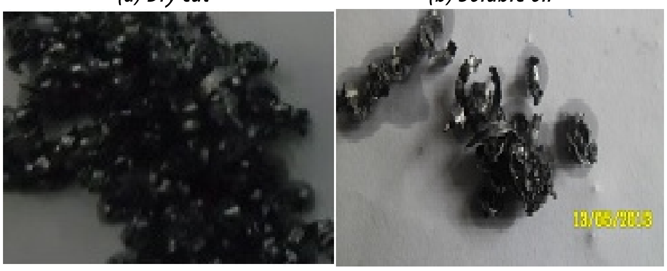


***Figure 4:** Variation of temperature and depth of cut at 260 rpm*

At low spindle speed of 80 rpm, the chips from the work piece using soluble, groundnut and melon oils as coolant were discontinuous Fig.5b – Fig. 5d. Burnt and discontinuous chips were obtained for dry cut machining as a result of the high heat generated in the cutting zone and this also makes the chips formed brittle.

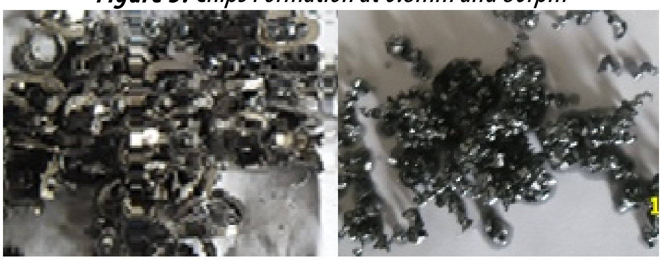


(a) Dry cut *(b) Soluble oil*

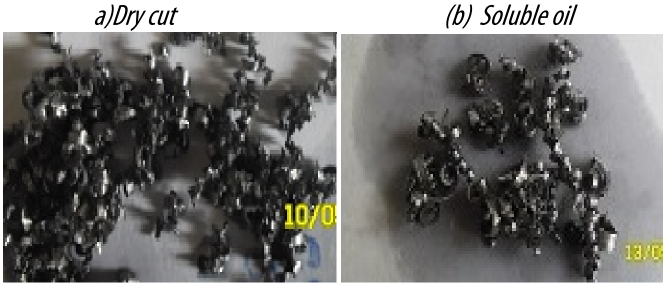


(c) Groundut oil *(d) Melon oil*

***Figure 5:** Chips Formation at 0.8mm and 80rpm*



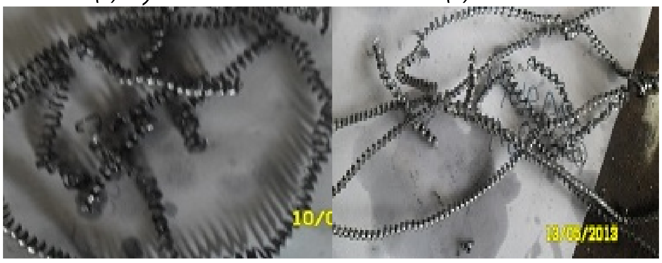
a)Dry cut *(b) Soluble oil*



(c) Groundnut oil *(d) Melon oil*

***Figure 6:** Chips Formation at 1.0mm and 108 rpm*

(a) Dry cut *(b) Soluble oil*



(c) Groundnut oil *(d) Melon oil*

***Figure 7:** Chips Formation at 1.2mm and 260 rpm*

At spindle speed of 108rpm the metal chips are continuous for melon oil and groundnut oil while soluble oil gave slightly continuous chips Fig.6a-d. At spindle speed of 260rpm, melon oil and groundnut oil gave ductile and continuous chips Fig.7c and Fig 7d). Soluble oil gave continuous and tiny chips while dry cut gave burnt and continuous chips.

CONCLUSION

The cooling ability of melon oil is better than that of groundnut oil but closer to soluble oil which absorbs heat the most from the cutting zone; the good performance cooling ability of melon oil over groundnut oil may be attributed to its higher kinematic viscosity. Investigation of the machined surfaces shows that the surface finish produced using vegetable oils as coolant was better compared to that of soluble oil, with melon oil giving the best surface finish among all the coolants used. The chips formed by vegetable oils are continuous and more ductile in nature than that produced using soluble oil coolants and dry cut machining; the continuity or discontinuity of chips depends on the spindle speed and the lubricity of the coolant used in machining. During machining, vegetable oil coolants produce less wear on the cutting tool compared to soluble oil as coolant thereby prolonging the tool life. The volume of vegetable oil used was less than that of conventional coolant used during the experiment which is in the ratio 2:3. Though the cooling capacity of conventional oil is better than that of the vegetable oil based coolants, vegetable oils can be used as coolants during machining as they produce better surface finish, longer tool life, continuous chips coupled with the fact that less quantity was expended during the machining process.

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