Performance Evaluation of Cutting Fluids Developed from Fixed Oils

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Abstract

In this work, different cutting fluid emulsions of about 10% concentration were developed from fixed oils and the performance of each of the developed cutting fluid was evaluated by a direct comparison with as purchased conventional cutting fluid (control sample), using the ability of each sample to effectively perform as coolant and lubricant during machining operation as determinant. In the evaluation process, straight turning operation on lathe machine at various speeds, but equal time intervals of 10 minutes was used with a 2 mm/min feed rate. It was found that cutting fluid developed from groundnut oil (Sample B) performed best as coolant at all experimented speeds, with maximum temperature of 60.5° C at the working zone as against 71.39° C observed for the Control (Sample A). The viscosity 10.76 cSt of Sample B was however, higher than those of Samples A (4.79 cSt) and C (6.20 cSt). It was recommended that further work be done to synergize Samples B and C and the cooling effectiveness of the hybridized cutting fluid on the tool-chip interphase, as well as its lubricity be evaluated.

Keywords

Cutting fluids, Performance evaluation, Fixed oils, Viscosity, Acidic value

Introduction

One of the interesting recent developments is a growing realization that bioresources present practical alternatives to fuels and lubricants derived from liquid fossil fuels. About 30 years ago in Tanzania, locally pressed castor oil, strained through an old sock was used as gearbox engine oil [1]. That this was no eccentricity was shown by the many tests carried out on its uses as lubricating oil and its eventual acceptance as a jet engine lubricant [1]. However, no pure vegetable or mineral oil possesses all the properties required by modern technology in machining processes, therefore, a mixture of some sort is necessary. This has led to the development of several cutting fluids using many soluble mineral oils [2].

Cutting lubricants may consist of pure oil, a mixture of two or more oils or a mixture of oil and water [2]. 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 [3].

During machining operations, heat is generated and this has adverse effects on work piece surface finish and dimensional accuracy, tool wear and life, as well as production rate. Lubricants are therefore employed in machining operations to either achieve cooling, cooling and lubrication, lubricate mainly, or minimize chip adhesion to work piece or tool; and the goal of employing a lubricant in any machining operation is dependent on choice from among the listed functions [4,5].

Whichever function a cutting fluid is to serve in any machining operation, it must possess some qualities, which have been identified [6] as: high decomposition or oxidation temperature, must not be gummy, should not foam or smoke unduly, must not be a contaminant to lubricants used elsewhere in the machine. If these qualities are lacking, the cutting fluid may result in serious ecological or health issues [7]. It has been observed [9] that expenses on cutting fluids form major parts of manufacturing costs per part produced. It is therefore, a cost cutting measure to develop cost effective and efficient cutting fluids for machining processes. This could be achieved through the use of cheap and readily available fixed oils.

This work therefore took as its objective the development and performance evaluation of cutting fluid from fixed oils (ground nut oil, palm kernel oil and palm oil) and available additives. This was achieved by formulation and testing the ability of each of the developed cutting fluid to conduct heat away from the cutting zone as well as the determination of their acidic and viscosity values. In order to establish their suitability as cutting fluids, the developed oil values were compared with those of an established conventional cutting fluid.

Materials and Methods

Cutting fluid preparation

The oil samples used in this work were prepared into cutting fluid using the suggestions given by earlier researchers in this field [3, 9]. In preparing each sample of cutting fluid, 500 ml of fixed oil was measured (using a 1-litre measuring beaker) and mixed with water in oil to water ratio of 1:10 [3]. This mixture was thereafter blended with 10 % vol/vol ordinary soap, and other ingredients in their respective percentages, all at room temperature. The formulations are tabulated in table 1.

The samples of cutting fluid used for the experiments were labeled samples A-E and their fixed oil constituents are as follows:

Sample A: As purchased cutting fluid (used as the control sample)

Sample B: Groundnut oil

Sample C: Palm kernel oil

Sample D: Palm oil

Sample E: Cutting without coolant.

Each of the cutting fluid developed had the following formula:

Table 1. Cutting fluid formula

Material	Function	Content (% volume/volume of fixed oil)
Fixed oil	Base oil	80
Washing soap	Emulsifier	10
Phenol	Disinfectant	5
Sulphur	Extreme pressure agent	5

Performance test methods

The major test parameter used to investigate the performance of each of the developed cutting fluid was temperature; the determinant being a measure of the ability of the cutting fluid to conduct heat away from the work zone during machining operation. In addition, the acidic and viscosity values of the developed cutting fluids were also determined.

Temperature Measurement

In order to evaluate the ability of each sample cutting fluid to conduct heat away from the work zone, a bar of circular cross section (0.02 m in diameter) was mounted on a three-jaw chuck of a lathe machine and straight turning operation was carried out on the bar using a feed rate of 2 mm/min for ten minutes while applying the cutting fluid directly at the tool tip-work piece point of contact. The tool used was one with positive rake; a new one used for each sample, but with the same original tool-tip grinding configuration. The cutting speed was varied form 58 rpm to 370 rpm. The cutting fluid was applied with the aid of coolant delivery system inbuilt in the lathe machine. A thermocouple made of copper and Constantine wire was used to measure the temperature right at the point where the tool tip made contact with the work piece during chip removal. The reference junction of the thermocouple was always kept at 0^0 C by constant monitoring and addition of ice at 0^0 C to the junction. The temperature reading at this point (which was read from the thermocouple as electric voltage) was noted and recorded and the procedure was repeated for all samples A-E at the specified cutting speeds.

The obtained milli-Volts readings were converted to temperatures by the help of standard tables that followed the thermocouple used, with interpolations.

Determination of Acidic Valu

10 g of each sample of cutting fluid was carefully weighed and then dissolved in phenolphthalein solution. It was then titrated with 0.1 mol potassium hydroxide (KOH) until the faint colour persists for between 20-30 seconds. The number of milliliters of standard alkaline (KOH) required to dilute the sample was noted and the acid value of the fat (samples) calculated at this point. Table 2 shows the results obtained.

Table 2. Acidic values of the oil samples

S/No	Sample	Acidic value
1	A	41.19
2	B	4.57
3	C	3.05
4	D	54.9

Determination of Viscosity

The method described by [10] was used in the viscosity determination except that it was conducted at normal average room temperature in Yola Nigeria, which is 37.8^0 C. Table 3 shows the results obtained.

Results and Discussions

From figure 1, it could be observed that Samples A and B, which are respectively the control cutting fluid and the one developed from groundnut oil had the same ability to conduct away heat from the work zone at lower cutting speeds (below 180 rpm). However, at cutting speeds greater than 180 rpm, Sample B out weighed Sample A in temperature lowering at the work zone. One explanation that has widely been used for this is the one given by Sales et al [11] attributed this phenomenon to the difference in the cutting fluids wettabilities.

Thus it is fair to say that Sample B may have had the same wettability at lower cutting speeds, but its better perceived thermal stability due to its higher viscosity (Table 3) at higher temperatures due to the raised cutting speed may have accounted for the higher ability of Sample B to cool the work zone than every other Sample. Though, it would have been a reasonable conclusion to exalt sample B over every other sample at this stage, it is nonetheless having a higher viscosity than all other Samples. This has some implications. It might not be able to penetrate rapidly to the tool-chip interphase, where maximum working temperatures do occur [12]. Also, a fluid with a higher ability to conduct heat away from the work zone may promote the softening effect of the work piece material caused by the heat [13]. With this the metal keeps its resistance at higher levels than when a cutting fluid with lower cooling ability is used [11]. The acid value of the oil gives a measure of how corrosive the cutting fluid developed from it could be to the work piece, especially if it is mild steel. The very low acid values of Samples B and C put them forward ahead of others for use in machining operations involving mild steel. The high acid value of Sample D may have been responsible for its highest translucent nature above other samples. A high acid value promotes emulsification with higher corrosion tendencies.

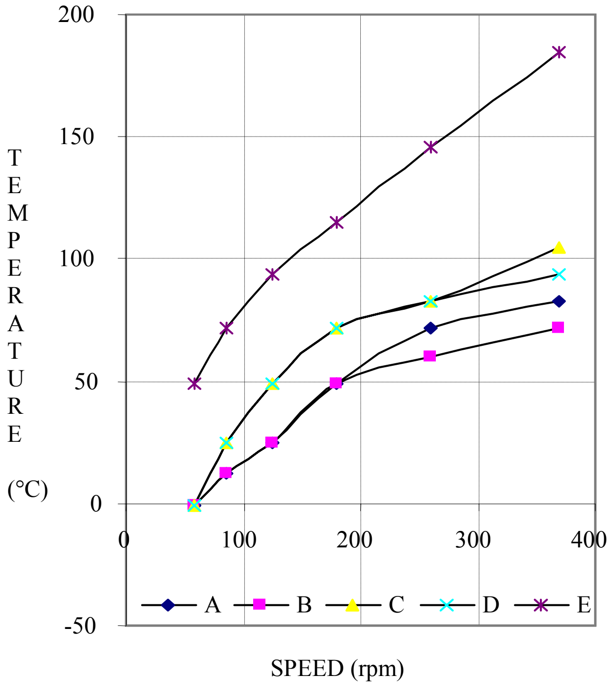

Figure 1. Graph of maximum cutting temperature against cutting speed for all samples

Table 3. Viscosity values for the sample of oils (Centi-Stokes)

S/No	Sample	Viscosity (cSt)
1	A	4.79
2	B	10.76
3	C	6.20
4	D	7.64

A synergy effect in terms of temperature regulation, acidic and viscosity values could be produced if Samples B and C are combined to produce one cutting fluid.

Conclusions

On the basis of the experiment carried out on the various samples of oils the following conclusions could be made.

1. All the samples can be used as cutting fluids because their performances show that they have the ability to remove heat during machining operations.
2. The acid values of samples B and C, which are 4.57 and 3.08 respectively have the least tendency to corrode the work piece (mild steel) compared to samples A and D with 41.19 and 54.9 respectively.
3. Sample B will remove heat from the overall work piece more than other samples under the same conditions.

It is recommended that further work be done to synergize Samples B and C and the cooling effectiveness of the hybridized cutting fluid on the tool-chip interphase, as well as its lubricity be evaluated.

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