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Comparative Analysis on Sodium-Based and Polyethylene-Based Greases as Anti-Friction Agents

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ABSTRACT
The activities of greases have been well utilized for regular lubrication purposes, as well as in friction control in machineries. These have, over the years, led to the increased demand for the product, which in turn have opened ways of livelihood to many. But the more attractive this business becomes to the dealers, the more sub-standard products fill up the market, especially in our localities. Many users of the products, thus, resorted to patronizing importers of these products, who deal mainly on Sodium-based greases that are after all not the best (in spite of their cost). The present study tends to draw attention to an alternative 'friction controller' – the Polyethylene Grease (otherwise called Copolymer greases) through a concise comparative analysis with the commonly used Sodium-based grease. The study samples were normally formulated by dispersion of low-density polyethylene in base oil at varying capacities, through saponification, evaporation, milling (homogenization) and filtration of the dispersed thickener in the base oil; Polypropylene was used as an additive to enhance the binding property of the product. A blend of the two grease samples (Sodium and Copolymer) was also obtained at the ratio of 1:3. Results of analysis conducted on the products showed that the Sodium-based grease has a higher dropping point (120-190^oC) when compared with the Polyethylene and the blended greases, whose dropping points both fall between 120 – 185^oC. The worked penetration for Polyethylene grease was found to be 280-340, while that of the Blended and Sodium are 275-340 and 230-340 respectively. Also, the copolymer grease appeared smooth and soft, while the Sodium grease appeared buttery and fibrous. However, it was demonstrated that the Copolymer grease is of better grade than the Sodium-based grease, and would resist water penetration very readily as well.

Keywords: *Comparative Analysis, Sodium-based, Polyethylene-based, Grease.*

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I. INTRODUCTION

Grease from the early Egyptian or Roman eras is thought to have been prepared by combining lime with olive oil. The lime saponifies some of the triglycerides that comprise oil to give calcium grease. In the middle of the middle of the 19th century, soaps were intentionally added as thickeners to oils. Over the centuries, all manner of materials have been employed as greases. For example, black slugs "Arion ater" were used as axle grease to lubricate wooden axle-trees or carts in Sweden (Svanberge, 2006). The oil Mist principle was developed by a bearing manufacturer in Europe during the 1930s. The problem that nurtured this development was the inability to satisfactorily lubricate high speed spindle bearings on grinders and similar equipment. The speed of these bearing was too high for grease lubrication, and liquid oil generated too much heat through fluid friction, necessitating an expensive recirculating system. Continuous thin-film lubrication with oil Mist provided a solution. The purging and slight cooling effects of the carrier air gave additional benefits. The oil Mist generator resulted later from this development and used a small amount of air to produce a less dense concentration of small oil particles. About 97% of these particles could be transmitted to the bearings without condensing in the piping, regardless of the distance of the bearings from the oil Mist generator itself.

In some cases, the lubrication and high viscosity of grease are desired in situations where non-toxic, non-oil based materials are required. Carboxymethyl Cellulose (CMC) is one popular material used to create water-based analogue of greases. ***CMC*** serves both as a thickener to the solution, as well as to add a lubricating effect to the device, after which silicone-based lubricants could be added for additional lubrication. The most familiar example of this type of lubricant, used as a surgical and personal lubricant, is k-y Jelly. After a few decades, air heaters were developed because it was discovered that, by heating the air used to generate oil Mist, oils of just about any viscosity could be atomized. Many applications, subject to extremes in ambient temperature, use air heaters to ensure a constant oil/air ratio regardless of the oil viscosity. Today oil Mist is still used to lubricate high speed spindles in grinders. Included in the increasing range of oil Mist applications are systems applied to all types of other machine tools, web and sheet processing equipment, belt and chain conveyors rolling mills, vibrators, crushers, centrifuges, kilns, pulverizers, ball mills, dryers and liquid processing pumps.

Regrettably, sodium-based greases that are commonly used in our devices are no longer promising as they are readily soluble in water. However, classification and standards jointly developed by ASTM international, the National Lubricating Grease Institute (NLGI) and the Society for Automotive Engineers (SAE) International, for automotive service greases was first published in 1989 by American Society for Testing and Materials (ASTM) international. It categorizes greases suitable for the lubrication of chassis components and wheel bearing vehicles, based on performance requirements, using codes adopted from the NLGI's ***"Chassis and wheel bearing service classification system"***.

The present study, therefore, tends to draw attention to comparative features of the water-soluble grease (sodium-based) with an alternative option (polyethylene-based) in their activities as lubricants.

MATERIALS AND METHOD

Materials Used for the Study

The apparatus used in the study include the following:

- Beakers
- Conical Flasks
- Constant temperature water batch
- Electromagnetic hot plate
- Thermometers (0-360^{o}C range)
- Burette and pipette
- Weighing Balance
- Flat bottom flask
- Measuring cylinder
- Electric grinder
- Funnel and filter paper
- Hydrometers (for low and high density liquid)
- Penetrometer and Grease worker
- Dropping point apparatus
- Grease cup (seta cup)
- Heat resistant glass test-tube
- Spatula
- Reactor (metal containers - 4 litres capacity jug)

Reagents Used for the Study

Similarly, the reagents used for the study include the following:

* Sodium hydroxide (caustic soda)
* Potassium hydroxide
* Hydrochloric acid
* Neutralized ethanol
* Phenolphthalein and methyl orange indicators
* Fatty materials/vegetable oils
(i) Palm oil from Owerri (OHAJI)
(ii) Shea butter from Ilorin
(iii) Tallow from (cow)
(iv) Soya - bean oil.
* low density polyethylene
* Base oil
(i) 500N
(ii) 650N (Bright stock)
(iii) 100N
(v) 150N

Research Methodology

Dispersion of Low-density Polyethylene in Base Oil (100N, 500N, 650N)

Measured quantities of low density polyethylene was dispersed in separate grades of base oils (100N, 150N, 500N, 650N or B/S) by heating. Example: 5grams of polypropylene was transferred into five (5) beakers each containing about 300mls of base oil and the content of the beaker was heated, each to a temperature of about 170 to 180^{0}c to melt. It was later allowed to cool to a room temperature of 30^{0}c as shown in the table 1 below:

TABLE1: VARIATION OF DISPERSED WEIGHT OF POLYETHYLENE IN A FIXED VOLUME OF BASE OIL AT 180^{o}C

A: ***100N (BASE OIL) AT 180^{o}C*** **B:** ***150N (BASE OIL) AT 180^{o}C***

MASS OF POLYETHYLENE(g)	VOLUME OF BASE OIL (cm^3)	MASS OF POLYETHYLENE(g)	VOLUME OF BASE OIL (cm^3)
5	300	5	300
10	300	10	300
15	300	15	300
20	300	20	300
30	300	30	300

C: ***500N (BASE OIL) AT 180^{o}C*** **D:** ***650N (BRIGHT STOCK (B/S)) AT 180^{o}C***

MASS OF POLYETHYLENE(g)	VOLUME OF BASE OIL (cm^3)	MASS OF POLYETHYLENE(g)	VOLUME OF BASE OIL (cm^3)
5	300	5	300
10	300	10	300
15	300	15	300
20	300	20	300
30	300	30	300

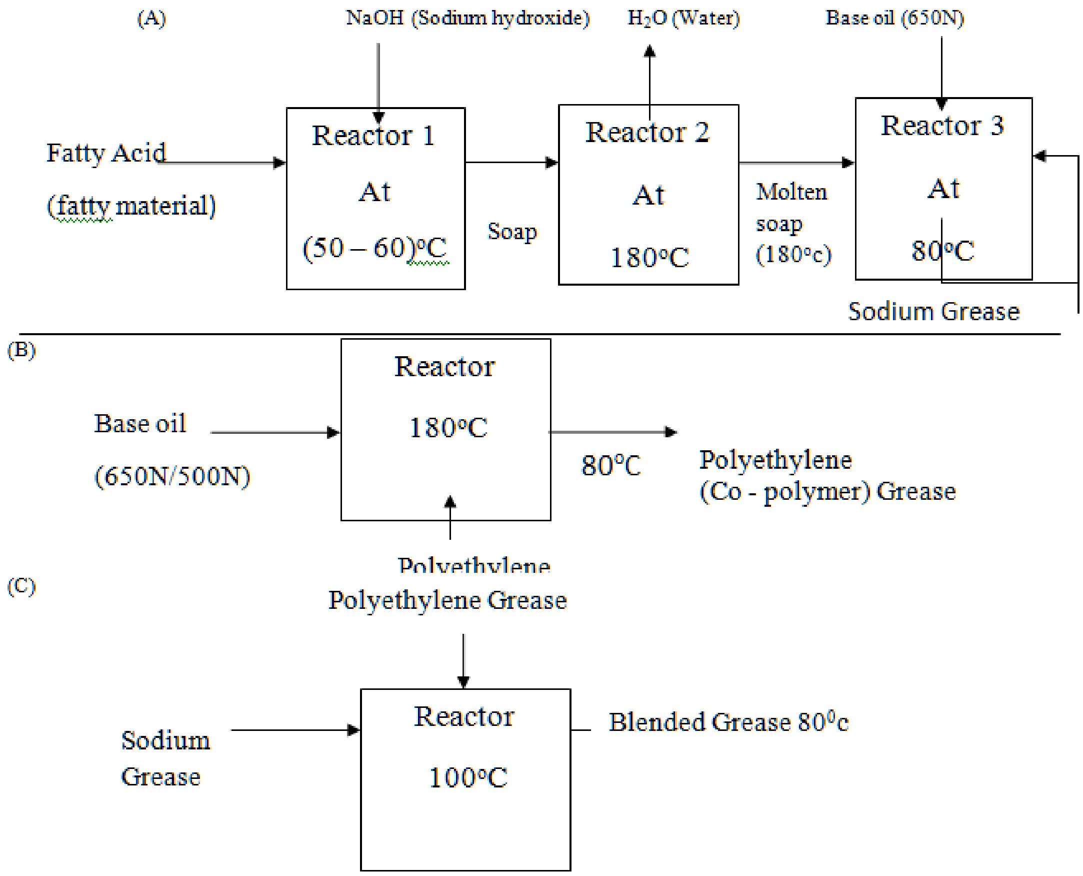
Production of Sodium Base Grease

Grease production involves a batch process that incorporates a technology bounded by saponification, evaporation, dispersion in a mineral fluid (Base oil), Recycling/cut back, milling or homogenizing and filteration of dispersed thickener in a base oil mixed with additives and modifiers (Totten et al, 2006).

SAPONIFICATION AND EVAPORATION

Saponification is the alkali hydrolysis of fatty matters to form soap. 103 grams of caustic soda solution prepared by dilution to a concentration of 26% with the specific gravity of 1.275 at room temperature of about 30^{o}C was weighed into the plastic container based on (S.V) of palm oil. The palm oil in the reactor was heated to a temperature of 60^{0}C (saponification temperature), followed by the gradual addition of already weighed caustic soda into the reactor. The mixture of the two components was stirred for a period of (5) minutes depending upon the volume of the reactants (fatty matter plus caustic soda solution) to saponify and form soap. The soap formed in the process was later heated up to a temperature of about (120^{o}C to 130^{o}C) (at atmospheric pressure) in other to remove water (by evaporation). That is the temperature at complete saponification, and the soap obtained at this stage was very thick and in a solid state.

Fig. 1: Process Flow Sheet of Production of Sodium-Polyethylene (Co-Polymer) Greases.



GREASE FORMATION AND MILLING OPERATION

After saponification and evaporation at about 130°C, the soap formed is further heated to a temperature range of 170°C – 180°C. A little quantity of base oil was also added (depending on the mass of soap formed), so as to reduce friction or ease the stirring.

At this temperature, the thickened soap melted to a liquid state and becomes gummy or sticky on little exposure to air. At this temperature (180°c) the soap was dispersed in base oil by gradual addition and stirring until the grease was formed. Here reasonable quantity of base oil was added (900m/s for 650N, 800mls for 500N and 500mls for 150N) in the respective production and dispersion of each of these base oil samples.

NOTE: The total volume of base oil to be added per batch depends on the texture of the product sample on cooling to room temperature: say 30°C

However, before allowing the grease to cool to room temperature, milling operation was performed by means of grinder at the temperature of 80°C (for homogenization). This method helped in reducing the particle size of the undispersed thickener in the base oil.

BLENDING OPERATION

Two hundred grams of dispersed polyethylene product and 200grams of the sodium grease were blended together at the temperature of 100°C by heating and stirring the two in a metal container (Reactor) for a period of 10–15 minutes, after which it was allowed for 24hours to cool.

Quality Control Analysis of Grease

WORKED PENETRATION

400g of grease was cooled to 25°C and later transferred into the grease worker cup. The grease cup was Jared sharply on the bench to remove the air pockets. The grease cup was finally filled above the rim of the cup and scraped at an angle of 45^0c with the aid of spatula. The vent cock was closed and the grease inside the cup was subjected to 60 full double strokes of the plunger, completed in about one minute by timing it using a stop-watch, the plunger was finally returned to its top position at the end of one minute.

The vent cock was opened and the top and plunger were removed. The plunger itself was scraped with spatula to remove all the grease that clings to it. The seta cup was used to fill the worked grease sample in readiness for penetration test. After loading the cup with grease, the excess grease was scrapped off above the rim of the cup by moving the blade of the spatula, held inclined towards the direction of the motion at an angle of 45^0, across the rim of the cup.

PENETRATION MEASUREMENT

400g of the test specimen was placed on the penetrometer table with one of the prepared faces upward. The mechanism was set to hold the cone in the "zero" position, and the apparatus was adjusted such that the tip of the cone just touched the surface at the centre of the test sample. Finally, the cone shaft was released rapidly and was allowed to drop for 5(five) seconds. The indicator shaft was gently depressed until it touched the cone shaft and penetration reading was taken from the indicator. The experiment was repeated up to three times. Hence the average result was recorded.

DROPPING POINT OF LUBRICATING GREASE

The Dropping Point is the temperature at which a conventional soap (thickened grease) passes from a semi–solid to a liquid state under the conditions of test; it is the temperature at which other non–soap (thickened greases), rapidly, separates from oil. This was determined by placing the grease sample in the cup, and a cone–shaped space created by means of a rod (manipulated through the orifice). A thermometer occupies the space, out of contact with the grease. Heating took place at specified rate and the temperature at which oil falls or drops (through the orifice of the cup) to the bottom of the test tube was noted. The operation was repeated as a check for consistency of the result, and the average reading was determined and recorded.

RESULT AND DISCUSSION

The results of analysis of the Samples are presented in figures 2 and 3, as well as tables 2–4 below.

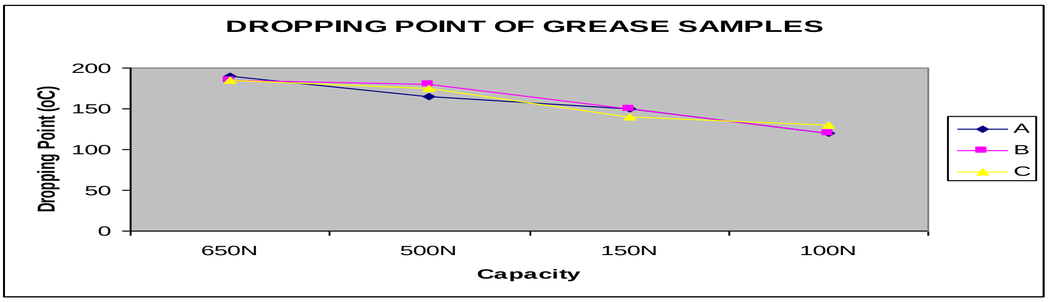


Fig. 2: PLOT OF DROPPING POINT OF SAMPLS AT VARYING CAPACITIES

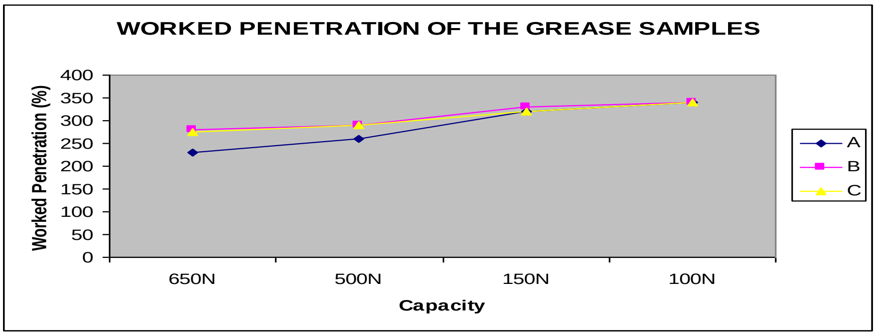


Fig. 3: PLOT OF WORKED PENETRATION OF SAMPLS AT VARYING CAPACITIES

TABLE 2: ANALYSIS OF SODIUM-BASED GREASE (SAMPLE A)

Sodium/polypropylene = 1:1	**Sodium plus polypropylene Grease with:**			
PROPERTIES	**650N**	**500N**	**150N**	**100N**
Dropping point (^oC)	190	165	150	120
Worked penetration	230	260	320	340
Appearance	Smooth and fibrous	Smooth and fibrous	Buttery and fibrous	Buttery and fibrous
Other Properties	Adhesive and cohesive	Adhesive and cohesive	Adhesive and cohesive	Adhesive and cohesive

TABLE 3: ANALYSIS OF POLYETHYLENE CO-POLYMER GREASE (SAMPLE B)

	Polyethylene Grease			
PROPERTIES	**650N**	**500N**	**150N**	**100N**
Dropping point (^oC)	185	180	150	120
Worked penetration	280	290	330	340
Appearance	Smooth and buttery	Smooth and buttery	Smooth and soft	Smooth and soft
Other Properties	Cohesive	Cohesive	Cohesive	Cohesive

TABLE 4: Analysis Of Blended Sodium/Polyethylene Grease At 1:3 Ratio (Sample C)

	Sodium plus polypropylene Grease			
PROPERTIES	**650N**	**500N**	**150N**	**100N**
Dropping point (^oC)	185	175	140	130
Worked penetration	275	290	320	340
Appearance	Smooth & fibrous	Smooth & fibrous	Buttery & fibrous	Buttery & fibrous
Other properties	Adhesive	Adhesive	Adhesive	Adhesive
Pumpability(in centralized systems)	Poor to fair	Poor to fair	Fair to good	Fair to good
Water resistance	Fair to good	Fair to good	Fair to excellent	Fair to excellent
Oxidation stability	Good	Good	Good	Good

The result of the analysis shows that there is higher dropping point in the Sodium-based grease (120-190^oC) when compared with those of Polyethylene copolymer and the blended greases, whose dropping points both fall between 120 – 185^oC. This is traceable to the fact sodium concentration increases the gelatinization temperature, and as such reduces the intermolecular bonding between the molecules of the product (Astrom and Hoglund, 1990). It could be observed, also, that the Worked Penetration is best with the Polyethylene (Copolymer) grease sample (280-340), followed by the Blended sample (275-340), but least with the Sodium grease sample. This shows that the Polyethylene grease possesses greater ability of friction control as it will travel farer into the axles than its Sodium counterpart. The analysis also indicated that the lower cadre (100N and 150N) of the Polyethylene grease appears smooth and soft, unlike the Sodium-based grease that is buttery and fibrous. This feature goes a long way to demonstrate that the Copolymer grease is a better sample than the Sodium-based grease, and would resist water penetration very readily as well.

CONCLUSION

The present study shows that suitable and ideal concentration of caustic soda for soap manufacture is 26% and it corresponds with the specific gravity of (1.275) at the temperature of 30^oC. The density of dispersed polyethylene/polypropylene in a fixed volume of base oil increases with increase in the mass of polyethylene/polypropylene dispersed. Even 10% of dispersed polypropylene in 650N (Bright stock) base oil is ideal to fortify sodium grease in a good ratio (such as 3:1) in order to produce water resistance grease suitable for servicing bearings and other heavy duty equipment.

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