# Development and Properties Test of Aluminum Grease for Low Velocity Applications.

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## ABSTRACT

This work considers the use of palm kernel oil for the production of bio-based lubricant. Laboratory scale quantities of aluminium grease were produced by saponification reaction through dissolving soaps made from different percentage of fats and palm kernel oil and saponified with calculated quantity of caustic soda in lubricating oil (SAE 20-50). These were later converted to aluminium soap using aluminium chloride solution prepared from reacting aluminium chips with dilute hydrochloric acid. Aluminium lubricating grease produced were subjected to physical characterisation tests such as relative density, melting temperature range and solubility in water.

The results of Oando and Texaco conventional grease were used as control experiment having the same properties produced from 40% fat, 60% PKO, and having 30% soap in lubricating oil. The density of this particular sample is 0.98 and the melting range is $38^0$C to $64^0$C, while the solubility (percentage of grease dissolved) is 20%. Results also indicated that future research can improve temperature resistant in sodium soap grease.

(Keywords: characterization, palm kernel oil, lubricating oil, solubility, saponification)

## INTRODUCTION

Lubrication is the process employed in reducing wear or tear of one or both surfaces in close proximity and moving relative to each other by interposing a substance between the surfaces to carry the load between the imposing loads (Musa, 2009). It could be a solid, liquid, solid-liquid dispersion (e.g. grease). It helps to reduce the friction generated between the surfaces in contact, frictional forces tend to develop within the surfaces and this phenomenon can be of adverse effect if not controlled. However, all of these effects can be minimized if surfaces are kept constantly lubricated. The main advantages of grease over oils are their ability to hold on in unsealed lubrication points, serviceability over wide range of temperature and speed, better lubricity, higher corrosion protection properties, serviceability in contact with water and other corrosive media and a higher economic efficiency of application (Anonymous, 2010) The lubricating fluid in most cases are mineral oils (petroleum fractions) having the Society of Automotive Engineers (SAE) specification between SAE 5-SAE 80.

Due to growing environmental concerns, low cost, dependable, and sustainability, vegetable oils are finding their way into lubricants for industrial and transportation applications. Some vegetable oils applicable as lubricants or base-oil include palm oil, palm kernel oil, cottonseed oil, groundnut oil, soybean oil, linseed oil, etc. Honary (2001) and Gawrilow (2003) reported that vegetable oils are perceived as base fluids in lubricants as a result of non-toxic, good lubricity, biodegradability, affordable application cost and high viscosity index.

Today, there are many types of lubricating greases, but the basic structure of these greases is similar. Modern industry rests on a layer of lubricant which separates moving machine element from each other. The chemical and physical properties of a lubricant have a direct effect on the lubrication situation (Vahaoja, 2006). Mechanical testing and evaluation has been a major effort in supplementing simple non-bearing bench tests by providing laboratory rig tests using actual bearings and gears (Barnet, 1970).

The effect of friction on industrial equipment and on automobiles is a critical issue affecting man. Hence, lubricants or grease made from petroleum products were initially developed to reduce this dangerous situation. There has been a need since ancient times for lubricating greases. The Egyptians used mutton fat and beef tallow to reduce axle friction in chariots as far back as 1400BC Good lubricating greases were not available until the development of petroleum-based oils in the lates1800s (Boner, 1954).

Over the years, little attention was paid to the industrial use of palm kernel oil. Nevertheless, recent studies have indicated that apart from their domestic uses that can be used as engine lubricant (Abere et al., 2008 and Musa, 2009).

Animal fats (beef tallow) are highly viscous and mostly in solid for ambient temperature because of their content of saturated fatty acids (Oner and Altun, 2009).

In general, grease consists of a thickening dispersed through lubricating oil. The thickening agents or gallant include alkali metal soaps, clays, polymers, carbon black, colloidal silica, and aluminium complexes. To properly thicken the grease the soap must be in the form of fibres of suitable sizes dispersed throughout the lubricating oil.

Lubricating oil is commonly a mineral oil from paraffinic, naphthenic, or aromatic hydrocarbons. Other components of these greases include unreacted fats, fatty acids, alkali un-saponifiable matter (including glycerol and fatty alcohols), rosin or wool grease, and water. Some of the other additives employed in grease are oxidation inhibitors, rust and corrosion inhibitors, color stabilizers, metal passivators, water repellents, and viscosity index improvers (Boner, 1954).

The gelling agents are usually metallic soaps mainly sodium, calcium, aluminium, lithium, and lead soap (Samuel and Omoleye, 2009).

SPX (2008) reported desired properties characteristics for grease such as consistency, stability to shear, surface affinity, thermal stability, flow viscosity, syneresis, texture, and water resistance. The NLGI (1989) uses consistency numbers that correspond to penetration values to classify grease.

Boner (1954) highlighted that the formulation and processing of grease will determine the type of structure the product has and its physical properties.

Aluminium soap grease possesses translucent thixotropic, displays low dropping points, offers fair resistance to water, and exhibits good oil separation at moderate temperature (Adeleke, 1999 and Boner, 1986). Borner (1986) also defined aluminium soap grease as lubricating grease which consists of petroleum oil thickened with aluminium soap.

Archaeology has shown that tallow was employed to lubricate chariot wheel before 1400BC (SPX, 2008). The production and consumption of lubricating grease grew at an enormous rate as a result of the advanced in engineering and technology.

Chapman (1985) highlighted that rolling action of ball and roller bearings requires lubrication. Dolan (1978) cited that greases are classified according to their purposes e.g. water pump grease, chassis grease, multipurpose, or by the type of soap base.

Low-speed pins and bushings are a form of journal bearing in which the shaft or shell generally does not make a full rotation. Grease for low speed, high temperature and for pins and bushings may use a higher viscosity base oil and be formulated with heavier base oils, different thickeners and special additive formulations. Grease for improved water resistance may be formulated with heavier base oils, different thickness and special additive formulations. Also, grease for low temperature may incorporate a low-viscosity base oil manufactured to an NLGI number 1 specification (Scott, 2011)

Dudu et al. (2006) reported the development of poly-oxo-aluminium acrylates that are dissolved in synthetic lubricants. They stressed that the greases are proven to be mechanically and chemically stable. Kyriakopoulous (1995) highlighted the formulation of aluminium complex with synthetic ester based stock. The grease samples formulated were smooth. Samuel and Omoleye (10) reported that sodium soap as a gellant is not suitable for a high water resistance. They recommended that aluminium soap be used as gallant instead. They recommended a fraction of calcium acetate in sodium soap grease. US Patent (1955) detailed that a homogenizer can be employed in accelerating the saponification reaction.

Kawamura (2008) reported that the most wanted technology in the bearing market is adoption of a grease lubricating system that is eco-friendly and is easy to handle and maintain. He also remarked that grease with easy oil separation and stable thickener structure had longer life. Conradson (1904) remarked that the price of grease is an indication for its suitability for certain work.

## MATERIALS AND METHOD

The materials used for this work include weighing balance, flasks, measuring cylinder, Bunsen burner, spatula, wash bottle, stirrer, thermometer, animal fat (beef tallow), lubricating oil (SAE 20-50), palm kernel oil, caustic soda, aluminium chips.

To investigate the effects of soap content of the grease, various weight percents of soap in lubricating oil (SAE 20-50) were used for compounding grease samples for all the samples prepared, a fixed ratio of 2:3 for palm kernel oil and beef tallow respectively was used. To investigate the effect of beef tallow, various fractions of palm kernel oil from 10% to 100% are blended with beef tallow (Table 1). The soap content ranges from 10% to 50% as shown in Table 2.

Methods of blending of fractions of palm kernel oil and beef tallow, saponification reaction, and the processing stages leading to aluminium compounding are explained below:

### Palm Kernel Oil and Beef Tallow Blend

Because of its relative cheapness, beef tallow is usually blended with palm kernel oil in the saponification reaction of soap. To investigate the effect of beef tallow, various fraction of palm kernel oil from 10% to 100% are blended with beef tallow.

### Saponification Reaction

The palm kernel/tallow blend was heated to 40$^{o}$C. A measured quantity of 12.5M sodium hydroxide, sufficient for total saponification of the oil blend, as prescribed by their various saponification numbers (249 for palm kernel oil and 197.8 for beef tallow) and their various fractions were run into the oil blend gradually with stirring. The neutral viscous liquid soap as indicated by an indicator (litmus red) was allowed to cool down to room temperature the quantities of sodium hydroxide solution and the respective fat and PKO blend are shown in Table 7.

### Preparation of Aluminium Chloride Solution

Aluminium chips (waste from central workshop) were added to 2 molar solution of HCl. The flash in which the reaction took place was left until there was no more hydrogen gas evolving. The amount of aluminium added had been calculated to be 18g in 171.8cm$^3$ of HCl. The molarity of the resulting $AlCl_3$ = 0.67m and it contain 89.4g of $Alcl_3$ per 1000ml of solution.

The reaction equations and the calculations have been reported (Adeleke, 1999).

### Conversion of Sodium Soap to Aluminium Soap

25% of each sample of sodium soap previously produced was melted and calculated amount of $Alcl_3$ solution was added with vigorous stirring until the reaction was completed was discussed elsewhere ( Adeleke, 1999).

### Aluminium Grease Compounding

Desired quantities of aluminium soap (gellant) free of water by re-melting and heating to 110$^{o}$C before cooling down to solid soap, is melted in a little quantity of lubricating oil. The remaining quantity of lubricating oil (SAE 20 – 50) was run gradually into the melted soap while stirring. The mixture is allowed to cool to room temperature. The production set up is as shown in Plate 1.

**Plate 1:** Grease Production Set-up.

## Property Tests

The relative density, melting temperature range and the percentage solubility of each of the grease samples prepared were determined.

## Relative Density (RD)

With the use of relative density bottle, the weight of quantity of grease filling the bottle and the weight of the same volume of water were obtained for each grease sample prepared using the expression below. The RD of each sample was calculated.

Relative density, $RD = (W_3 - W_1)/(W_2 - W_1)$

Where:

$W_1$ = weight of empty relative density bottle

$W_2$ =weight of water filling density bottle

$W_3$ = weight of grease filling density bottle

The results are shown in Tables 1 and 2.

## Melting Temperature Range

Some of grease samples are packed into the test tube supported in a water bath and at the inner side of which thermocouple sensor was inserted.

The water bath was gradually heated and the state of the grease monitored. The temperature at which the first liquid appeared was recorded as well as the temperature at which the last grease solid melted. The results are shown on Tables 3 and 4.

## Solubility of Grease in water

The water resistance ability of each grease sample was determined. Dry, water resistant tile (5cm x 12cm) was weighed and coated with thin film of the grease sample for test. After weighing, the coated tile was immersed in water at room temperature of about 30$^o$C for 24hours. It was then removed and air dried to remove water vapour before taking the final weight. The water resistance (WR) of the grease expressed as percentage grease undissolved ($s_g$, $H_20$) was then determined using the expression:

$$WR = (W_2 - W_3) \bullet 100 / (W_2 - W_1)$$

Where:

$W_1$ = weight of empty tile

$W_2$ = weight of tile coated with grease sample

$W_3$ = weight of tile after removing from water and air dried

The results for all the samples are shown on Tables 5 and 6

## Control Test

All the above tests were carried out in the same manner on commercial lubricating grease available in the market for comparison. The results are indicated on Tables 1 to 7.

## Results

Both the fraction of beef tallow and the percentage soap (Gellant) have noticeable effects on the properties of the lubricating grease.

## The Beef Tallow Effects

As the fraction of tallow increases, the density of soap decreases as it is observed in Table 1. At a 40% by weight of beef tallow, 30% of soap in the grease gives the same relative density of 0.78 obtained for the commercial sample.

**Table 1:** Relative Density of Grease with constant Gellant: (30% Soap + 70% Lubricating Grease).

| **PKO (%)** | 100 | 80 | 60 | 40 | 20 | Reference Grease Samples |
|---|---|---|---|---|---|---|
| **Fat (%)** | 0 | 20 | 40 | 60 | 80 | --- |
| **RD** | 1.05 | 1.02 | 0.94 | 0.94 | 0.90 | 0.98 |

**Table 2:** Relative Density of Grease with varied Gellant: (40% PKO + 60% fat Oil).

| | | | | | |
|---|---|---|---|---|---|
| **Soap (%)** | 10 | 20 | 30 | 40 | 50 |
| **Lubricating Oil (%)** | 90 | 80 | 70 | 60 | 50 |
| **RD** | 0.9 | 0.93 | 0.96 | 1.00 | 1.03 |

**Table 3**: Melting Temperature of Grease with Constant Gallant: (30% Soap +70% Lubricating Oil)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **PKO (%)** | 100 | 80 | 60 | 40 | 20 | 10 | Reference |
| **Fat (%)** | 0 | 20 | 40 | 60 | 80 | 90 | Grease Sample |
| **Lowest Melting Temperature, $T_1$($^0$C)** | 42.0 | 40.0 | 38.0 | 37.0 | 35.0 | 34.0 | 39.0 |
| **Highest Melting Temperature, $T_2$ ($^0$C)** | 70.0 | 67.0 | 64.0 | 61.0 | 58.0 | 57.0 | 70.0 |

**Table 4:** Melting Temperature of Grease with Varied Gallant:(40% PKO + 60% Fat)

| | | | | | |
|---|---|---|---|---|---|
| **Soap (%)** | 10 | 20 | 30 | 40 | 50 |
| **Lubricating Oil (%)** | 90 | 80 | 70 | 60 | 50 |
| **Lowest Melting Temperature, $T_1$ ($^0$C)** | 33.0 | 36.0 | 38.0 | 40.0 | 43.0 |
| **Highest Melting Temperature, $T_2$($^0$C)** | 53.0 | 57.0 | 61.0 | 65.0 | 68.0 |

**Table 5**: Percentage Solubility (by weight) Versus Percentage Fat in Grease.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **PKO (%)** | 100 | 80 | 60 | 40 | 20 | 10 | Reference |
| **Fat (%)** | 0 | 20 | 40 | 60 | 80 | 90 | Grease |
| **Sg, $H_20$** | 11.1 | 12.5 | 15.4 | 20.0 | 25.0 | 37.5 | 20.0 |

**Table 6**: Percentage Solubility (by weight) of Grease Versus Soap

| | | | | | |
|---|---|---|---|---|---|
| **Soap (%)** | 10 | 20 | 30 | 40 | 50 |
| **Lubricating Oil (%)** | 90 | 80 | 70 | 60 | 50 |
| **Sg, $H_20$** | 20.0 | 11.1 | 10.0 | 0.0 | 0.0 |

**Table 7**: Volume of NaOH(aq) Saponified with Samples of Volume of (PKO + Fat Blend) and Aluminium Chloride Solution.

| **Sample No** | **0** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|
| **% of Fat in PKO/Fat Blend** | 0 | 20 | 40 | 300 | 80 | 90 |
| **NaOH (mi), Vs** | 14.2 | 13.6 | 13.1 | 62.36 | 11.9 | 11.69 |
| **(PKO + Fat), mi** | 40 | 40 | 40 | 200 | 40 | 40 |
| **Al $Cl_3$(aq) (mi)** | 22.24 | 21.25 | 20.34 | 97.44 | 18.76 | 18.09 |

From Figure 1, the use of fraction of fat between 0% and 40% gives higher density than those between 60% and 90%, thus making it a little more difficult to throw the former off the joint on radial motion. However, the presence of tallow lowers the melting temperature range of the grease (Table 3). The use of tallow above 40% gives grease with a melting temperature range lower than that of the commercial sample ($39^0$C – $70^0$C). The higher the melting temperature range of a lubricating grease the better it is able to withstand high joint temperature of the machine. Also, the higher the percentage of beef tallow, the less soluble the compounded grease in water (Table 5). This renders it more applicable to joint exposed to water. From Figure 3, the use of tallow above 60% increases the solubility of resulting grease below that of the commercial market brand by 20% within 24 hours, thus rendering it inappropriate for joints exposed to water.

**Soap (Gellant) Content Role**

The gellant enhances the role of maintain the lubricant in semi-solid state under the condition of usage. Table 2 indicates that, as the percentage of the gellant increases in the grease, relative density of the grease increases. At a 40% by weight of PKO/beef tallow blend, 30% of soap in the grease as obtained for the relative density of the commercial brand.

The melting temperature range of the grease increased from $33^0$C to $53^0$C range at 10 percent gellant content to $43^0$C to $68^0$C range at 50 percent. The gellant content of about 39 percent in the grease by extrapolation on Table 4 will give a melting temperature range of about $39^0$C – $70^0$C a range observed for the commercial/market sample. Table 6 shows that as the soap content increases, the solubility of the grease in water also increases. The percentage solubility of the commercial grease sample was found to be 20% and this is equivalent to that of the sample with 10% soap and 60% fat by extrapolation from fig. 3. However, at higher soap content, the solubility of the grease decreases. This renders such grease less applicable for joint to water.

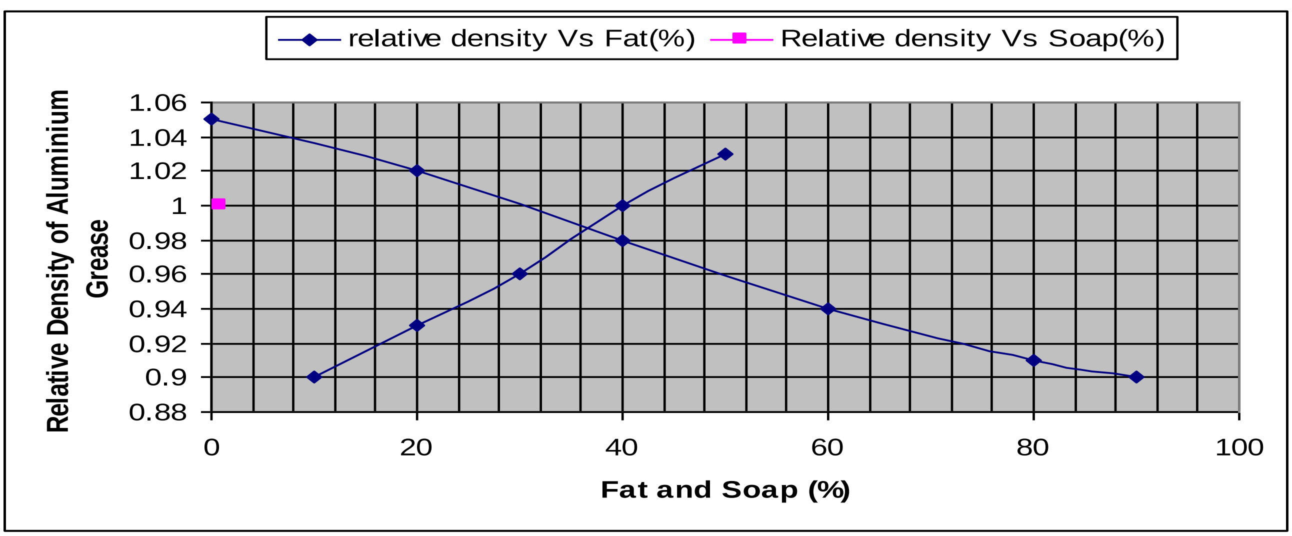


**Figure 1:** Graph of Relative Density of Aluminium Grease versus Fat and Soap.

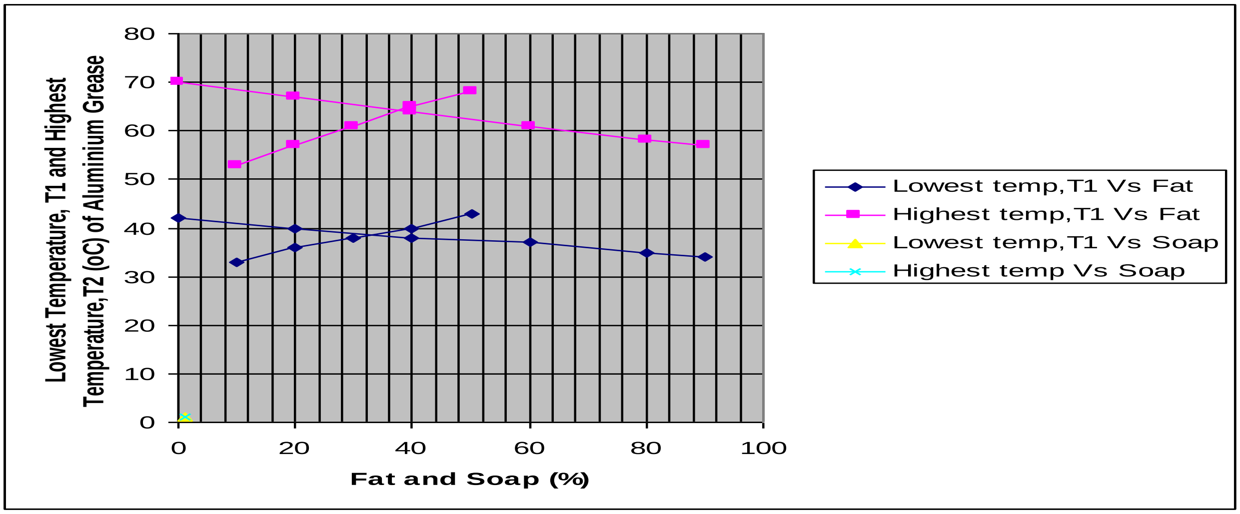


**Figure 2:** Graph of Lowest Temperature and Highest Temperature of Aluminium Grease versus Fat and Soap.

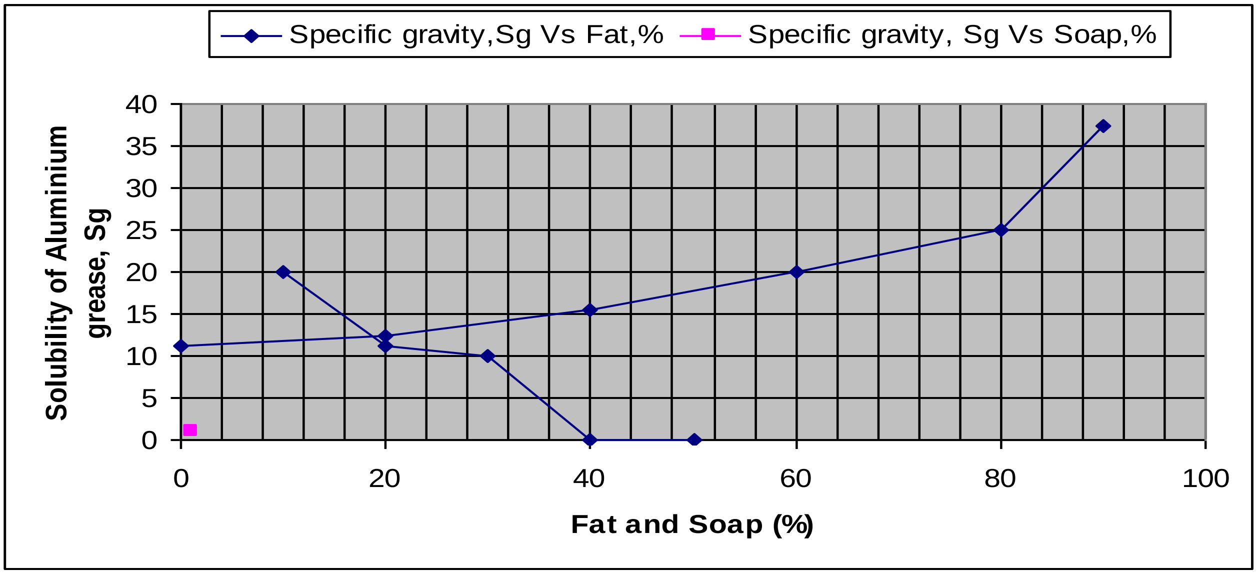


**Figure 3:** Graph of Solubility of Aluminium Grease versus Fat and Soap.

## CONCLUSION

Based on the results obtained from the various tests carried out on the production of aluminium lubricating grease, the following conclusions can be drawn:

- Lubricating grease from local raw material has been successfully compounded using aluminium based soap.
- Increasing the percentage of fat increases the solubility, lowers the melting point and increases the specific gravity of the grease sample.
- Increasing the soap content of the grease lowers the solubility, increases the relative density and raises the melting point range of the grease.

- The recommended composition that compares very favourably with a commercial market sample will be 40% beef tallow, 60% PKO and 30% soap, 70% lubricating oil for formulating grease sample.

The limited lubricating physical characterization carried out demonstrated that aluminium biodiesel can be successful employed in low temperature application such as pins, bushings, etc.

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