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Experimental Investigation of Lubrication by Wax Dissolved in Chemical Lubricant

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Abstract

Lubrication can describe the phenomenon where reduction of wear occurs without human intervention .It is an important fact while considering reduction of friction and wear. The aim of this project was to improve the lubrication ability of a lubricant by the addition of wax into it. Wax was added to lubricant to modify the lubrication properties. Ester was chosen as the lubricant whose properties were to be improved which has been successfully used in lubrication for more than 50 years. The properties that have impact on the behavior of a lubricant such as density, pour point, viscosity etc had been observed for pure ester as well as for wax-ester mixture with 4%, 5%, and 6% wax in it. The test results showed that improvement took place in these properties with the increase in percentage of wax. Also the comparison of resistance to wear of ester and wax-ester mixture gave a clear indication of improved lubricity of wax ester mixture.
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Keywords: Lubrication, ester, wax, lubricant.

1. Introduction

Lubrication is the process or technique employed to reduce wear of one or both surfaces in close proximity, and moving relative to each other, by interposing a substance called lubricant between the surfaces to carry or help carry the load (pressure generated) between the opposing surfaces. Reducing friction is the main objectives of lubrication, but there are many other benefits of this process. Lubricating film can help prevent corrosion by protecting the surface from water and other corrosive substances.
Currently, the lubrication is a decisive factor in the power of being a source of competitiveness gains, providing improvements in equipment performance, and especially the reduction in maintenance costs **[1].**
Differing widely in viscosity, specific gravity, vapor pressure, boiling point and other properties, lubricants also offer a wide range of selection for the increasingly varied needs of modern industries.
Lubricants containing oil have additives that enhance, add or suppress the properties within the base oil. The amount of additives depends on the type of oil and the application for which it will be used.
The objectives of this project were to study about lubrication and lubrication by ester, to modify the lubricant properties of chemical lubricant by adding wax, to measure the lubricant properties of the modified lubricant and finally to compare the lubrication by wax-ester mixture with chemical lubrication.

2. Theoretical aspect

Esters are the reaction products of acids and alcohols. Within the realm of synthetic lubrication, a relatively small but still substantial family of esters have been found to be very useful in severe environment applications.
Synthetic oils are manufactured polyalphaolefins, which are hydrocarbon-based polyglycols or ester oils **[2].**
Esters have been used exclusively in jet engine lubricants worldwide for over 40 years due to their unique combination of low temperature flow-ability with clean high temperature operation. Esters are also the preferred stock in the new synthetic refrigeration lubricants used with CFC replacement refrigerants. In automotive applications, the first qualified synthetic crankcase motor oils were based entirely on esters and these products were quite successful when properly formulated. Esters are nearly always used in combination with PAOs in full synthetic motor oils in order to balance the effect on seals, solubilize additives, reduce volatility, and improve energy efficiency through higher lubricity.
In many cases, the very same equipment which operates satisfactorily on mineral oil in one plant could benefit greatly from the use of an ester lubricant in another plant where the equipment is operated under more severe conditions.

3. Test procedure

Density, viscosity, flash point,pour point,surface tension and acid number were tested. The test procedures are discussed below.

Density test

Density is a key property not only in lubricants but in all fluids. It is the measure of the mass of a substance in relation to a known volume **[3].** Density test were done with a density kit along with a balance by the following formula-

$$\rho = (M2-M1)/V \tag{1}$$

Fig. 1. Density kit and digital balance

Where,M1 is mass of the mass of the density kit when it was empty in gm and M2 is the mass of density kit when it contained V cc of the lubricant.

Viscosity test

Viscosity is the resistance to flow **[4].**Viscosity test was done by using Saybolt viscometer. Time (t) for flowing 60 mL of liquid was measured in seconds and viscosity was calculated from the following formula-

$$\upsilon = 0.0022t - 1.95/t \text{ [when } t < 100] \tag{2a}$$

$$\upsilon = 0.0022t - 1.35/t \text{ [when } t > 100] \tag{2b}$$

$$\mu = \upsilon*\rho \tag{3}$$

Where ν is kinematic viscosity in stokes, t is in seconds, μ is absolute viscosity in Poise and ρ is density of the oil in gm/cc.

Fig. 2. Saybolt viscometer for viscosity measurement

Flash point determination

The flash point of oil is the temperature at which oil begins to burn**.**

Fig. 3. Closed cup flash point tester

Flash point was tested using a closed cup flash point tester. The cup containing the lubricant sample was heated.At intervals a flame was brought over the surface. The temperature at which ignition began, was found by a digital thermometer which was recorded as the flash point.

Pour point determination

The pour point of lube oil is the temperature when the oil stops flowing smoothly as a liquid. Pour point test was done in domestic refrigerator. A sample of lubricant was chilled in a test jar to a set of defined temperatures. At each temperature the test jar was tilted horizontally. When the fluid did not flow within 5 seconds, then that was the experimentally determined pour point. The recorded temperature was 3°C higher.

Fig. 4. Pour point determination

Surface tension calculation

Surface tension is the elastic tendency of liquids which makes them acquire the least surface area possible **[5].** Surface tension was calculated in capillary rise method using three capillary tubes by the following formula-.

$$S_1=0.5*\rho*g*r_1*(h_1+r_1/3) \quad (4a)$$

$$S_2=0.5*\rho*g*r_2*(h_2+r_2/3) \quad (4b)$$

$$S_3=0.5*\rho*g*r_3*(h_3+r_3/3) \quad (4c)$$

Where r_1, r_2, r_3 are internal tube radius in cm ; h_1, h_2, h_3 are height of liquid meniscus in cm; S_1,S_2, S_3 are surface tension in dynes/cm.

$$S = (S_1 + S_2 + S_3) /3 \quad (5)$$

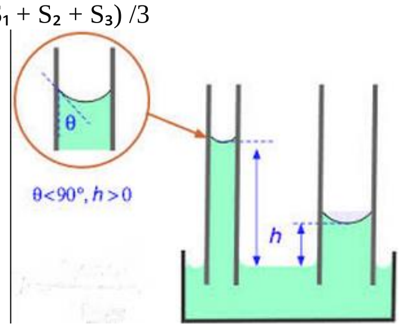

Fig. 5. Surface tension calculation

Acid number test

Acid number is an important quality measurement of crude oil and used as a guide in the quality control of lubricating oil formulations. Acid number was tested using color-indicator titration method by the following formula.

$$\text{Acid Number, (mg NaOH/g sample)} = V \times N \times 56{,}1 / P \quad (6)$$

Where V is milliliters of NaOH solution required for sample titration, N is normality of NaOH solution and P is grams of sample used

4. Discussion

The project was performed with a view to investigating lubrication by wax dissolved in chemical lubricant. Methyl acetate ester was used as the chemical lubricant since it was easily available in market.

Variation of density with weight percentage of wax in Fig.6.showed that density increases with the increasing weight percentage of wax. The rate of increase of density suddenly became very high at 6% wax-ester mixture. As the density increases, the fluid becomes thicker. Thus the distance between contacting surfaces increases and friction is reduced.

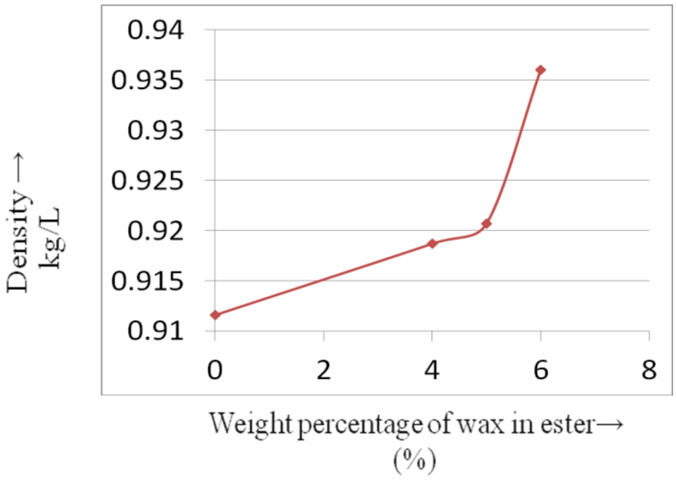

Fig. 6. **Re**lation between weight percentages of wax and density

Fig. 7. showed that the kinematic viscosity gradually increases with the increasing weight percentage of wax. With the increase in viscosity, the ability of the lubricant to resist shearing increases, which affects the improvement of machinery life.

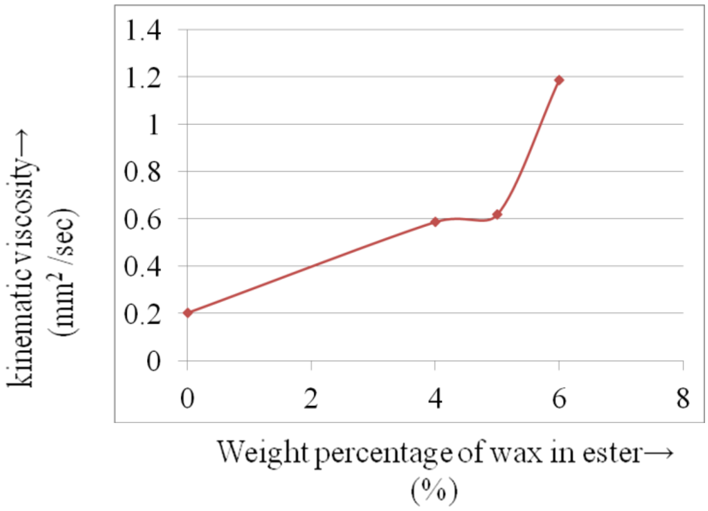

Fig. 7.Relation between weight percentages of wax and kinematic viscosity

It was observed that the pour point of wax-ester mixture was very low (less than -20°C) .That's why it would be successfully used as lubricant in low temperature condition rather than high temperature.
Often lubricant will come in direct contact with flame or enough heat generated from the friction of moving parts will cause it to burn. It is important to use lubricant with a high flash point as it is more stable and will withstand higher temperatures, burning less.
It was seen from Fig. 8. that flash point increased with wax percentages though the variation is very small.

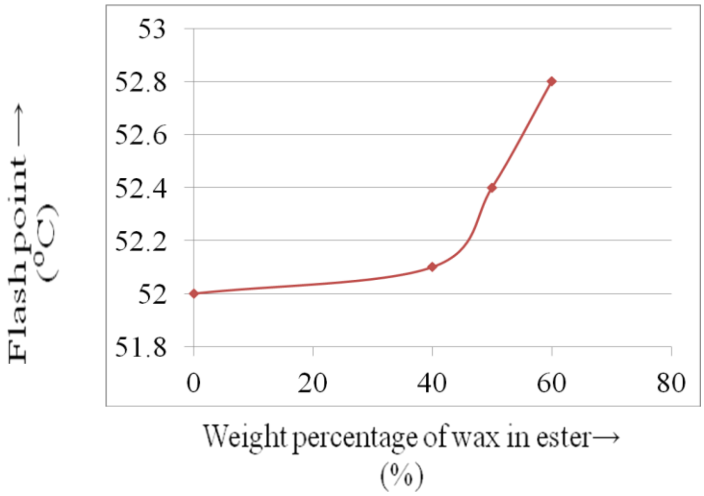

Fig. 8. Relation between weight percentages of wax and flash point

From Fig. 9. it was found that up to 4% wax, the surface tension remained almost constant There was a slight increase when wax was 5% and a rapid increase occurred when the percentage of wax was increased to 6%.Due to increase in surface tension ,the lubricant become more resistant to oxidation and contamination so that lubrication property improves by the addition of wax.

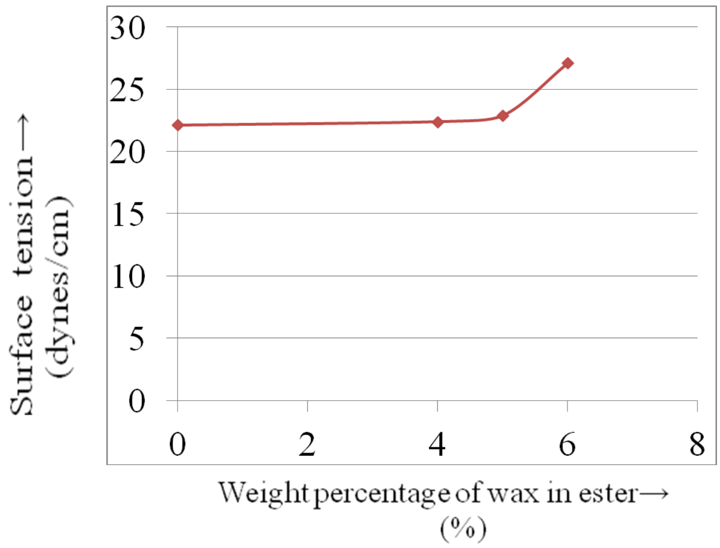

Fig. 9. Relation between weight percentages of wax vs. surface tension

Fig. 10. showed that the acid number gradually increases with the increasing weight percentage of wax. AN was tested in order to prevent problems such as machine corrosion, wear, varnish and clogged filters.

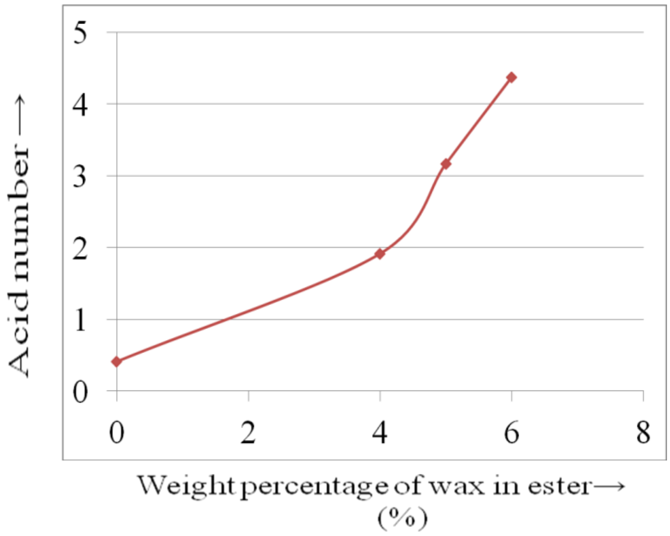

Fig. 10. Relation between weight percentages of wax vs. acid number

From the analysis of effect of ester and wax-ester mixture on wear behavior, it was seen that wax-ester mixture showed better resistance to wear than ester.

Since methyl acetate has a very low boiling point (about 56.9 ^{o}C) at high temperature wax-ester mixture got evaporated. But if wax could be added with ester of high boiling point then lubricity of the esters could be improved by the addition of wax.

One of the objectives of this project was to study about lubrication and lubrication by ester which has been fulfilled in the "theoretical aspect" section. The lubricant properties such as density, viscosity, flash point, surface tension, acid number have been measured for pure ester first and then for modified wax-ester mixture. From the property measurement, it was clearly observed that wax-ester mixture has shown an improvement in these properties.

5. Conclusion

Various features about lubrication such as its regimes, lubrication properties etc along with role of ester in lubrication were studied. Lubricating properties such as density viscosity acid number, surface tension etc were measured for both pure ester and wax-ester mixture containing 4%, 5%, and 6% wax respectively. The variation of these properties with increasing percentage of wax was also shown to compare the effect of wax in the lubrication of ester. From wear test it was found that the lubricity of ester increased with the addition of wax.

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