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Experimental Analysis and the Development of Ground Nut Oil for Machining Operation

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Abstract- Metal removal process is one of the major methods of shaping materials to meet its environmental need. It requires the use of forces thus, heat would be generated and if not controlled, it could affect the expected end results. One of the major ways of controlling the heat during cutting is the use of lubricant. The cutting fluid commonly used for machining in a standard machine shops, are imported at exorbitant cost, hence, analysis was carried out on a vegetable oil from ground nut (GNO)and its properties were integrated by adding additive and emulsifying agents to develop it to a suitable soluble oil for machining operation. The experimental results concluded that the saturated solution of NaOCl and NACO3 when added to the GNO in ratio 1:2 formed perfect emulsiable oil (GNSO). The GNSO and conventional cutting fluid (CCF) were used to carry out machining of mild steel on a Lathe Machine. The results obtained shows that the surface finish of the sample cut with the GNSO is the finest. The two samples were observed for 70days for corrosion effect and their microscopic structure picture were observed, the sample cut with CCF was majorly affected. The reliability of the GNSO was further determined through the various soluble oil ASTM tests, least square regression analysis was used to interpret the correlation coefficient data collated which shows that GNSO is equally reliable and more cost effective than CCF since it can be sourced locally in abundant.

Keywords: metal cutting theory, development, and experimental analysis of GNO for machining.

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Experimental Analysis and the Development of Ground Nut Oil for Machining Operation

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Abstract- Metal removal process is one of the major methods of shaping materials to meet its environmental need. It requires the use of forces thus, heat would be generated and if not controlled, it could affect the expected end results. One of the major ways of controlling the heat during cutting is the use of lubricant. The cutting fluid commonly used for machining in a standard machine shops, are imported at exorbitant cost , hence, analysis was carried out on a vegetable oil from ground nut (GNO)and its properties were integrated by adding additive and emulsifying agents to develop it to a suitable soluble oil for machining operation. The experimental results concluded that the saturated solution of NaOCl and $NACO_3$ when added to the GNO in ratio 1:2 formed perfect emulsiable oil (GNSO). The GNSO and conventional cutting fluid (CCF) were used to carry out machining of mild steel on a Lathe Machine. The results obtained shows that the surface finish of the sample cut with the GNSO is the finest. The two samples were observed for 70days for corrosion effect and their microscopic structure picture were observed, the sample cut with CCF was majorly affected. The reliability of the GNSO was further determined through the various soluble oil ASTM tests, least square regression analysis was used to interpret the correlation coefficient data collated which shows that GNSO is equally reliable and more cost effective than CCF since it can be sourced locally in abundant.

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I. Introduction

Cost of acquiring materials for further processing to acquire the desire shape is of high critical concern for the determination of the method needed for its process, this is done to minimise waste. Materials processing is all that is done to develop either its chemical properties or physical shape. (Ekundayo, 2004); Smith (1987), admitted that in acquiring the desire shape, many methods can be used and that each method are chosen on their merits of how it may be easy to generate the desire shape and the overall cost of doing that. Ekundayo (2004), listed out the following processes of materials processing as a means of generate the require shape such as: casting process, metal removal (Machining) process, deformation and consolidation processes. This paper limit its consideration on machining process since it is where the use of soluble oil is mostly needed for cooling during machining.

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Metal removal (Machining) involves forcing of cutting tool through the excess materials of the work-piece, this is done progressively by separating the excess from the work-piece in form of chips. The process of metal removal and its technology is otherwise called metal cutting theory. This theory is a complex theory and it is difficult to predict accurately the number of forces involved. This involves the traditional machining processes such as metal cutting and grinding, as well as various non-traditional methods of machining.

II. Principle of Metal Cutting

To successfully carry out cutting of metals to the desirable shape, some principle must be well understood since the operation involves the use of cutting tools. Hence, the following principles must be taken into consideration before embarking on any cutting.

- The relative motion of the work- piece to the hard edge of the cutting tool
- The chemical and physical properties of the work-piece
- The cutting tool material
- The cutting fluid(Soluble oil) (Ekundayo, 2004)

Smith, (1987), opined that, in a modern workshop practice of any industry where power is needed for cutting, enormous amount of power is lost either through heat generation or friction between tool surface and work- piece. In Metal removal process, heat is generated due to plastic deformation and the chip/tool friction on the rake and flank faces. Smith (1987), estimated the energy lost due to heat generation during cutting to be between 20 and 30 percent of the total energy invested in the metal removal process and to considerably reduce this, cutting fluid is needed, hence this paper discusses the possibility of replacing GNO with the convention soluble oil.

III. Type of Cutting Operations

There are many methods of metal cutting here-in refers to as machining. According to Encyclopaedia (2012), Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. This processes are today refers to as subtractive manufacturing in distinction from processes of controlled material addition, which are known as additive manufacturing. The world machining has been in use for the past two centuries (Machine age) and today engineers call these traditional (conventional) machining processes such as turning, boring, drilling, milling, sawing, broaching etc. These involve the use of sharp cutting tools to remove the materials to achieve the desire geometry on machine tools such as Lathe, Milling machines and drilling press. The world conventional or traditional is used to differentiate the old methods from the newly developed technologies methods of machining processes such as EDM, ECM, EBM, PCM and UM(today most of the traditional processes have been upgraded to Computer Numerical control Machine, CNC). This paper is concern about the traditional machine tools where the use of soluble oil for cooling during machining is very important. There are many kinds of machining operations, each of which is capable of generating a certain part geometry and surface texture. During turning, a single point cutting tool is required; the tool is moved toward the work piece while the work piece rotates on its axis to generate cylindrical shape. Drilling uses a rotating tool that typically has two or four helical cutting edges to create hole. The tool is fed in a direction parallel to its axis of rotation into the work piece to form the round hole, while milling uses multiple cutting edge tools to generate a plane or straight surface, the direction of the feed motion is perpendicular to the tool's axis of rotation. The speed motion is provided by the rotating milling cutter. Other conventional machining operations are shaping, broaching, sawing, and grinding. According to Groover (2002), approximately 98% of the energy in machining is converted into heat which can cause very high temperature at tool-chip zone while the remaining energy (about 2%) is retained as elastic energy at chip. To reduce the heat generated at the tool-chip tips, correct cutting fluid is required for cooling and lubrication during machining so as to prolong the life's of the cutting tools and creates good surface finish.

IV. Cutting Fluid

Tools failure, poor surface finish and seizure between tool and chip occur during metal cutting. The reasons for this had been traced to heat generated during cutting as tools are forced through the excess materials of the work –piece, hence chips are formed due to the plastic deformation of the work- piece which normally take place ahead of the cutting area. According to the British Petroleum Company (1972), work done in deforming metal is converted to heat due to the very high local forces applied to the metal, which set up tremendous pressure on the cutting tip. Heat can also be generated during cutting due to the friction between the chip/tool faces when the chip moves under high pressure across the tool face, some of these heats affect the cutting tool. Smith (1987) opined that 20 to 30% energy lost during cutting are due to heat generation resulting from the friction between the tool surface and the work – piece. Muktar and Ibhadode (1999) described friction and heat as the two major effects that accompanying machining operation. Therefore, to minimise energy lost, generate good surface finish and protect the life of the cutting tool, the British Petroleum Company (1972), propounded that even if the structure of the materials are modified and cutting tools are well designed heat will still be generated. Hence, it can only be reduced by using three means, such as the use of refrigerant (Carbon dioxide), air blast and cutting fluid. Smith (1987) agreed with the British Petroleum Company (1972) but stated that cutting fluid is the most widely used among all these methods and to reduce power lost during metal cutting, cutting fluid is inevitable.

Many definitions had been given to cutting fluid. Bello (1994), described cutting fluid as a material that make surface smooth and slippery and they are used to reduce heat, friction, wear and vibration during cutting operation. The British Petroleum Company (1972), refers to it as a cooling system which carries away heat generated during cutting from the cutting area. Adejuyigbe (1999), defined cutting fluid as an auxiliary materials that embraces lubricant which reduces friction between moving parts and as well as protecting the component against corrosion. Ekundayo (2004), summarised that cutting fluid is any substance that is able to provide cooling and lubrication during machining operations.

V. Types of Cutting Fluid

According to Smith (1987), cutting fluid may be in three forms, Solids, Liquid and gasses. Their purposes are, decreasing friction between the tool face and chip formed during cutting. Examples of the solid lubricants are graphite, molybdenum, disulphide and stick waxes. Liquid and gases used in cutting operation are broadly referred to as cutting fluid and they appeared in two forms:

- Mineral having water based oil
- Mineral having mineral based oil

Many additives are added to the cutting fluids which assist them in performing specific functions during cutting.

Water based oil are generally used where cooling is required. While mineral based oil are used where lubrication is needed. Krar (1984), grouped cutting fluid into active and inactive, Active cutting fluid darkened copper strip when it is immersed in it for three hours at a temperature 100°C or 212°F. Inactive cutting fluid is made of the following:

- Straight oil
- Fatty oil
- Fatty and mineral oil blends
- Sulfurized fatty- mineral oil blends.

They can be used where ferrous and the non-ferrous were been machined at the same time. British Petroleum company (1972) categorised cutting fluid as; Soluble oil Emulsion, Chemical coolant and neat cutting oil. The soluble oil emulsions are generally used where very high cutting speed and relatively low pressure on the surface of the tool are applied.

Muktar and Ibhabode (1999) said that 90% of the cutting fluids used were from soluble oil emulsion. Water – mixable oil or emulsifier oil are non-expensive coolant, it contains soap like materials that make them soluble in water and cause them to adhere to work-piece. They appeared in form of cream or milk-water colour. The portion of water for one pan of oil varies from 1 to 50. When not properly mixed (weak mixture), it causes rusting. During use, air circulation is required to reduce the removal of water via evaporation. Cutting fluid is an important factor in metal removal process to obtained the desired shape, hence they are not available in abundant and even when available the cost of purchasing them are beyond the reach of small-scale machine shops considering the exchange rates. Thus, many operators of these machines resulted into the use of ordinary water, soap mixed with water, ordinary palm oil, diesel-in–water, kerosene or dry cutting. (Ekundayo, 2004). The overall effect s of these actions on cutting process are; poor machining, quick tool wear, rough surface finish, rusting and changing of the work-piece internal structure due to chemical reaction.

Hence, in this paper, groundnut oil (GNO) a local vegetable oil was developed into emulsiable oil using emulsifiable agent, and extreme-pressure (EP) agent. The emulsifiable GNO is herein refers to as Ground Nut Soluble Oil (GNSO), and used for straight turning on a lathe machine and the results were compared to that of conventional cutting fluid (CCF).

VI. Methodology

In a bid to achieve the objectives of this research GNO was extracted from endosperm which was obtained after the removal of the ground nut kernel shell (nut), .The extraction was done by using solvent extraction method and this was done in an oil producing industry (JOF Ideal family Farm, Owo). Laboratory test was carried on it to determine its chemical composition. Reagents (Emulsifier and EP additive) and water were mixed with the GNO to develop the GNSO, and its physical properties were compared to that of CCF.

Experimental analysis was further carried out on the GNSO and its results were also compared with that of CCF. The two cutting fluids that is, the GNSO and CCF were used in carrying out machining operations on mild steel, using the same cutting speed, same chip thickness and the same Lathe machine. The physical properties of the two machined samples were compared and placed under observations for 70 days and observed for corrosion resistant. The data collated were analysed using the simple statistical analysis such as mean value, standard deviation and least regression method and their microscopic picture were also compared.

VII. Experimental Procedure

The GNO extracted from JOF Ideal Family Farm was initially tested to confirm its chemical composition, this was done when it was extracted at its crude state and the results were as shown in the table 1 below:

Table 1 : The laboratory Chemical composition of the extracted GNO

Properties	Crude GNO
Sponification value(mgKOH/g oil)	196
Iodine value(Wijs)	102
Unsaponifiable value	10g/Kg
Peroxide value	5mgO_2 /Kg
Refractive index (nD 40°C)	1.465
Moisture	0.2%
Acid value	0.6mgKOH/g
Relative Density 25°C/water at 25°	0.917
Soap value	0.05%

Sources: Author's laboratory tests result carried out at JOF ideal family farms (2004).

VIII. Solubility of GNO in Water to form Soluble Oil (GNSO)

At the natural state of oils, they will not dissolve in water that was why British Petroleum Company (1972) regards the use of soluble oil as a general terminology for cutting fluid as misnomer. According to Krar (1986) soluble oil or emulsifiable oil are those mineral oils that contain soap like mineral (emulsifier), which make them soluble in water. The emulsifiers break the oil into minute particles and keep them separated in the water for long. Hence, GNO was tested with some emulsifiers and EP additives , these were done in the Federal Polytechnic, Ado-Ekiti and the results obtained were shown in the tables 2 below; The two locally available emulsifiers are Na_2CO_3 (sodium trioxocarbonate iv) and $NaHCO_3$ (Sodium hydrogen carbonate)and they were used for the tests.

Specimen used.

- 10ml (millilitre) of GNO
- 6ml (millilitre) of emulsifier were mixed and samples observed.

Table 2 : Determination of emulsifying properties of the GNO

	Test	Observation
1	10ml of GNO was added to 6ml of Na_2CO_3 in test tube and agitated vigorously and left for five minutes	Both mixed together and form good emulsion. The colour turned from yellow to milky. The mixture remains in the form of fine disperse droplets even for three days
2	10ml of GNO was added to 6ml of $NaHCO_3$ in test tube and agitated vigorously and left for observation	The emulsion remains for 5 minutes and start to separate into two layers

Source: Laboratory experiment carried out at the Federal Polytechnic, Ado–Ekiti (chemistry) lab by the author (2004).

Table 3 : Experimental analysis for the determination of the appropriate EP additive for the development of the GNO into standard soluble oil

	Test	Observation
1	10ml of chloroform + 20ml of GNO in a test tube and agitated vigorously	Both mixed together perfectly
2	A pinch of sulphur was added to 20ml of GNO in a test tube and agitated, then heated to 40°C and above	The sulphur did not dissolve even when heated. At 40°C its melted , at 60°C it form a cake while at 96°C its melted and dissolved completely but the sulphur reappeared during cooling
3	10ml of GNO + 6ml of NaOCl in a test tube and agitated vigorously	It was observed that they both form good emulsion and it was milky in nature even after shake thoroughly.

Source: Laboratory experiment carried out at the Federal Polytechnic, Ado–Ekiti (chemistry) lab. by the author (2004).

Table 4 : Using the formation of saturated solution of NaOCl + Na_2CO_3 to form the GNSO

	Procedure	Observation
1	10ml of GNO + 6ml of saturated solution of NaOCl + Na_2CO_3, and agitated very well	They form good emulsion even when agitated vigorously. it was milky in nature

Source: Laboratory experiment carried out at the Federal Polytechnic, ado–Ekiti (chemistry) lab. by the author (2004).

IX. Results

From the various experiments carried out as shown above, the saturated solution of NaOCl (EP) and Na_2CO_3 (emulsifier) when added to the GNO formed perfect emulsifiable oil at ratio 1:2 without separation, flocculation and sedimentation even after being kept for over one hour. Other tests carried out following the ASTM to be sure of the suitability of the properties of the GNSO were: foaming test, pouring point, emulsion stability, PH test, viscosity and specific heat capacity.

a) *The Determination of the Reliability of the GNSO for Machining*

Adejuyigbe (1997), defined machine tool as power driven machines, while Oswald et al (1985), described it as an equipment that are capable of producing work piece to extremely fine tolerance. The developed GNSO and CCF (soluble oil emulsion) were used separately for cutting on a Lathe Machine in the Rufus Giwa Polytechnic workshop, Owo, Ondo State, Nigeria.

The method used for pouring was manual down pour cooling at an average of 20ml per minute. The work piece used was Mild steel of 25mm diameter. The length of cut was 38mm long. Observations were taken during each cutting to know the effectiveness of the GNSO as compared to CCF (see the table below).

	Local developed soluble oil (GNSO)	Soluble oil emulsion (CCF)
Initial Temp. °C of fluids before cutting	25	25
Final Cutting Temp. °C	36	36
Cutting speed (rpm)	230	230

Observation: During cutting GNSO shown little smoke but not as it was in the case of CCF which shown a visible smoke almost getting to flash point.

The surface finish of the two cutting samples were compared, the sample made from GNSO has a fine surface finish while that of CCF was not too coarse and not as fine as that of the sample from GNSO. The two samples were later left opened under atmospheric conditions and observed for 70days, measurement were taken daily and the final results was analysed. The microscopic pictures of the two samples were also taken and observed and their results show that the sample from CCF was majorly affected. (Fig.1 and 2 below).

Fig.1: Microscopic picture of Sample 1 after 70 days (groundnut emulsion as cutting fluid)

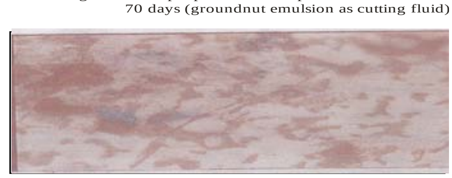

Fig.2: Microscopic picture of Sample 2 after 70 days (soluble oil as cutting fluid)

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X. Results Analysis and Discussion

The results obtained from the various experiments carried out during the development of the GNSO to Emulsifiable oil shows that NaOCl and Na_2CO_3 were two major favoured EP additive and emulsifiable agents and that at the mixture of their ratio of 1:2 of the saturated solution of the above agent formed the perfect emulsion of the GNSO as developed.

The mathematical analysis used in interpreting the data recorded from the two machined samples after being observed for 70 days under open atmospheric condition for corrosion tests were as shown below using the formula shown below to calculate for their means values and the standard deviation.

$$\chi = \frac{\sum^{n} f_1 x_1}{\sum^{n} f_1}$$ Where $\chi =$ mean value and χ_1 and

f_1 are the variable and frequencies

$$S^2 = \frac{\sum^{n} f_1(\chi_1 - \chi)}{\sum^{n} f_1}$$ $S =$ Standard deviation

The various results obtained from the calculation shows that, the mean value of the sample from GNSO = 53.76 while that of the sample from CCF = 53.05, the standard deviation are GNSO = 4.50and CCF = 4.92. To establish correlation between the developed soluble oil and the conventional soluble oil, least square regression method was used and from the graph of line of best fit, the developed GNSO was equally correlated as that of the CCF (0.946 and 0.949 respectively).

XI. Conclusion

It was obvious that metal cutting or metal removal require the use of force to penetrate the cutting tools to remove the excess and create the desired shape. The heat generate during this process if not adequately controlled could render the materials useless by creating poor surface finish, quick tool wear, and other damages to the metal. To reduce therefore the effect of heat generated during metal removal process, efficient cutting fluid is required for cooling and lubrication of the material. The development of GNSO to an emulsifiable oil to replace the conventional cutting fluid which was initially considered to be too costly and beyond the reach of the small- scale machine shops operators, as demonstrated when used for cutting operations, shows that the GNSO is reliable and suitable. This was further confirmed through the various tests carried out it using it as coolant and lubricant during cutting.

The formation of perfect emulsion of the developed GNSO occurs when the saturated solution of NaOCl+Na_2CO_3 and GNO were mixed at ratio 1:2. Other experimental analysis and their results showed that the developed GNSO is reliable and stable during cutting as shown from the following test; foaming, flash point, viscosity, PH value and the surface finish of the material after cutting and the correlation coefficient value of 0.946. In overall the sample from the GNSO shows more corrosion resistance than the CCF as shown from the microscopic pictures of the two samples. The cost of developing the GNSO was at an average of #114 per 30ml compared to#300 of equivalent CCF. Hence, this paper concludes that GNSO should be used to replace CCF since according to Kochhar (1981), Indian and Nigeria were rated 1st and 6th major producers of ground nut in the world. The excess production of GNSO could be exported for foreign exchange.

XII. Recommendations

With the reliability of GNSO for metal cutting operation as demonstrated from the various analyses shown above, Government should embark on mass production of the developed GNSO, so as to finally solve the problem of using the imported cutting fluid (CCF) which in all indications it is more costly coupled with its less resistance to corrosion compared to the newly developed GNSO made from ground nut oil, a locally available vegetable oil.

Companies and Individuals should be encouraged to invest on the production of this fluid so as to increase job opportunities and encourage exportation of this product for foreign exchange, this can be done by giving it publicity among the local and international market.

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