Performance analysis of ceramic hybrid lubricant

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Abstract:
The aim of the present work is to synthesize and analyze the mechanical properties of a semi solid engine lubricant which is made up of graphite and kaolin as major constituents which are mixed with CNSL (Cashew Nut Shell Liquid) lubricant as the resin. A normal engine lubricant needs to be drained in an average time interval of 3000kms or 6 month time periods since it loses its properties. A very large quantity of engine oils and coolants are disposed in each service station as waste during each day. So it is necessary to increase the durability of lubricant without losing its properties. The heat dissipation properties, viscosity, thermal conductivity, adhesiveness, wear resistance, etc. of this lubricant is also analyzed and studied.

Key words: Graphite, Kaolin, Lubricant, CNSL, Coolant, Viscosity, Thermal conductivity

1. Introduction

A lubricant may be a material, usually organic, applied to scale back friction in mutual interaction between surfaces, which essentially decreases the heat induced as the surfaces move. This may also be used to transmit forces, transmit foreign particles, or heat or cool the surfaces. The minimize friction property is known as lubricity. Engine oil or engine lubricant is among a number of substances consisting of base oils enhanced with additives, in specific anti-wear additives plus detergents, dispersants, and viscosity index improvers for multi grade oils. Engine oil can be used to lubricate combustion engines. Engine oil has the main function of reducing friction and wear on rotational motion, moving parts and cleaning the engine from sludge and varnish (detergents)[13]. It also neutralizes acids from fuel and lubricant oxidation (detergents), increases piston sealing and cools the engine by bringing heat away from the engine.
Also, the gasoline and especially the additives undergo thermal and mechanical degradation which reduces the oil's viscosity and reserve alkalinity. The oil is not as capable of lubricating the engine at reduced viscosity, thereby increasing wear and thus the risk to overheat. Reserve alkalinity is therefore the oil's capacity to withstand acid production. When the reserve alkalinity decreases to zero, the engine becomes corroded by such acids. The quality of the oil used is also important, particularly with synthetics (synthetics are more stable than conventional oils). Many manufacturers (e.g. BMW and Volkswagen with their respective long-life standards) resolve this, while others do not. For a shift in the fuel, manufacturers advise not to surpass their time or distance-driven period. Most of the new technology cars now report somewhat higher intervals for filter and oil change, with the “extreme” service restriction being required. This refers to short journeys of less than 15 km (10 mi), where the oil does not reach maximum operating temperature well enough to burn off condensation, excess fuel, and other contaminants resulting in "sludge," "varnish," "acids," or other deposits. Most manufacturers have engine computer calculations to measure the state of the oil assisted variables that degrade it, such as RPM, temperatures and duration of the trip; one device uses an optical sensor to assess the visibility of the oil inside the engine. Such devices are usually known as Oil Life Monitors (OLMs). A standard engine oil must be drained within an average time period of 5000 kms or 6 months, because it loses its properties.

2. Literature Review

During every day very large amounts of engine oils are generated as waste at each service station. So the longevity of engine lubricant must be improved without losing its properties. Different processes such as centrifugal separation, magnetic separation, vacuum dehydration/distillation, acid refining, and solvent refining can regenerate the used lubricant oil. These are discussed briefly as below:

N.N.Li [1] found that centrifugation separated wax and oil. To reach a broad efficiency, chill levels can be employed more than 100 times those used in traditional processes. Plate-type crystals give maximum initial settling rate and compaction of waxes. Using modifier, crystal needles can be turned into aggregates to increase centrifugation efficiency.

M.A. Scapin et.al.[2] indicated that in the environmental protection sense, the recycling cycle of the mineral oils used has acquired a very significant distance. The lubricating oils are not consumed entirely during their use by petroleum mineral oils; therefore, it is appropriate to use a treatment for recovery seeking their reuse. Jesusa Rincon et.al.[3] identified that a composite solvent for the recovery of base oil from used lubricant oil was developed by proper selection of components and compositions. There are two main components of the dissolvable composite: methyl ethyl ketone (MEK) and 2-propanol. The best extraction results were obtained when the single solvents selected were combined to a proportion of 2-propanol/MEK of 3 g/g. This solvent was also unable to extract metals and oxidation products entirely, however. To solve this problem, very small amounts of KOH [from 1 to 7 g/kg of solvent] were applied to the composite solvent, and its impact on both the extraction yields and the recovered oil quality was established. The most acceptable concentration of KOH 2 g/ (kg of solvent) was found. The vacuum distilled oil pretreated with this solvent (2-propanol / MEK at a weight ratio of 3 g / g to 2g of KOH)/(kg of the solvent)) was almost identical to virgin oil and, thus, appropriate for identifying new lubricants. Extraction of CNSL oil from cashew nut shell includes the open pan roasting, drum roasting, hot oil roasting, cold extraction, solvent extraction, supercritical fluid extraction [4], pyrolysis process [5,6]. The Soxhlet extraction process [7] and work were performed to increase the percentage of yields from the raw cashew nut using modern extraction
methods such as Sub Critical Water extraction and two-step extraction methods [8]. The percentage yield of oil varies with the form of extraction. Because the process of extraction varies, the volume and consistency of the oil vary with the amount of Anacardic acid, Cardanol and cardol composition. There are two types of CNSL oils, known as regular or immature (CNSL) oil and professional (CNSL) oil. CNSL concentrations are 70% anacardic acid, 18% cardol, 5% cardanol, and other phenols and fewer polar compounds exist. The composition of CNSL oil is 83-84 percent cardanols, 8-11 percent cardol, 10 percent polymeric materials and methylcardol traces [9].

CNSL has many medicinal and industrial applications as it can easily react to the formation of different derivatives, including polymers and resins [10]. It can substitute phenol with a proportionate or better outcome of Phenolic Products for any application: Since of the electrochemical process, CNSL decreases the corrosion on carbon steel surfaces. Its efficiency declines as temperature increases. CNSL and its derivatives are of anti-oxidant nature. CNSL-derived poly films additized with new antioxidant thiophosphate esters have improved film thermal stability in the presence of thiophosphate ester additives [11]. Cardanol related polyhydrins have been used as sensitizers to import the bare TiO2 photo-catalytic action. The porphyrins are brown-red, sticky solids, in CHCl2 or CH2Cl2, very soluble.

In this research, we aim to synthesize and examine the mechanical properties of a semi-solid engine lubricant consisting of graphite and kaolin as major components that are mixed as resin in CNSL (Cashew Nut Shell Liquid) lubricant. The properties of this lubricant for heat dissipation, viscosity, thermal conductivity, adhesive property, wear resistance, etc. are also tested and studied.

3. Types of Lubricants

A record 37,300,000 tones excess of lubricants were used worldwide in 1999. Automotive applications dominate, but other automotive, marine and metal-working uses are still major lubricant users. Despite the fact that air and multiple gas-based lubricants are known (e.g. in liquid heading), the industry is dominated by fluid greases, accompanied by solid lubricants. Lubricants are usually made up of a majority of base oil, with a variety of additives to express attractive properties of lubrication purposes, mineral oil, vegetable oils, concrete lubricants; poly tetra fluoro ethylene (PTFE), inorganic solid and metal/alloys are used. Anti-tack coating is the main feature of lubricants, holding moving parts apart, minimizing friction, heat transfer, transmission power, Protect against wear, Prevent corrosion and seal of gases.

3.1 LIMITATIONS OF TRADITIONAL LUBRICANTS

- Disposal of lubricant in open environment contaminate water body and air breathing of soil.
- The cost of maintenance and replacement of lubricants are costly and should be done regularly.
- If the wrong lubricant is applied or used, the functions are unlikely to be carried out efficiently - which can result in seizure, overheating and damage.
- Oil lubricants cannot be broken down to a level that just rots away and disappears such as organic waste. Heavily polluted areas must be professionally cleaned at high expense.
4. Materials Required

1. Kaolin  
2. Graphite Particles  
3. Cashew Nut Shell Oil (CNSL)

Kaolin is a type of clay found in nature shown in figure 1. It can also be made in a laboratory. People use it to make medicine. Kaolin is used for mild-to-moderate diarrhea, severe diarrhea (dysentery), and cholera. Kaolin is sometimes applied to wounds to help stop bleeding. It may also be applied to the skin to dry or soften the skin.

Graphite, referred to as plumbago, is a crystalline allotrope of carbon, a semimetal, a native element mineral, and a form of coal which is shown in figure 2. Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in thermochemistry as the standard state for defining the heat of formation of carbon compounds.

CNSL or Cashew Nut Oil or Cashew Shell Oil or CNSL Oil is a versatile by product of the Cashew industry. The nut has a shell of about 1/8 inch thickness inside which is a soft honey comb structure containing a dark reddish brown viscous liquid shown in figure 3. It is called CASHEW NUT SHELL LIQUID or CNSL. This is the pericarp fluid of the Cashew Nut. It is often considered as the better and cheaper material for unsaturated phenols. The physical properties of CSNL is shown in the table 1.

| Components                      | Specifications       |
|---------------------------------|----------------------|
| Specific Gravity 300°C          | 0.950 - 0.970        |
| Viscosity 30°C in centipoises   | 200 max              |
| Moisture by weight              | 1.0 max.             |
| Ash % by weight                 | 1.0 max.             |
| Iodine Value : (min.)           | 250                  |

5. Synthesis of The Product

The various steps involved in the synthesis of the product are shown in figure 4.
5.1 PROCEDURE OF SYNTHESIS

- Kaolin (10%) of 22μm size is mixed with graphite (40%) of 65μm.
- Then this quantity is ball milled for 24 hours to reduce the size and for the perfect mixing of the particles.
- After ball milling, the resultant product is given a settling time.
- Then they are dried at 65°C for 6 hours in a drier.
- After being dried, 20g resultant dried powder is mixed with 20ml of CNSL oil.
- Then the re-dispersion process is done.
- The required product is synthesized and is ready.

Fig. 4 Process Flow Chart

After synthesis procedure the required final product we got is shown in figure 5.

6. Results & Discussion

6.1 Thermogravimetric Analysis (TGA)

Thermo gravimetric (TG) is a branch of thermal analysis examining the mass changes of a sample as a function of temperature (in the scanning mode) or as a function of time (in the isothermal mode). Thermal gravimetric analysis or thermo gravimetric analysis (TGA) is a method of thermal analysis in which changes in physical and chemical properties of materials
are measured as a function of expanding temperature (with consistent heat rate), or as a component of time (with steady temperature and additionally consistent mass loss). Isothermal or Static TGA, for this situation, test is kept up at a steady temperature for a while during which change in weight is recorded. The figure 6 shows the results between the weight loss in mg and the temperature.

![Graph showing Weight Loss (mg) vs. Temperature (°C)](image)

**Table 2. Temperature range and %Weight loss**

| Temperature range      | %Weight loss |
|------------------------|-------------|
| 33.56– 229.26          | 2.68        |
| 229.26– 406.28         | 18.722      |
| 406.28– 617.26         | 25.768      |
| 617.26– 881.72         | 3.613       |
| 33.56 – 881.7 (T.Wt loss) | 50.783    |

From the table 2, it is observed that during the first phase of the decomposition, only 2.68% of the total weight has been decomposed. In the second phase of the decomposition, 18.72% of the total weight has been decomposed in the temperature range of 230-400 degree Celsius. In the third phase of the decomposition, only 3.61% of the total weight has been
decomposed. In the first phase, all the water content present in the material is removed. In the second and third phase, the solvent present in the material starts to decompose. About 0.83mg of the material has been decomposed in the first phase. In the second phase, about 5.61mg of the material is decomposed. In the 3rd phase, 7.99 mg of the material is decomposed. In the final stage, it is observed that only 1.12mg of the material has been decomposed

6.2 Hydrophobicity test

Hydrophobicity is the property of a molecule (known as a hydrophobe) that's seemingly repelled from a mass of water. In contrast, hydrophiles are interested in water. Hydrophobic molecules tend to be nonpolar and, thus, prefer other neutral molecules and nonpolar solvents. Because water molecules are polar, hydrophobes do not dissolve well among them. Hydrophobic particles in water frequently bunch together, forming micelles. Water on hydrophobic surfaces will exhibit a high contact angle which is shown in table 3.

| Condition     | Nature      | Surface Energy | Effect                          |
|---------------|-------------|----------------|---------------------------------|
| $0^\circ < 90^\circ$ | Hydrophilic | Increases      | Water droplets spread out       |
| $0^\circ > 90^\circ$ ($90^\circ$-$120^\circ$) | Hydrophobic | Decreases      | Water droplets, beads-up        |
| $0^\circ > 150^\circ$ | Super-hydrophobic | Decreases    | Water droplets highly beaded; repelled |

Thus the test material is found out to possess the physical property that will repeal a mass of water and the sample is said to be hydrophobic because it shows a contact angle of $107\pm2^\circ$.

6.3 Muffle furnace test

A muffle furnace may be a furnace during which the topic material is isolated from the fuel and every one of the products of combustion, including gases and flying ash. This confirms the thermal stability of our ceramic hybrid phase changing lubricant. This test proves the hybrid ceramic phase changing lubricant is stable up to 422 degree Celsius. Figure 7 shows the test sample is inside the muffle furnace.

Fig 7. Lubricant inside furnace
6.4 Rheometer – to test the viscosity

A rheometer could be a laboratory device used to measure the way within which a liquid, suspension or slurry flows in response to applied forces. It is used for those fluids which can’t be defined by one value of viscosity and thus require more parameters to be set and measured than is the case for a viscometer. The graph has drawn from the results taken from the rheometer which is shown in Figure 8 and Figure 8.

![Graph showing Viscosity (Pa.s) vs. Speed (1/min)](image1)

**Fig 8.** Graph showing Viscosity (Pa.s) vs Speed (1/min)

![Graph showing Viscosity (Pa.s) vs. Shear rate (1/s)](image2)

**Fig 9.** Graph showing Viscosity (Pa.s) vs. Shear rate (1/s)

By observing the graphs we can see that viscosity decreases as speed and shear rate increases. After studying the above graphs we can conclude that the lubricant we synthesized has similar properties compared to the results of the existing lubricant.
7. Conclusion

At present, there is a need for a wear resistant, durable lubricant with good mechanical properties which can reduce the wastage of oils. By following the work plan mentioned, we aim to synthesis and analyses a phase changing hybrid lubricant which can serve as a variable replacement for conventional lubricants used. This ceramic hybrid lubricant does not need to be changed regularly because of its chemical properties and will avoid the wastage of lubricants in the industry. The synthesis of this hybrid lubricant is comparatively easy and can provide better lubrication and coolness respective to the applications. It can be used in closed bearing as a lubricant instead of grease. After adding additives it can be used as engine lubricant in wood cutters and similar small engines. Used to reduce the heat expelled between the gears of heavy machineries.

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