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Determination of Suitability of Screw Compressor Waste as an Alternative to Soluble Oil in Machining Operations

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Abstract: The objective of this work was to anticipate the suitability of screw compressor waste as an alternative to soluble oil in machinery. Analysis was carried out to ascertain the properties of the samples collected from functional and operational water cooled screw type compressor. Parameters for a typical cutting fluid obtained from three lubricant manufacturing companies were used as reference for this study. The result showed that waste obtained from the screw type water cooled compressor can be used as cutting fluid in a machine shop especially for mild steel material.

Keywords: Coolant, Cutting fluid, Mild steel, Screw compressor, Machine shop.

I. INTRODUCTION

In machining process, the tool removes material from the surface of a less resistant body through relative movement and application of force. The material removed called chip slides on the face of the tool submitting it to high coefficient of friction during chip formation. Most of the mechanical energy used to form the chip becomes heat, which generates high temperature in the cutting region [3]. A major portion of the energy is consumed in the formation and removal of chips. The greater the energy consumption, the greater the temperature and the frictional force at the tool-chip interface and consequently the higher is the tool wear. For this reason conventional coolant is often used on the cutting tool to prevent overheating [5, 6 and 8]. Machining leads to environmental pollution and health hazards mainly because of cutting fluids [1 and 2]. Skin exposure to cutting fluid can cause various skin diseases [7] such as folliculitis, oil acne and keratoses. Skin exposure to soluble, semi-synthetic and synthetic cutting fluid would result to irritant contact dermatitis and allergic contact dermatitis. Other effects of cutting fluid on health include lipid pneumonia, asthma and chronic bronchitis among others [2, 4 and 7].

Over time machining operation has been carried out using plain water as the coolant, to cool the cutter or cutting tool regardless of whether it provided any lubrication at the cutting edge-chip interface. Soda water was also used as coolant for better inhibition of rusting of the machine slides, red and white lead mixed into lard or lard oil was also used but for the lead toxicity it is absolute.

But more recently other additives have been developed to make cutting fluids more effective such as I, I, I,-trichloroethane this has also been phased out due to its ozone depleting and central nervous system –depressing properties [6].

These different properties of existing cutting fluids have necessitated further search for fluids with improved and better properties of cutting fluids for machining efficiency. There are generally three types of cutting fluids; minerals, semi-synthetic and synthetic. Semi synthetic and synthetic cutting fluids represent attempts to combine the best properties of oil with the best properties of water by suspending emulsified oil in a water base [10]. These properties include rust inhibition, tolerance of a wide range of water hardness, ability to work with different metals, resist thermal breakdown and environmental safety. In this study the cutting fluid developed here is the semi-synthetic fluid which is also called "soluble oil" which is an emulsion or micro-emulsion of water with mineral oil. This category of cutting fluid has been in use for several decades and even up to date in CNC machines [9 and 11]. Oil-injected screw compressors are machines that produce compressed air and delivering same to appliances or devices through piping. These compressors are available in either water or air cooled versions. These machines are sometimes robust, reliable in design, easy to service and environmentally friendly. Their efficiencies are high with low noise level. The class of oil injected screw compressor considered here is the water cooled type.

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This work therefore intends to investigate the suitability of the waste from the compressors of the water cool type as an alternative to soluble oil in machining operation. Sample of the compressor waste were collected and tested against standard parameters for soluble oils such as kinematic viscosity at 40^0C, pour point, sulphur level, oil content, Ph value, density, flash point, corrosion, break point and emulsion stability. Screw compressors are machines that pressurize liquid or gas such as water, oil and gas. There are positive displacement mechanisms where large volumes of high pressure air are needed either for large industrial applications or to operate high powered air tools and equipment. Their advantages over the other types include; low leakages and low parasitic losses [9]. Using normal clean water with rotor inject oil of the following specification, density 860kg/m^3, flash point 240^0C pour point 39^0C and viscosity at 40^0C to be 45.2. This oil has low forming tendency, high resistance against oxidation, good protection against corrosion, excellent seal compatibility and maintains excellent internal surface cleanliness. The wastes from these compressors are often emptied into gutters and earth surface, causing pollution of different magnitude. Therefore it became imperative to convert these wastes to useful substances.

II. MATERIALS AND METHODS

A. Materials

Samples of waste products were obtained from a cement manufacturing company located in Calabar, Southern Nigeria and laboratory analysis carried out on these samples. Equipment used in this analysis included; Ph meter, spectrophotometer, density bottles, test tubes, titration set, measuring cylinders, pycnometer, volumetric and conical flasks.

B. PREPARATION OF SAMPLES AND TESTING OF PROPERTIES

The properties tested, for were viscosity, pour point sulphur, oil content, Ph values and density, color determination and viscosity. Kinematic viscosity of the waste product was used to measure its viscosity. Testing was done at 40^0C using the Houillon viscometer baths and result obtained were recorded in table I.

PH VALUE: This was done using a Ph meter which was standardized with a Ph electrode and butters of Ph 4 and at the temperature of 28^0C and the Ph meter was set at 0 and the electrode dipped into the beaker of the waste sample and the Ph value was observed and recorded.

SULPHUR CONTENT: Sulphur content was determined by using precipitation method, sulphur ions were precipitated in an acid medium with barium chloride (BaCl) to form barium sulphate ($BaSO_4$) crystal of uniform size. Light absorbence of the $BaSO_4$ suspension was measured by spectrophometer and the concentration was determined by reading the standard after 20 minutes of stirring with a spatula at constant speed.

DENSITY: The determination of density of the compressor waste was done using the pycnometer which is one of the most precise methods of density determination for liquids. Distilled water was used on the pycnometer glass flask with a close fitting ground glass stopper with a capillary hole through it. The pycnometer was filled with distilled water and the volume of the water was determined using the formula $V = \frac{M_{H_2O}}{\rho_{H_2O}}$

Where M_{H_2O} is experimentally determined weight of water (empty pycnometer weight subtracted).

The procedure was repeated for the compressor waste (liquid) with 4 unknown densities ρL and the weight (ML) was also determined (measured weight minus weight of empty pycnometer).

The final value of the density of the compressor waste was determined using the relation, $\rho L = \frac{ML}{MH_2O} . \rho H_2O$

Where ML is weight of liquid and ρL is liquid with unknown density.

III. RESULTS AND DISCUSSION

The result of the compressor waste and those of the reference lubricant manufacturing companies are shown in Table I.

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Table I: Comparative Results of the three Lubricant Companies and the Tested Samples

Properties	Chevron/ Texaco bright-cut	Conoco Phillips Soluble oil	Oando Soluble oil	Sample (test)
Viscosities cp or ps	4.68	28.5	42	18.55
Pour point	21.2	-20	-21	-15.0
Sulphur %	0.10	0.28	2.0	0.20
Oil %	1.8	Nil	1.0	1.5
Density g/mm^3	1.0	0.64	0.91	0.66

The compressor (oil inject screw compressor) where the samples were gotten has the specification as follows; Atlas Copco type ZR300 50Hz, 7.5 bar free air delivery (1643Cfm, 46.5M^3/min and 775L/S) for dry air absolute meet pressure of 14.5Ps; and cooling and air intake temperature of 68^{0}F and nominal working pressure with installed motor capacity of 315kw, cooling water consumption rate of 63gpm, at the rise of 27^{0}F after cooler approach temperature of 4^{0}F and sound pressure level of 70 dB(A)±3 dB(A) according to Pneurop (PN8N TC 2.2) test code measured at a distance of 1meter.

Cutting fluid generally increases the economy of cutting tool when used and it becomes easier to keep close tolerance and maintain work-piece properties without damage. From the values shown in Table 1.0, the free flow of the fluid which is the viscosity can really affect the machining process. The relative viscosities of the reference source show that our viscosity result lies between the range of the Chevron/Texaco and ConocoPhillips soluble oil. Addition of about 6% of fatty acid to the waste condensate can improve the viscosity to an acceptable value, this is because for Chevron/Texaco oil with viscosity of 4.68 it is normally diluted with some amount of water before it is used in some work pieces like mild steel.

For the Ph value from table 1.0, the condensate show a comparable value to the referenced valued of Chevron/Texaco oil and Oando oil. In this case a relative percentage of caustic soda can be added to the waste condensate to increase its alkalinity and subsequently enhance the Ph value. The density of the waste condensate at 15^{0}C shows an acceptable value with those of ConocoPhillips and Oando soluble oils.

Other properties tested upon such as color, water concentration and sulphur falls within acceptable standards. From Table 1.0, the viscosity of the waste sample was found to be 18.55 compared to Chevron/Texaco oil, ConocoPhillips oil and Oando soluble oil with the radius of 4.68, 28.5 and 42.0 respectively. This show that 6% of fatty oil can be added to the compressor waste to increase the viscosity to achieve better cutting efficiency when compared to the Chevron/Texaco oil and 3% to achieve Oando soluble oil efficiency equivalent. The Ph values of the compressor waste sample was measured to be 8 while those of Chevron/Texaco oil, ConocoPhillips and Oando oil were 9, 9.6 and 8 respectively. This agrees with the Ph value of Oando oil but caustic soda can be added to the waste sample to achieve an average Ph value of the standard cutting fluid. The density of the waste sample at 15^{0}C was found to be 0.66g/mm^3 while those of Chevron/Texaco, Conoco Philip and Oando soluble oil were 0.1, 0.64 and 0.91 at the 15^{0}C respectively. These show that, the density of Conoco Phillips agrees with the waste sample. In which case for every property of the cutting fluid testing each of the value obtained falls within one of the reference lubricant manufacturing companies' values.

IV. CONCLUSION

The sample can be used as the cutting fluid because the values of properties tested shows that it has the ability to remove heat during machining operation. The sample can be classified into semi-synthetic fluid concentrate with moderately low mineral oil. Based on the analysis carried out on the screw compressor waste it can be used as cutting fluid in machining operation. Further work can be done on the screw compressor waste on its corrosive effect on the machine surface and its effect on other steels like medium carbon steel.

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