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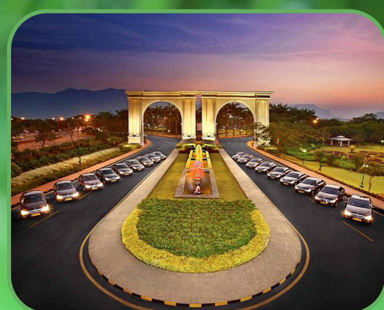

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Lubrication in Mining Equipments

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Abstract
Mining industry deploys a large number of heavy earth moving equipments like draglines, shovels, dumpers, dozers etc. for the extraction of minerals and coals via surface or undergroundmining. Effective lubrication to protect the heavily loaded components of these equipments is a key responsibility of the users, lubricant manufactures and original equipment manufacturers (OEMs). Maintaining proper lubrication on production equipments can reduce the number of breakdowns due to failure of lubricating components. Dispensing of right lubricant, in right quantity at right time is very crucial to prevent the system failure. Designing of right lubricant for different components of mining equipments viz. enclosed gear drives, open gear drives, different types of bearings, circulating and hydraulic components, is a challenging task for lubricantmanufactures. Present paper elaborates on various criteria & considerations for the development of appropriate lubricants for different components of mining equipments especially for draglines and shovels.

Introduction
Maintenance of production equipments in mining industry is very essential to keep the equipments in efficient working condition to increase the productivity by reducing downtime. Maintenance people seek to reduce the maintenance costs, increase equipment utilization and improve equipment reliability. To achieve this, maintenance personal often look to upgrade the lubricants to the latest technology.

Primary function of any lubricant is to reduce the friction which is normally achieved by introducing an ideal film of oil or sufficient amount of grease between two surfaces in relative motion. This lubricant film prevents the two surfaces to come in contact under the conditions of speed and load imposed on the moving parts. In the absence of proper lubrication machine parts develop friction, heat and rapid wear, which may eventually cause machine failure. Improper lubrication also results in frequent downtime, higher operating cost due to lower efficiency. Some of the direct costs resulting from improper lubrication include cost of replacement spares and components, labor for replacements and repair, excess lubricant consumption and labour for inefficient manual lubrication practice. Therefore proper lubrication of each lubricating surface of production equipments is very essential for the smooth operations of any industry.

Present paper elaborates about the development of appropriate grease lubricants for different lubricating surfaces of mining draglines & shovels. For the development of suitable greaselubricants mode of application, various tribological aspects and original equipment manufacturers (OEM) recommendations related to lubricants are also taken into consideration.

Mode of Lubrication
Lubricants can be applied on lubricating surfaces by manual or automatic lubrication methods. The main difference between manual and automatic lubrication is that in the case

of manual mode, technicians tend to lubricate on schedule (once a day, week, month, year, etc.) rather thanwhen the lubricating surface needs it. This sets up an over lubrication or an under lubrication scenario (Figure 1 and 2). Conversely, automated lubrication provides lubricant constantly at an appropriate amount that allows the lubricating component to operate at its optimum. When the lubricating surface is properly lubricated in this manner, it also helps to seal from contaminants. In addition, there is less downtime compared to the manual lubrication process, as well as substantially reduced man-hours required for the task. It is possible with automated lubrication system to lubricate machine parts while the machine is in operation and also the machine parts which are inaccessible or difficult to access manually can be easily lubricated with automated lubrication system. However it is very important to maintain the automated lubrication system in proper working condition.

Tribological aspects of lubrication

Lubricants have continuously improved over the years to take care of the modern machines running hotter, faster and longer. Today's lubricants must satisfy extreme requirements that are specific to each application. Type of motion, speed, temperatures, load and the operating environment are the certain tribological aspects which have to be identified before the development of any lubricant. Once these tribological aspects identified, the lubrication engineer can utilize different lubricant chemistry to design a lubricant that will optimize the performance of the application.

Type of Motion

The first parameter of the tribological aspect involves the type of motion. The motion may be sliding or rolling. Combined sliding and rolling is also a possible form of motion in certain rolling- element bearings including the tapered roller bearing. Protection of machine components under these types of motion can be optimized with specific chemistry. Some specific chemistry is more effective in sliding contacts than in rolling contacts. Combination of synergistic additive system is required for motions which involve both sliding and rolling contacts.

Speed

Speed of moving components can be categorized into the general ranges of fast, moderate and slow. Knowing the speed of the contact, a lubricant can be selected with the optimum physical attributes to minimize friction. In general, for higher speed applications lubricants should be with lower viscosity and for lower or moderate speed applications, lubricant should be designed with medium to higher viscosity.

Temperature

All lubricants have specific temperature ranges for optimal performance. Many lubricants have a broad operational temperature range, however, some lubricants are more suited for lower temperatures. For example, there are some greases with low viscosity synthetic hydrocarbon base oil can operate at temperatures as low as -60°C. Other lubricants are designed for high temperature applications, such as greases with high viscosity synthetic hydrocarbon base oil thickened with Calcium Sulphonate Complex soap that can lubricate an oven chain bearing at 220°C. Knowing the application temperature the lubricant manufacturer should develop the lubricants which can provide optimum performance at the application temperature.

Load

Load is an important factor affecting the lubricant requirement. A light load may indicate that application is sensitive to frictional torque and therefore a lubricant with low viscosity should be designed to minimize the fluid friction while still providing adequate protection from friction and wear. For heavily loaded application, a high viscosity lubricant is required with specific extreme pressure additives to protect the machine parts from pitting, galling and extreme wear. Therefore, for heavily loaded applications lubricants should be formulated with high extreme pressure and anti-wear additives.

Operating Environment

If the environment includes moisture or water, the lubricant must provide good anticorrosion properties as well as resistance to water washout. If the application involves the presence of certain chemical liquids or vapors, the lubricant must be resistant to these chemicals.

Special Requirements

Many applications have special requirements that go beyond the tribological aspects that must betaken into consideration. Lubricants development is also dependent on certain specialized requirements i.e. Lubrication equipment, re-lubrication intervals, cost, special certifications such as DGMS approval, biodegradability etc. Therefore, by identifying various tribological aspects a lubrication engineer (or tribo-engineer) can design proper lubricant for different lubricating surfaces of any machine.

Lubrication in Mining Draglines and Shovels

Big, bigger and biggest are the standards in Mining. Draglines and Shovels are of prehistoric sizes but their gears and other lubricating parts are amongst the largest applied anywhere. In both closed and open systems a variety of different lubricants is being used. Extreme pressure protection, reliability, consistency and performance in dusty environment are key factors for the development of correct lubricant for different moving surfaces of these equipments.

Lubrication in Swing Gear and Swing Rack Gear system

During the operation of shovels and draglines the whole upper body of the machine can be swing in each direction on lower base body with the help of swing gears. In draglines the swing gear is composed of swing pinion shaft, swing pinions & swing rack gears and swing circle rollers & rollerpath, which is known as swing Rack gear system (**Figure 1**).

(1a) (1b)

Figure 1: Lubrication in swing gear system (a) Internal view of swing Rack gearsalong with swing rollers of dragline (b) Swing gear of electric rope shovel.

Swing Pinion Shaft: This is a large shaft which is mounted below the swing gear box and at base of which is mounted the swing pinion. The shaft is supported by anti-friction bearings which are lubricated with grease.

Swing Pinions & Rack Gears: These are located in the sub-floor of dragline. Depending on the size and age of machine the no. of these may be between 4 to 8 pinions. The swing rack is always internally geared & the gear is made up of segments that are bolted to the tub frame. The swing rack and pinions are lubricated with open gear compounds. Method of lubricant application is normally by spray where grease is delivered via injectors and atomized by air.

Swing Rollers & Roller Path: At upper rotating deck & lower frame of the machine in between two large bearing raceways (roller paths) a series of parallel face rollers contained within a cageis positioned. The path and outer surface of the rollers are lubricated with open gear compound that is usually applied via drip feed from pipes connected to grease injectors. The rollers have centre bearings to support each roller and these bearings are lubricated with grease, which can be applied manually, or via single point lubricators.

Usually lubrication in swing rollers is provided by automated pumping system and in swing rack gear system by automatic spray system. In case of failure of automated lubrication system, lubrication can be carried out manually by maintaining proper amount and frequency of re- lubrication. Swing rack gear system and swing rollers work under tremendously high load conditions by moving with low speed. The lubricant used for swing rack gear system should create a tenacious / tacky film which resists breakdown and wiping under high load conditions. The lubricant should be based on very high base oil viscosity and fortified with extreme pressure additives, anti-wear additives and solid lubricants, to provide adequate protection to the heavily loaded open gears and extend the component life while reducing consumption. The lubricant should also have water resistance property to prevent the lubricant from being washed off in rainyseason.

Development of Grease Compound 1

By considering the mode of applications, working conditions and environmental effects along withOEM specifications of swing gear lubricants for shovels and draglines, **grease compound 1** has been developed. This grease is suitable for lubrication of all types of large and small open gears working under heavy loads and prone to excessive pitting, scaling or abrasive wear. This compound is right lubricant for typical applications including swing rack gear and pinion, swing rollers, hoist and drag gear system of draglines, swing gear and pinion and hoist gear system of shovels. This compound is highly water resistance even in rainy season and easily can be applied on lubricating surfaces either by automatic lubrication system or by manual method. Grease compound 1 can easily be applied even in cold season as compared to bituminous lubricants which becomes very stiff in cold climatic conditions. The performance of this grease compound was found excellent in terms of easy application, less consumption and less maintenance requirement. The properties of Grease Compound 1 are given in **Table 1**.

Table 1: Properties of grease compound 1.

S. No.	Properties	Typical Values	Method
1.	Colour	Black	Visual
2.	Appearance	Very Tacky	-
3.	Unworked penetration, @ 25 °C	367	ASTM D 217
4.	Base oil Viscosity, cSt @ 40 °C,	1627	ASTM D 445
5.	Four Ball Weld Load, Kg.	800	ASTM 2596
6.	Four Ball Wear Scar Dia, mm	0.77	ASTM 2266
7.	Water spray off, % loss	6.48	ASTM D 1264
8.	Dropping Point, °C	>180	ASTM D 2265
9.	Copper Corrosion Test, Rating	1b	ASTM D 4048
10.	EMCOR Rust Test, Rating	0,0	IP 220

Lubrication in Hoist and Drag gear pinion

The conventional dragline hoist drum has two hoist ropes that run in unison and are both connected to the bucket rigging at the same attachment point (**Figure 2**). Hoist and drag drum run independently to each other in both direction and speed up by enclosed gear-pinions.Lubrication of these enclosed gear-pinions is carried out by manual or automated lubricantpumping system. Heavy duty **grease compound 1** developed for swing rack gear system and swing gears also gives excellent performance when used in hoist and drag gear pinions of draglines.

(2a) **(2b)**

Figure 2: Lubrication in Hoist & Drag gear Pinions (a) Lubrication in enclosedhoist gear box (b) Open hoist gear of dragline.

Lubrication on Hoist, Drag and Dump Wire Ropes

The ropes are made up of many strands and configurations to cope with continuous movementas load is applied & released and also as the rope bends over sheaves during use. Wire ropesare made of high carbon steel wires that have been cold drawn, producing very ductile, fatigue resistance properties, as well as very high strength. The rope life can be reduced from 40-50 % if the ropes are not lubricated beyond what was applied during rope making. Inadequate lubrication could also seriously impact on the wear of the sheaves and drums. The type of lubricant used and means of lubricant application can also have a significant impact on the rope life. Therefore, hoist, drag and dump wire ropes should be lubricated properly to extend their service life.

Ropes are lubricated as they pass over deflection rollers and through sheaves. The most common method of rope lubrication is drip tubes or spray nozzles, through some sites use pressurised applicators that straddle the rope as it passes through the application. Rope lubricantshould be designed with low viscosity oils to adequately penetrate the strands (wires) of rope which can prevent internal wear as well as higher viscosity base fluids are required to prevent theexternal wear. For lubrication at external surfaces, oil thickened with soaps or non-metallicthickeners are beneficial. Rope lubricants are usually fortified with extreme pressure additivesand may contain plus a low percentage (typically 3 %) of lubricating solid additives.

Development of Grease Compound 2

Taking in consideration both internal and external wear of wire ropes **grease compound 2** has been developed which is based on moderate base oil viscosity along with highly water resistance soap thickener. Grease compound 2 is semi-fluid, tacky and specially suited for in-service lubrication of wire ropes under varying services. It contains a performance enhancing additive combination to offer protection of individual wire strands against friction, wear, and corrosion. It gives excellent performance for in-service lubrication and corrosion protection of wire ropes continuously exposed to atmosphere and for wire ropes requiring protection against varying climatic and environmental conditions. Grease compound 2 contains a highly water resistant soapbase to provide excellent corrosion/rust preventive characteristics. It is extremely tacky. Hence it does not sag out of the surfaces, adheres well on the surface of the wire ropes and resists throw- off during the service of the wire rope to offer extended protection. Its semi-fluid nature makes it easy to apply on the wire rope by drip tubes or by brush. Due to its moderate base oil viscosity it has the ability to penetrate between the individual strands and the inner core of the wire rope and also provide better lubrication at outer surface because of tacky and water resistance soap. Due to the presence of anti-corrosion additive it protects the wire strands and wire core as a whole against varying climatic conditions from rusting. Its operating temperature range is -10 °C to + 80 °C. Properties of grease compound 2 are shown in **Table 2**.

Table 2: Properties of grease compound 2.

S. No.	Properties	Typical Values	Method
1.	Colour	Black	Visual
2.	Appearance	Tacky	-
3.	Unworked penetration, @ 25°C	405	ASTM D 217
4.	Base oil Viscosity, cst @ 40°C,	154	ASTM D 445
5.	Four Ball Weld Load, Kg.	400	ASTM 2596
6.	Four Ball Wear Scar Dia, mm,	0.48	ASTM 2266
7.	Flash Point, °C	224	ASTM D 92
8.	Water spray off, % loss	22.08	ASTM D 1264
9.	EMCOR Rust Test, Rating	0,0	IP 220
10.	Dropping Point, °C	186	ASTM D 2265
11.	Atmospheric corrosion Protection	Passes	Internal
12.	Copper Corrosion Test, Rating	1b	ASTM D 4048

Lubrication in Eccentric Cam and Ball of walking boot

Most of the draglines have a walking mechanism which consists of an eccentric articulated arm, which is supported by a shaft and bearings on both sides (**Figure 3**). A link between the walking arm and the main frame stabilizes the eccentric motion. Lubrication of these parts can be carried out by using greases with extreme pressure properties along with very good mechanical shear stability and water resistance properties.

(3a) **(3b)**

Figure 3: Lubrication in (a) Eccentric Cam and in (b) Ball of walking boot of dragline

Development of Grease Compound 3

Grease compound 3 especially designed for walking cam which has high base oil viscosity and fulfils the boundary film lubrication conditions under the harshest loads found on a dragline. This is suitable lubricant for this type of application which is formulated with extreme pressure additives for lubrication under severe mechanical conditions and for extension of lubrication frequency. Lubrication by these grease results in significant reduction in wear and coefficient of friction of mating surfaces. This grease is fortified with solid lubricants and has good surface adherence property to give excellent protection against rust, corrosion, water washout and has excellent film strength. This grease is also recommended for all types of bearings operating underheavy loads, shock loads or under excessively wet/damp conditions. Properties of Grease compound 3 are shown in **Table 3**.

Table 3: Properties of grease compound 3.

S. No.	Properties	Typical Values	Method
1.	Colour	Black	Visual
2.	Appearance	Tacky	-
3.	Worked penetration, 60/60 strokes@ 25°C	287	ASTM D 217
4.	Worked penetration, 100000 strokes@ 25°C	309	ASTM D 217
5.	Base oil Viscosity, cSt @ 40°C,	322	ASTM D 445
6.	Four Ball Weld Load, Kg.	400	ASTM 2596
7.	Four Ball Wear Scar Dia, mm	0.49	ASTM 2266
8.	Water Washout % loss @ 80 ºC	3.76	ASTM D 1264
9.	EMCOR Rust Test, Rating	0,0	IP 220

10.	Dropping Point, °C	316	ASTM D 2265
11.	Copper Corrosion Test, Rating	1b	ASTM D 4048

Conclusions

Grease compound developed for different lubricating parts of draglines and shovels are found to be appropriate lubricants in terms of ease of application, less consumption and less maintenance requirements. Grease compound 1 gives a perfect solution for any type of swing gears which works under tremendously high load conditions by moving with low speed. Grease compound 2 isprovides excellent performance by preventing both internal and external wear of wire ropes. Grease compound 3 gives better lubrication in eccentric cam & walking boot along with all typesof bearings positioned in the machine.

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Synthesis and Characterization of bio lubricants from non –traditional vegetable oils.

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Abstract

Vegetable oils are noticed to be potential alternatives to mineral oils for lubricant base stocks because of certain inherent properties viz. high viscosity, high boiling range and biodegradability. Fatty acids present in oil can be chemically modified to form high molecular weight esters, which can substitute conventional mineral oil-based lubricants. This paper mainly reveals about structural modification namely esterification of fatty acids present in vegetable oils. The esterified products were thus examined by GC-MS for confirming the desired structure of fatty acid esters. Tribological study of the esterified products was done using pin on disc tribometer. The bio based grease had excellent tribological property compared to commercially available all-purpose grease NLGI grade 3 which proves it as potential base stock for biolubricant. Thermogravimetry analysis results shows that fatty acid esters had far more thermal stability commercially available all-purpose grease NLGI grade 3.

Key words: Base-stock for grease, Non-traditional vegetable oils, Esterification, GC-MS, Thermal Stability

Introduction:

Finite resources of crude petroleum oil and growing concern over climate change are driving investment and innovation in the biofuels sector as countries and industry increasingly look towards renewable bioenergy to replace fossil fuels. Vegetable oils are increasingly used as green raw materials in various areas of research in bio based fuels (1). Vegetable oils in comparison with mineral oils have different properties due to prescence of triglyceride in its chemical structures (2). They have good lubricity, viscosity indices, superior anticorrosion property and affinity to metal surfaces. High value of flash point over 300ºC classify vegetable oils to non-flammable liquids (3). Industrially, most fatty acids are obtained from animal or vegetable sources. It is possible to produce several industrial products from vegetable oils and fat. Vegetable oils as lubricants are preferred because they are biodegradable and non-toxic, unlike conventional mineral-based oils (4). Other industrial application of vegetable-oil based lubricants is biodegradable hydraulic fluids for use in environmentally sensitive areas (excavators, earthmoving equipment, tractors, agricultural, forestry, and fresh water). This can be done by overcoming the inherent disadvantages of vegetable oils viz. poor oxidative stability, poor corrosion resistance, and poor chemical stability.

Numbers of researchers have contributed to make vegetable oil based bio-lubricants by chemical modifications of the natural oil or fats. These modifications involves transesterification (5), epoxidation (6), enzyme catalyzed esterification (7) and esteloid formation (8). Traditional method which uses thickners is also reported by number of authors in which mineral oils are replaced by vegetable oils and fats (9). But use of thickners will leach heavy metals into water resources after the disposal of lubricants.

In the present work the attempt has been done to produce a base stock for lubricating grease by chemical modification of non-traditional vegetable oil. Neem oil was converted into its methyl ester which were then further modified by transestrification with different alcohols viz. Hexanol, Octanol and NPG. The transesterified products were confirmed by GC-MS and the base stocks thus produced were characterized by thermo gravimetric analysis (TGA), Co-efficient of friction, kinematic viscosity and viscosity indices. All-purpose grease of M/s Hindustan petroleum limited was used as a standard to compare various properties of bio-lubricants.

Materials and method

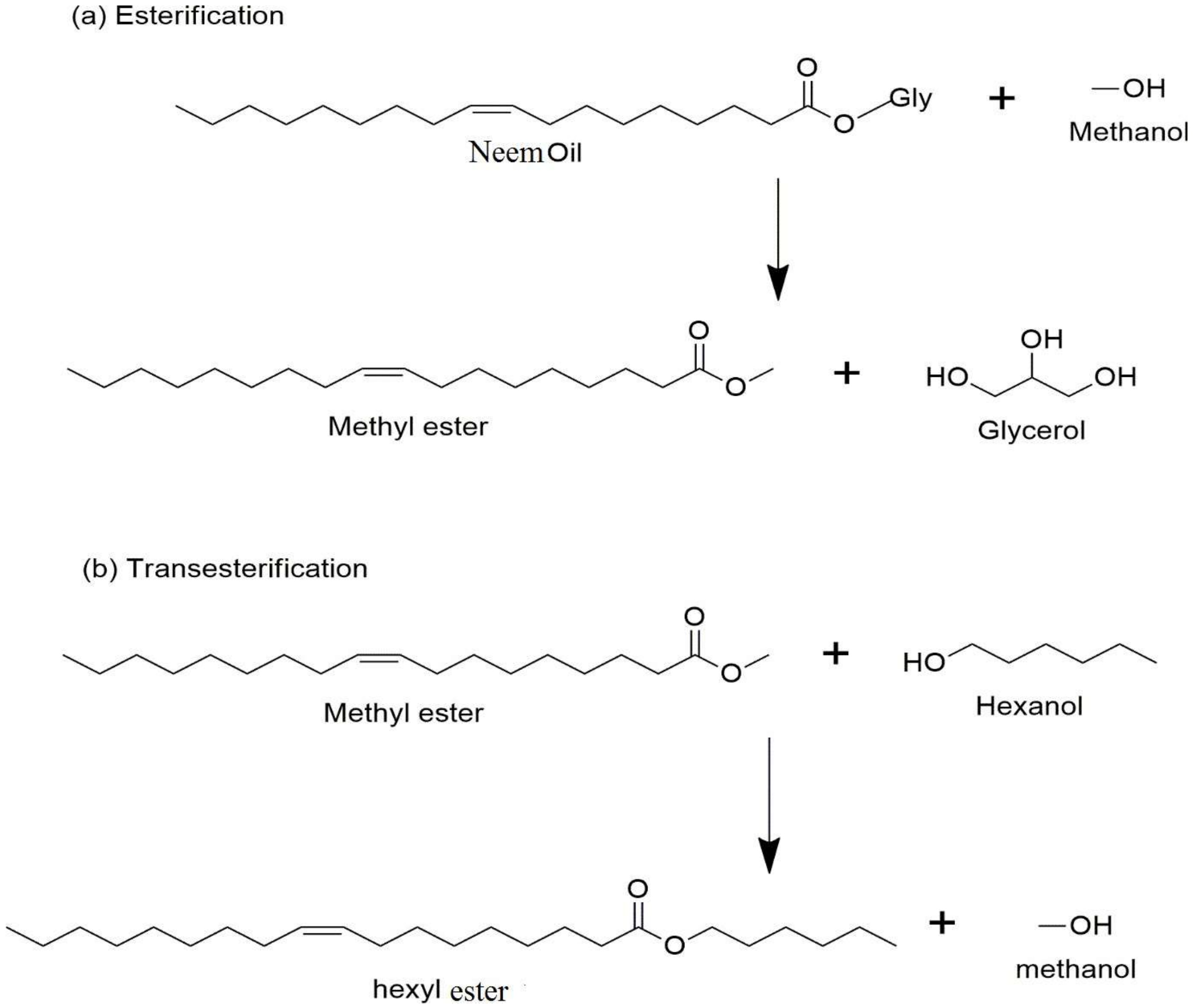
All the chemicals were procured from SD Fine chemical Baroda are of laboratory reagent grade and were used without any further purification. Neem oil was procured from Anand Agriculture University. It was evaluated for Iodine value, Saponification value and Peroxide value as per ASTM D5554, ASTM D5558 and ISO 3960 respectively. Fatty acid profile was evaluated by Gas Chromatography.

Synthesis of Fatty acid methyl esters

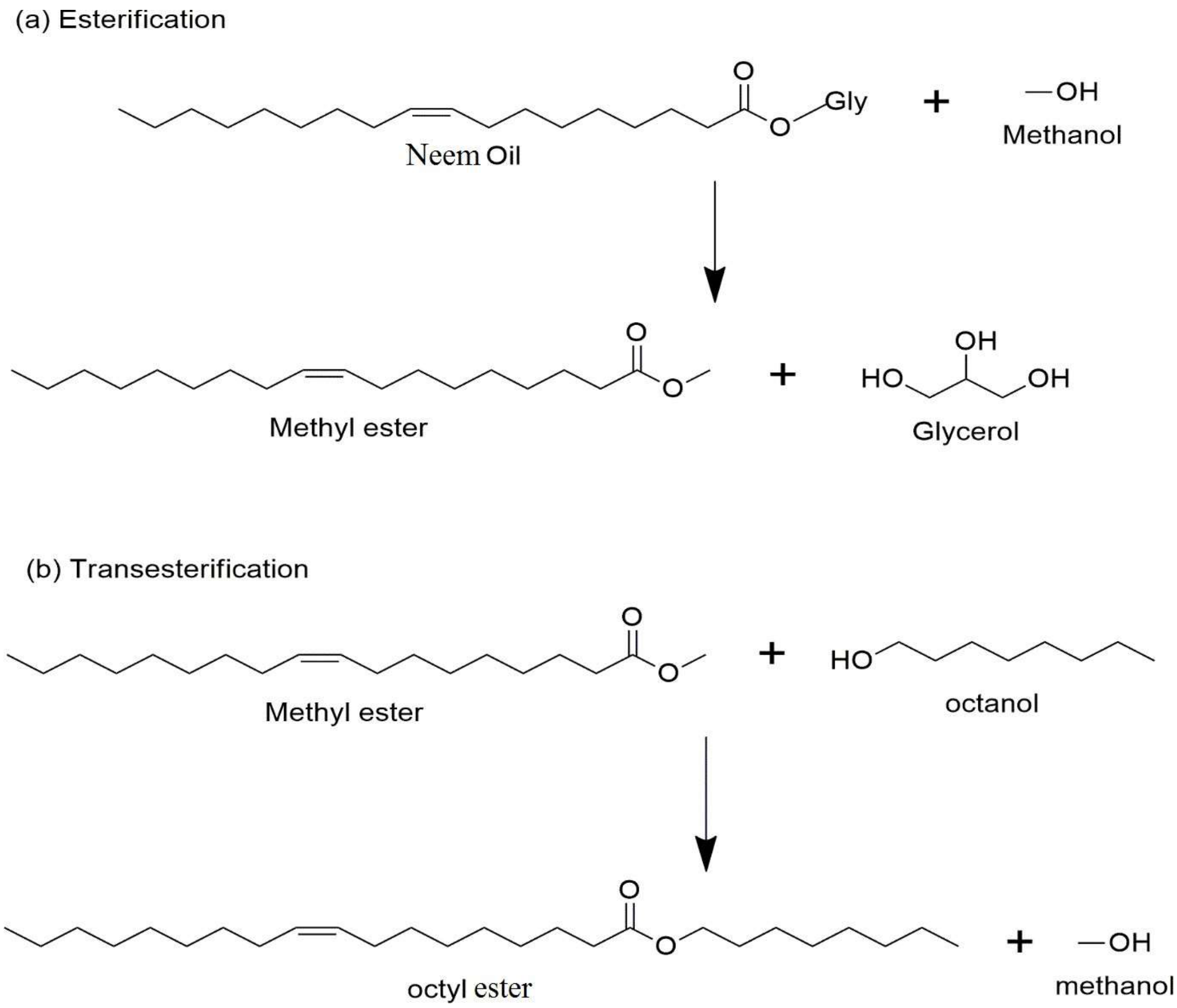
Vegetable oil was esterified with methanol to form Fatty Acid Methyl Esters (FAME). Catalyst used in this process was NaOH, 1%w/v, Oil to Alcohol ratio was kept as 1:6. Reaction was carried out at reflux temperature for 60 minutes (10). After the completion of reaction the mixture of methyl esters and glycerol was separated by a mixture of petroleum ether and methanol in the proportion of 60:20. The methyl ester thus synthesized was used for the production of lubricating grease base stock.

Synthesis of Lubricating grease base stock- Transesterification of Fatty acid methyl esters

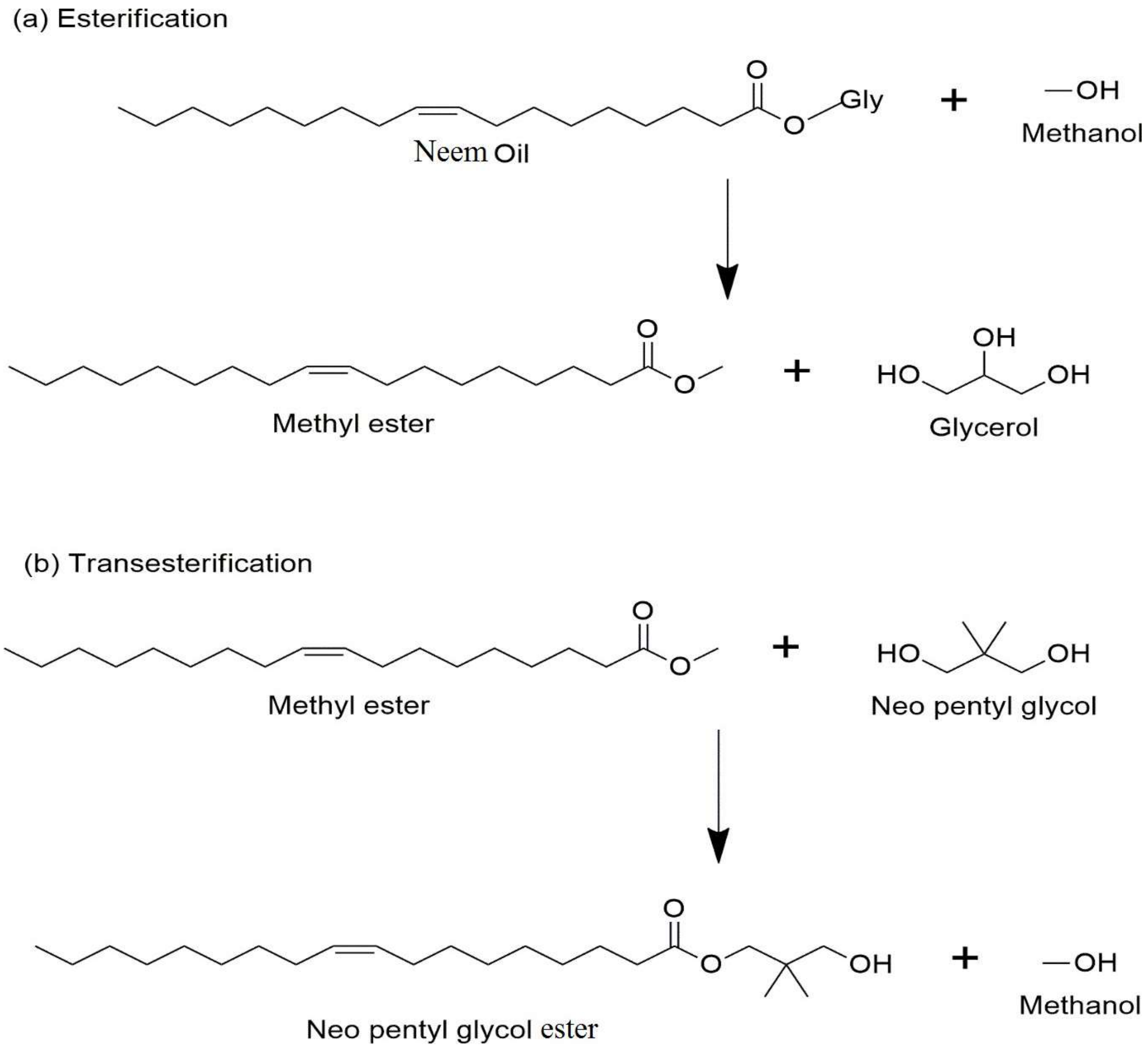
The methyl esters were further transesterified with various alcohols such as Hexanol, Octanol, Neo-pentyl glycol to form various high molecular weight esters- lubricating grease base stock. The reaction was carried out at desired temperature and pressure conditions using 3% sodium methoxide as catalyst. Entire reaction was conducted under vacuum which simultaneously removed the byproduct. The product obtained was characterized by GC-MS and its temperature stability was evaluated by TGA. It was evaluated for viscosity, viscosity index and co-efficient of friction. The representative structures of methyl esters of vegetable oil and Hexyl, Octyl and Neo pentyl glycol esters of Vegetable oil are shown in scheme 1, 2 and 3 respectively.



Scheme 1.(a) Methyl ester formation from Neem oil.
(b) Hexyl ester formation from Methyl esters of Neem Oil.



Scheme 2.(a) Methyl ester formation from Neem oil.
(b) Octyl ester formation from Methyl esters of Neem Oil.



Scheme 3.(a) Methyl ester formation from Neem oil.
(b) Neo pentyl glycol ester formation from Methyl esters of Neem Oil.

Thermo Gravimetric Analysis

Heat stability is an important characteristic for any lubricant. For this purpose, thermo-gravimetric analysis (TGA) of the vegetable oil ester was done using a Pyris-1 Thermogravimetry analyzer of Perkin Elmer. Around 10-20 milligrams of sample was taken and heated up to a final temperature of 600°C and a residence time of 1 minute at 600°C was allowed. TGA was performed in air atmospheres at a heating rate of 10°C/Min. Thermo-gravimetric weight loss curve was plotted against temperature. It provides a range of temperature in which the sample has maximum thermal stability and minimum weight loss.

Viscosity measurement and Viscosity Index

Viscosity measurement of all the vegetable oil esters was carried out on Brookfield viscometer at 40^0C and 100^0C using constant temperature water bath. The absolute viscosities were converted into kinematic viscosity by using the density of the ester samples.

Brookfield Viscometer Operating Conditions:

Spindle number	07
Rotations Per Minute	20
Factor	2000

Absolute Viscosity (Centipoise) = Dial Reading x

Kinematic Viscosity (Centistoke) = $\frac{\text{Absolute iscosity}}{\text{Density}}$

Co-efficient of friction

Co-efficient of friction for all the vegetable oil esters was measured by using Ducom Wear and Friction Monitor pin on disc equipment. A baseline was run without any lubricant sample to check the actual friction generated between pin and disc. Then after a thin coat of sample was applied on disc and then it was allowed to rotate against pin for 1000 seconds at 500 rpm speed. The friction factor was obtained for all the samples using the same procedure. All-purpose grease of Hindustan Petroleum Ltd. NLGI grade 3 was used as a standard sample for this test.

Operating Conditions were as follows:

Name of equipment	Ducom Wear & Friction Monitor.
Model no	TR-20LE-PHM-200.
Operating time	1000 sec.
Operating Temperature	Room Temperature (29 deg. Celsius)
Operating Speed	500 RPM.
Track Diameter	10mm.
Pin Diameter	3mm.
Material of pin	Aluminum
Material of Disc	EN31

Results and Discussion:

The carboxylic acid groups present in the fatty acid chains were converted in to methyl esters. These methyl esters were then transesterified with higher alcohols viz. Hexanol, Octanol and Neo-pentyl glycol. The resultant transesterfied products were then compared with commercially available grease for performance characteristics.

Physicochemical properties

Physicochemical properties of vegetable oils viz. Saponification value, Iodine value and Peroxide value were calculated which are tabulated in table 1

Table 1 Physicochemical properties of Neem oil

Saponification Value	159
Iodine value	74.17
Peroxide value	02.02

Table 2 Physicochemical properties of Karanja oil

Saponification Value	160
Iodine value	83.72
Peroxide value	04.03

Thermogravimetry analysis

Thermo gravimetric analysis (TGA) measures the amount and rate of change in the weight of a material as a function of temperature. TGA is helpful in determining the range of temperature under which the moisture and the volatile content of the substance is driven out. It also helps to study the decomposition of the material with increase in temperature and hence, to know about the thermal stability of a material. The percentage weight retained at 50^0, 100^0, 150^0 and 200^0 Celsius are tabulated in table 3.

Table 3 Comparative data of TGA at 50^0, 100^0, 150^0 and 200^0 Celsius respectively **(Neem oil)**

Sample	50^0 Celsius	100^0 Celsius	150^0 Celsius	200^0 Celsius
Hexyl Ester of Neem Oil	99.733%	98.237%	95.542%	83.724%
Octyl Ester of Neem Oil	99.944%	97.293%	93.394%	82.606%
Neo-pentyl glycol ester of Neem Oil	99.983%	95.956%	89.432%	74.979%
Commercially available grease	99.904%	90.983%	72.953%	54.372%

Table 4 Comparative data of TGA at 50^0, 100^0, 150^0 and 200^0 Celsius respectively **(Karanja oil)**

Sample	50^0 Celsius	100^0 Celsius	150^0 Celsius	200^0 Celsius
Hexyl Ester of Karanja Oil	99.959%	99.310%	97.868%	88.482%
Octyl Ester of Karanja Oil	99.895%	99.759%	96.462%	76.462%
Neo-pentyl Ester of Karanja Oil	99.926%	92.342%	79.530%	69.241%
Commercially availabe grease	99.904%	90.983%	72.953%	54.372%

Co-efficient of friction analysis

The coefficient of friction, often symbolized by the Greek letter μ, is a dimensionless scalar value which describes the ratio of the force of friction between two bodies and the force pressing them together. The NPG ester have the least co-efficient of friction indicating its highest lubricating tendency. The results of graph are tabulated in table 4.

Table 5 Comparative data of co-efficient of friction **(Neem oil)**

Sample	Co-efficient of friction
Dry condition	0.385
Neem Hexanol	0.105
Neem Octanol	0.022
Neem NPG	0.029
All-purpose grease(standard)	0.102

Table 6 Comparative data of co-efficient of friction **(Karanja oil)**

Sample	Co-efficient of friction
Dry condition	0.385
Karanja Hexanol	0.118
Karanja Octanol	0.112
Karanja NPG	0.072
All-purpose grease(standard)	0.102

Viscosity analysis

Viscosity is a measure of resistance to flow. It decreases (thins) with increasing temperature and increases (or thickens) with decreased temperature. Viscosity of lubricants is measured most commonly by kinematic viscosity and reported in a unit called the centistoke (cSt). Kinematic viscosity, viscosity index and shear stress/shear rate are all factors that should be taken into account during manufacture of lubricant.

Table 7 Absolute Viscosity, Kinematic Viscosity and Viscosity Index **(Neem oil)**

Sample	Absolute Viscosity @ 40 degree Celsius (Centipoise)	Absolute viscosity @ 100 degree Celsius (Centipoise)	Kinematic Viscosity @ 40 degree Celsius (Centistoke)	Kinematic Viscosity @ 100 degree Celsius (Centistoke)	Viscosit y Index
Neem Hexanol	40,000	11,600	47058.82	13647.05	634.87
Neem Octanol	22,000	9000	25882.35	10588.23	680.83
Neem NPG	10,000	8000	11764.70	9411.76	806.26
Commercially available grease	1,10,000	21,000	129411.76	24705.88	600.09

Table 8 Absolute Viscosity, Kinematic Viscosity and Viscosity Index **(Karanja oil)**

Sample	Absolut e Viscosit y @ 40 degree Celsius	Absolute viscosity @ 100 degree Celsius	Kinematic Viscosity @ 40 degree Celsius	Kinematic Viscosity @ 100 degree Celsius	Viscosit y Index
Karanja Hexanol	6000	3000	7058.82	3529.41	660.28
Karanja Octanol	46,000	3000	54117.64	3529.41	354.45
Karanja NPG	12,000	1000	14117.64	1176.47	315.32
Commercially available grease	1,10,000	21,000	129411.76	24705.88	600.09

Above shown table shows the data of absolute viscosity at 40^0 and 100^0 Celsius, Kinematic viscosity at 40^0 and 100^0 celsius and viscosity index of Hexyl, Octyl, Neo-pentyl glycol esters of Neem oil, Karanja oil and commercially available grease. Amongst the three bio-based basestocks for grease, absolute and kinematic viscosity of Neem oil hexyl ester was the highest. While the absolute and kinematic viscosity of commercially available grease was higher than all the three bio-based basestocks for grease. Viscosity Index of Neem oil Neo pentyl glycol ester was found to be higher than all the greases.

Conclusion

Vegetable oil based fatty acid methyl esters were successfully transesterified using various alcohols viz. Hexanol, Octanol and Neo-Pentyl Glycol. These esters exhibit comparative performance properties against standard and reputed product obtained in the market (Commercially available all-purpose NLGI grade 3). Thus these esters derived from Neem oil- a renewable source, can be used as base stock to formulate lubricating grease. Use of such natural materials for deriving a value added product like lubricants can eliminate various problems related to environment and depletion of finite resources; which are still in search of a legitimate solution.

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Development of Lithium Complex Grease for Steel PlantApplication- A Case Study from Tata Steel New Bar Mill

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ABSTRACT

Globally, Lithium complex grease is prepared by co-crystallization of two or more mono or dicarboxylic acids and or their esters with Lithium hydroxide. While manufacturing lithium Complex greases through such multi-components system requires extra time, close monitoring of the process and inventory of various ingredients resulting extra cost and occasional failure of product. Tata Steel, New Bar Mill was experiencing frequent Greasing failure with conventional Lithium Complex Grease.

Authors studied the system and developed a specialty Lithium Complex Grease to meet the requirement of New Bar Mill.

To avoid undesired failure of grease, extra manufacturing steps & hidden energy loss and raw material inventory reduction, we attempted a simple method of complexing lithium based greases.

In this study lithium based greases are prepared in conventional ways. A multifunctional additive system prepared separately, which contains self complexing agent, EP/AW additive, rust & corrosion inhibitor and antioxidant. This complexing improves the structure/mechanical stability, drop point, and resulting upper working temperature limit. To meet other requirements i.e. water washout resistance property, thermal and oxidation stability, rust & corrosion resistance and EP/AW properties, addition of other additives is inevitable. This complete additive was added to complex lithium soap grease after getting desired NLGI consistency to enhance all desired properties of grease in addition to enhancement of working limit without increasing the extra cost. The developed grease properties were compared with conventional lithium complex grease fortified with rust & corrosion inhibitor, antioxidant and EP/antiwear additive. The structure stability of new grease were comparable or better than conventional complex grease as evidenced by working upto 1,00,000 stroke worked penetration, high temperature roll stability tests and series of EP load carrying tests. Various physico-chemical properties and performance details have been revealed in this study from application point of view.

Li-Complex Grease is becoming popular in Steel Plant Bar Mill application. Change-over to this high performance Grease have significantly reduced the failure and increased Plant reliability. Based on performance report, consideration is being given to introduce this grease in similar type of application.

BACKGROUND :

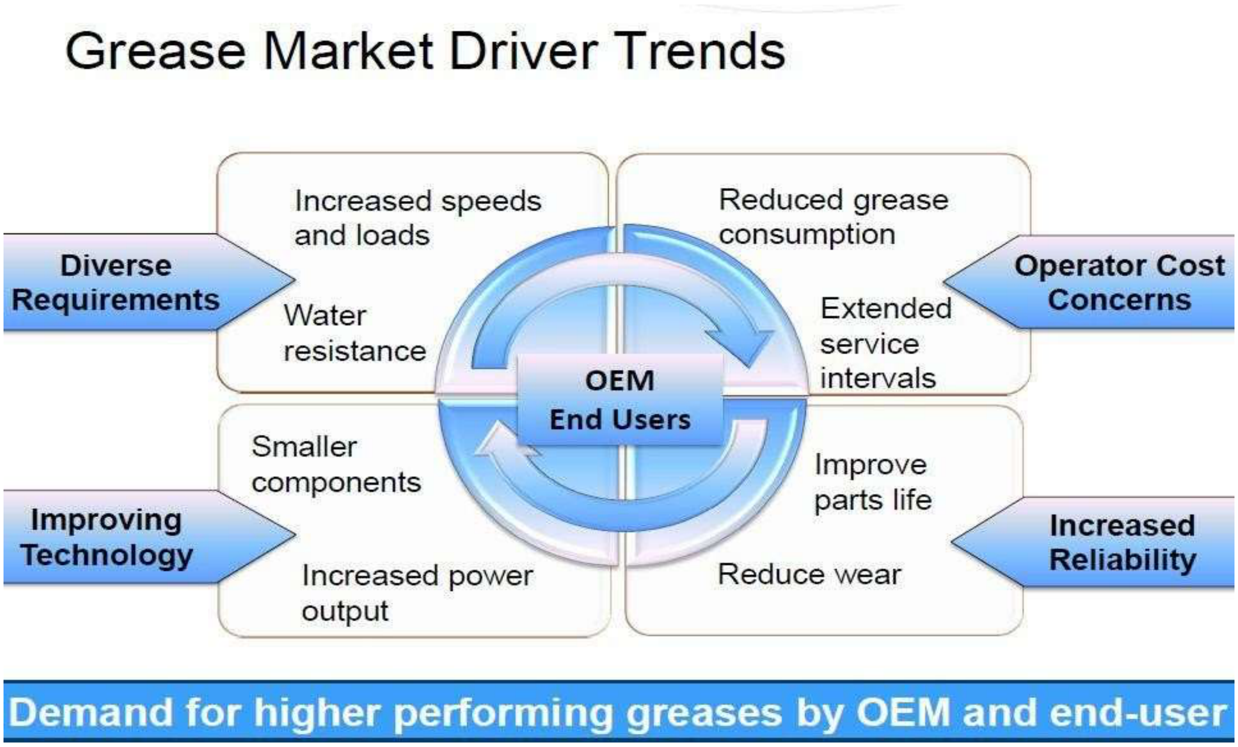
New Bar Mill, Tata Steel with a production capacity of 75000 tons of TMT Re-bars per monthis a very sensitive area of operation. Lubrication programme for such Integrated Steel Plant equipments is a challenge. Specialty Lithium Complex Grease has been developed for such system which can control contamination, filter chocking, pumpability and ultimately sustain very high mill speed without compromising lubrication property. This Grease can provide safe operating environment for industrial machines where load, speed, temperature, consumption of Grease and environment is a matter of concern.

THEORETICAL CONSIDERATION

The grease is recommended for Industrial applications where contamination is a big challenge. LC-2 grease is recommended for the lubrication of both frictional and anti-friction bearings in a wide variety of applications particularly in steel plants which is exposed to high temperature and water washout, high load condition, high speed and dusty environment. It is recommended for use in centralised lubrication system. The Technical parameters of the Pump for Lubricating the system is given below :

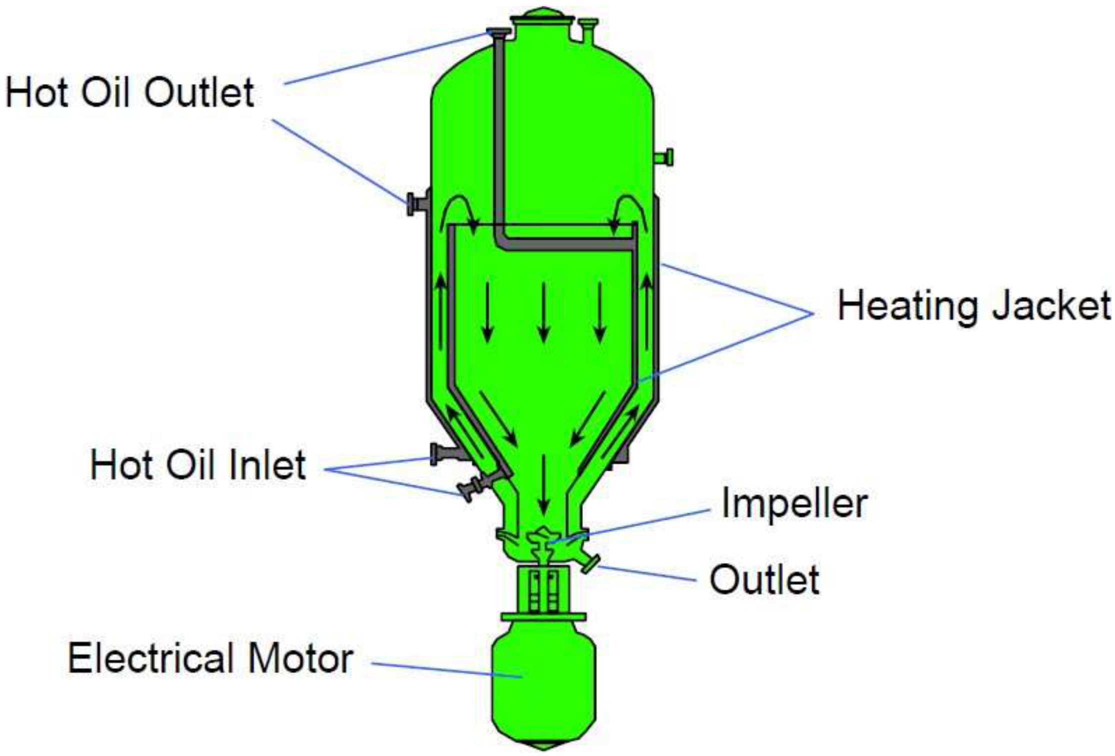
Lubricant output	14 Kg/Hr
Syn Speed/Output Speed	400/100 RPM
Operating Pressure	400 Bar
Direction of rotation of drive	Optional
Lubricant Filters	Filter Area 5.1 sq cm Grade of Filtration = 280 micron
Suitable Lubricant	Grease upto NLGI Gr 3
Sound Level	<70 dB (A)
Voltage	415 V
Frequency	50 Hz
Safety valve	410 Bar
Reservoir capacity	100 Kg
Insulation	Class „F"

CONSUMER DEMAND :

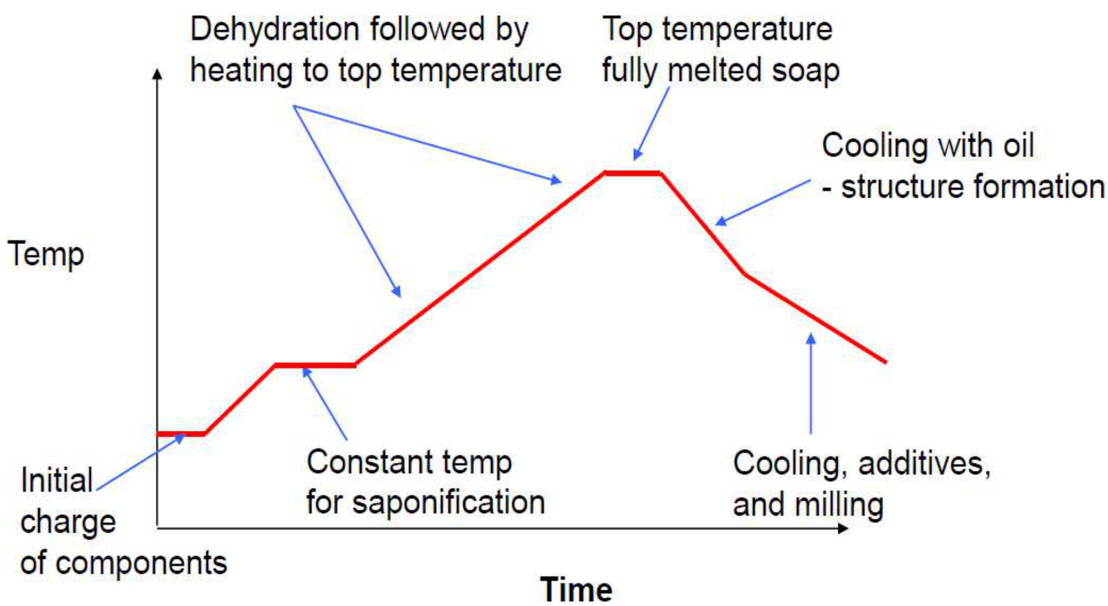


PROCESSING OF GREASE

Speciality Lithium complex grease manufactured from superior quality high viscosity base oil and fortified with solid additives to meet the demand of an EP type grease for boundary lubrication condition. Specific care is taken during manufacturing of the grease to impart fire resistant characteristics. The grease is manufactured by Contractor Processing by combining oil solutions of dissolved fats/fatty acids in mineral oil (heating in Reactor to 70-80°C) and metal hydroxide (base in water). In the process dry materials are added through top access with one-half total oil metered in and the vessel is sealed. Soap is cooked for 30 minutes at 100°C. Hot oil (260°C) is circulated through jacket due to which temperature increase from 100°C to 240°C in 30 min. 15 minutes of residence time is given at 240°C and the pressure maintained at 75-85 Psig. Then pressure is released through vent to dehydrate the mass. Mass is transferred to finishing kettle followed by a flush. Total time in the contactor is around 3 hours. Performance additives are added to the grease prior to milling.

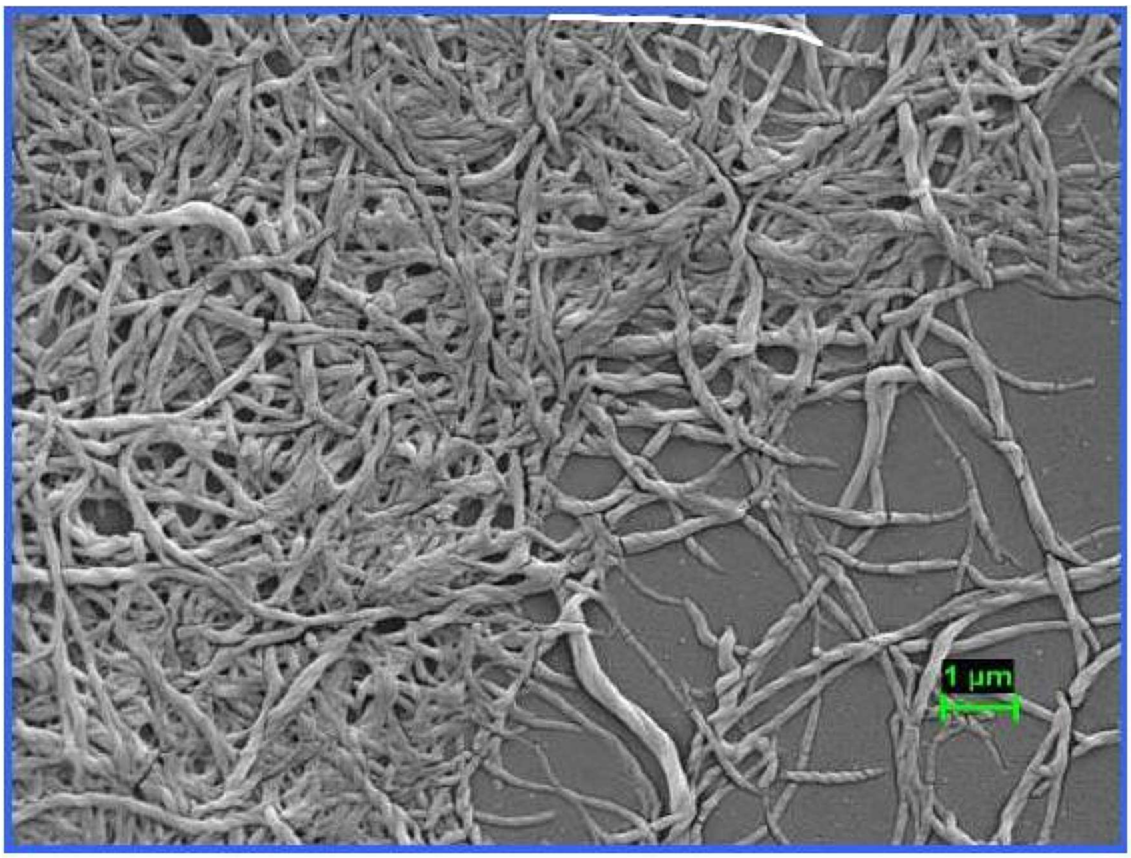


Generalized Soap Grease Process



Process Parameters Influence Grease Properties

Process Parameters	Property
Maximum heating temperature	Complete reaction
Cooling rate	Fiber formation
Alkalinity	Stability
Stirring time and rate	Texture/appearance
Milling	Homogeneity
Temperature of additive addition	Appearance/odor



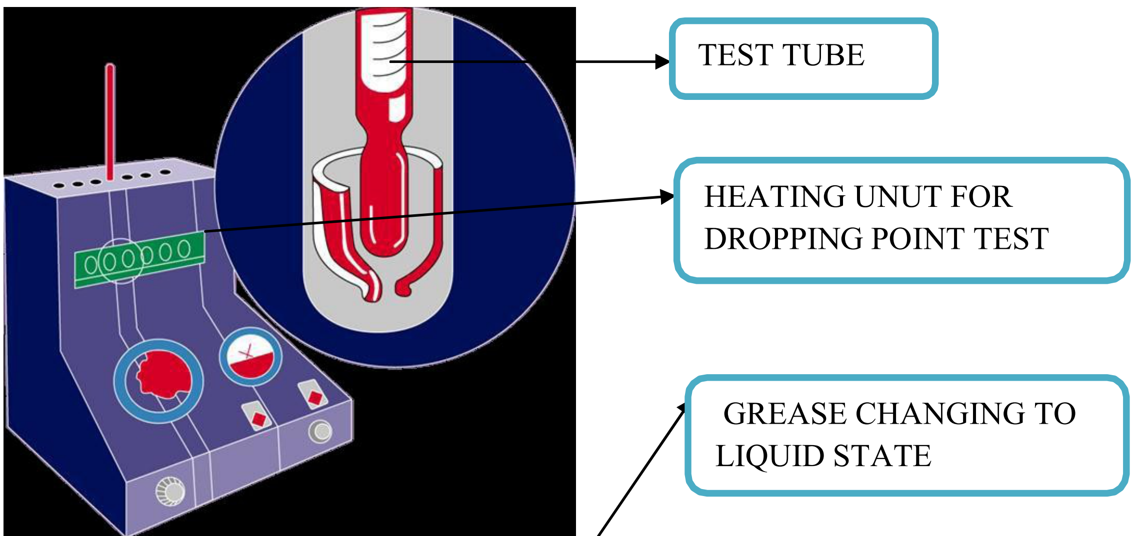
Electron Micron graph of Li-Comp

Cone Penetration Test (ASTM D217)

As per ASTM D217 candidate Grease A was evaluated. The worked penetration at @25 Deg C and after60 Strokes it is of NLGI -1.5

Grease Dropping Point Test(ASTM D566)

The Dropping point of the Grease A is found to be more than 280 Deg C.



Four-ball Test (EP)

For extreme pressure /anti-wear/friction ASTM D 2596 test was carries out and the weld load was foundout. The value of the tested weld load is over 310 kg.

Water Wash-out Test

ASTM D 1264 was carried out for washing out tendency of the candidate grease and it was found about2.5% which is very encouraging.

PUMPABILITY

The candidate grease shows good flow properties which is essential for grease to be used in steel plant application. Often the grease is dispersed throughout the centralised dispensing system. The developed grease possesses good pumpability characteristics particularly at low shear rate.

BIO-DEGRADABILITY:

The additives used in the grease are environmental friendly. These are not only readily bio-degradablemore than 90% but also non-hazardous in water.

TEST SUMMARY:

GRADE PROPERTIES	GREASE A
Color	Brown
Drop Point deg. C	Above 280
Worked Penetration@25 deg.C(Strokes)	NLGI- 1.5 to NLGI 2.0
Weld Load, Kg min.	>310
Base oil viscosity in cst@40 deg,C	Above 288
Copper corrosion test	Negative
Water Washout,% Wt.	<2.5
Timken OK load,lbs	Above 45
Wear Scar Dia (mm)	0.6 (max)

INDUSTRIAL APPLICATION:

The candidate grease is recommended for Industrial applications where load condition, speed, temperature, moisture and environment pose challenges to lubrication solution in steel plant.

PERFORMANCE BENEFITS OBSERVED:

High temperature operability and increased bearing lifeExcellent resistance to water wash out Reduced wear and tear Avoids seizure under shock loading.Extended component life.Low ainte-nance cost. Trouble free lubrication in centralised systemsExcellent resistance to corrosion and rust. Reduced Filter cleaning interval over conventional Li-complex

FIELD TRIAL CONDUCTED AT USER'S END:

Trial conducted at the following places at New Bar Mill, Tata Steel as per Table –A. Table B shows six months average trial results.

Table A

Equipment	Component	Load	SPD	Temp	Moist	Envn
Billet Skids	Billet end shop	2	6	12	16	20
Billet Skids	Moving skid free end	2	6	12	16	20
Furnace charging conveyer	Bearings	2	6	12	16	20
Walking beam mech.	Transverse cylin (wheels)	1	6	12	16	20
In Furnace Charging ROT	Bearings	3	6	12	16	20
Furnace discharging ROT	Cover cylinder	1	6	12	16	20
Furnace discharging ROT	Billet discard Cylinder	1	6	12	16	20
Toggle Shear	Pneumatic cylinder	1	6	12	16	20
Crop & Coble Shear	Fly wheel bearings	2	6	12	16	20
Crop & Coble Shear	Scrap deflector cylinder	2	6	12	16	20
Intemediate Mill # 9 to # 12	Entry guides	2	6	12	18	20
Intemediate Mill # 9 to # 12	Delivery guides	2	6	12	18	20
Intemediate Mill # 9 to # 12	Screw down mechanism	2	6	12	18	20
Intemediate Mill # 9 to # 12	Spindle spline	2	6	12	16	20
Pre-finish Mill # 13 to # 16	Entry guides	2	6	12	18	20
Pre-finish Mill # 13 to # 16	Delivery guides	2	6	12	18	20
Pre-finish Mill # 13 to # 16	Screw down mechanism	2	6	12	18	20
Pre-finish Mill # 13 to # 16	Spindle spline	2	6	12	18	20
Crop & divide shear	Pneumatic cylinder	3	6	12	17	20
NTM # 17 to # 22	cover lifting cycle	3	6	12	17	20
NTM # 17 to # 22	Bearings	3	6	12	17	20

Table A Cond.

Equipment	Component	Load	SPD	Temp	Moist	Envn
Dividing shear	Deflector bearings	3	6	12	16	20
Dividing shear	Deflector arm	3	6	12	16	20
Rotary entry system	Rotary union	3	6	12	16	20
Transmission unit	Shaft bearings	3	6	12	16	20
Chain transfer conveyor	Bearings	2	6	12	16	20
Alligning Rollers	Roller bearings	2	6	12	16	20
Trolley transfer assy.	Bearings	1	6	12	16	20
Trolley transfer assy.	Lifting mecha-nismcylin	1	6	12	16	20
ROT after cold shear	Bearings	2	6	12	16	20
Layer transfer device	Lifting mecha-nismcylin	1	6	12	16	20
Layer transfer device	Bearings	2	6	12	16	20
Layer Buffer ChainConveyor	Drive shaft bearings	2	6	12	16	20
Layer selector conveyor	Bearings	2	6	12	16	20
Layer selector conveyor	Cylinder arm	1	6	12	16	20
Short tail separating	Bearings	1	6	12	16	20
Short tail separating	Lifting mecha-nismcylinder	1	6	12	16	20
Short tail separating	Lifting mecha-nismcylinder	1	6	12	16	20
Bundle feeding chain conveyor	Bearings	1	6	12	16	20
Bundle transfer device	Bearings	1	6	12	16	20
Storage transfer device	Bearings	1	6	12	16	20
Load : Normal (1), Medium (2), Heavy (3), Very Heavy (4), Impact (5)						
Speed- Very Low (6), Low(7), Normal (8), High (9), Very High (10)						
Temp- Normal (11), Medium (11A), High (12), Very High (13), 12 means <80-130 Deg C						
Environment-Normal(19), Dusty (20), Acidic Fumes (21), Steam(22)						

SIX MONTHS TEST DATA (DEVELOPED GREASE/CONVENTIONAL)

Table B

Average Six months data (May'13 to Oct'13)		Operating Condition		Developed Li-Com AZ /Conventional Li-Com Grease
Equipment	Component	Load	Speed	Change in Operating Temperature
Billet Skids	Billet end shop	3	6	11A/12
Billet Skids	Moving skid free end	3	6	11A/12
Furnace charging conveyer	Bearings	3	6	11A/12
Walking beam mech.	Transverse cylin (wheels)	3	6	11A/12
In Furnace Charging ROT	Bearings	2	6	11A/12
Furnace discharging ROT	Cover cylinder	2	6	11A/12
Furnace discharging ROT	Billet discard Cylinder	1	6	11A/12
Toggle Shear	Pneumatic cylinder	1	6	11A/12
Crop & Coble Shear	Fly wheel bearings	2	6	11A/12
Crop & Coble Shear	Scrap deflector cylinder	1	6	11A/12
Intemediate Mill # 9 to # 12	Entry guides	2	6	11A/12
Intemediate Mill # 9 to # 12	Delivery guides	2	6	11A/12
Intemediate Mill # 9 to # 12	Screw down mechanism	2	6	11A/12
Intemediate Mill # 9 to # 12	Spindle spline	1	6	11A/12
Pre-finish Mill # 13 to # 16	Entry guides	1	6	11A/12
Pre-finish Mill # 13 to # 16	Delivery guides	1	6	11A/12
Pre-finish Mill # 13 to # 16	Screw down mechanism	1	6	11A/12
Pre-finish Mill # 13 to # 16	Spindle spline	1	6	11A/12
Crop & divide shear	Pneumatic cylinder	1	6	11A/12
NTM # 17 to # 22	Cover lifting cycle	1	6	11A/12
NTM # 17 to # 22	Bearings	3	6	11A/12

RESULT :

With the application of subject Grease the following outcome is observed :

Parameter	**Benefit Observed**
Filter Cleaning frequency	Once in week instead of thrice in a week in case ofcon-ventional Li-Complex
Water washout	In high moisture zone Grease change frequency is halved
Load	Grease is able to sustain normal, medium and very heavy load
Mill Speed	Uniform Mill Speed maintained in place of slight variation in speed earlier with conventional Grease
Bearing Temp	Uniform Bearing Temp in the range of 80-110 is maintained inplace of Temp variation in conventional Li-Complex
Environment	Grease is able to perform in dusty (20) weather
Consumption	There is 11.6 % reduction in Consumption over conventional Grease

CONCLUSION:

The data presented in the study indicate that the developed Li-complex grease possesses excellent properties suitable for used in critical Lubrication zone of New Bar Mill in Steel Industry. The application of the developed grease is expected to prolong the segment life of Bearings and also lead to much higher noof "heats" between re-lubrication.

Considering the technological demand such specialty grease formulated with special performance standard additives will be very useful for the Industry to meet Steel Plant Lubrication challenge.