

CHAPTER I  
INTRODUCTION



**1.1 General**

In 1970, the United states placed the sperm whale on the endangered species list and, in 1971, banned the import of its products. The unique liquid wax produced by sperm whales was of importance in various lubricant applications such as automotive transmission fluids, metal working oils, industrial and automotive gear lubricants, and tractor hydraulic fluids. [1]

Sulfurized sperm oil was used in many lubricants because it had a combination of properties not matched by other available additives: solubility in high viscosity paraffinic oils, low tendency to form sludge on oxidation, good antiwear, friction, and extreme pressure (EP) properties, as well as compatibility with other additives such as lead naphthenate. [2]

The ban on the use of sperm oil prompted the preparation of sperm whale oil replacements from renewable agricultural sources for example, sulfurization of lard oil. Sulfurized lard oil however is not a suitable replacement because of its poor solubility in high aniline point mineral oils and also poor thermal and oxidative stability. [3]

**1.2 Basic types of gears.**

Gear plays a very significant part in almost every application of mechanical engineering which being been in contact with today. It can be defined as a mechanical

device that transfers rotating motion and power from one part of a machine to another part. Gear consists of toothed wheels which are fitted to rotating shafts, as shown in Figure 1.1 A, and is often used to change shaft speeds, torques and directions of rotation.

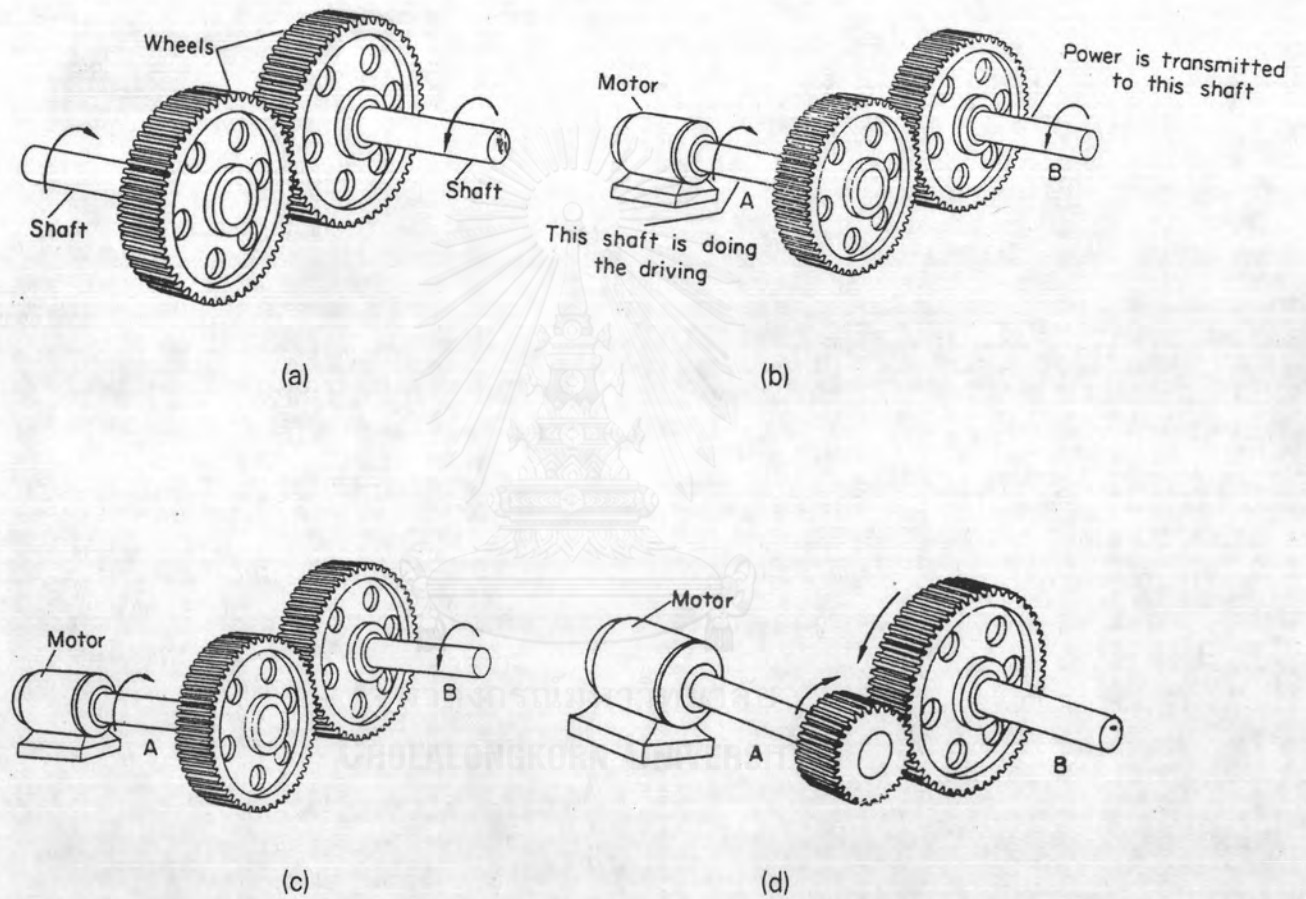


Figure 1.1 A gear; (a) Consisting of gear.

(b) Transmit power.

(c) Change the direction of rotation.

(d) Change the speed.

There are several basic types of gears in use today, including:

- Spur gears
- Helical gears
- Bevel gears
- Worm gears
- Hypoid gears

#### 1.2.1 Spur gears

As shown in Figure 1.2, these are the simplest type of gears. The teeth of the spur gear are straight and the gear connects parallel shafts. For straight cut spur gears, the contact line moves up and down the face of the gear teeth as rotation progresses, and the relative motion is partly rolling and partly sliding. Sliding starts at the point of engagement between the gears and continues until the contact line coincides with the pitch line where the motion is pure rolling, after which sliding occurs again until disengagement. At high speeds,

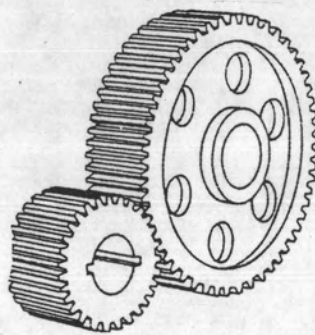


Figure 1.2 A spur gear.

spur gears tend to be noisy and rough because each initial engagement between the gears occurs over the full face width of the gear teeth instantaneously. Spur gears are used in car gear boxes.

### 1.2.2 Helical gears

A helical gear (Figure 1.3 a) is the modern equivalent of smoother, quicker and quieter transmission of motion between gear shafts. The zone of contact is a diagonal line across the face of the tooth. The designer can increase the number of teeth in simultaneous contact and obtain the best compromise of smoothness and mechanical efficiency.

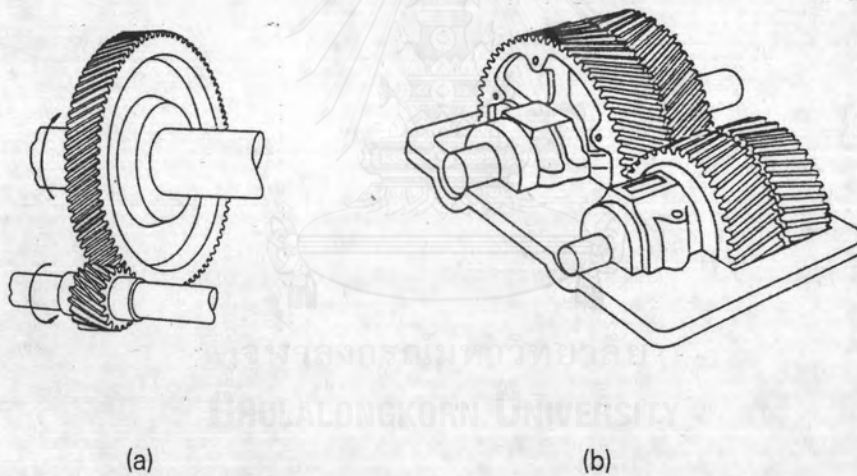


Figure 1.3 (a) A helical gear.

(b) A double helical gear.

*Double helical gears* (Figure 1.3 b) balance out the side thrusts of helical gears by using two pairs of gears side by side with their helices winding in opposite directions. Gears of this type are relatively expensive but are widely used where quietness and smooth

running are important in the transmission of heavy loads at high speeds.

### 1.2.3 Bevel gears

Simple bevel gears transmit motion between shafts that are in the same plane but disposed at an angle, as shown in Figure 1.4 a. If the action of spur gears can be compared with rolling cylinders, the action of bevel gears resembles that of rolling cones with their points coinciding. *Simple bevel gears* have straight teeth radiating from the point of the cones and at high speed display the noise and high tooth loading that characterize spur gears.

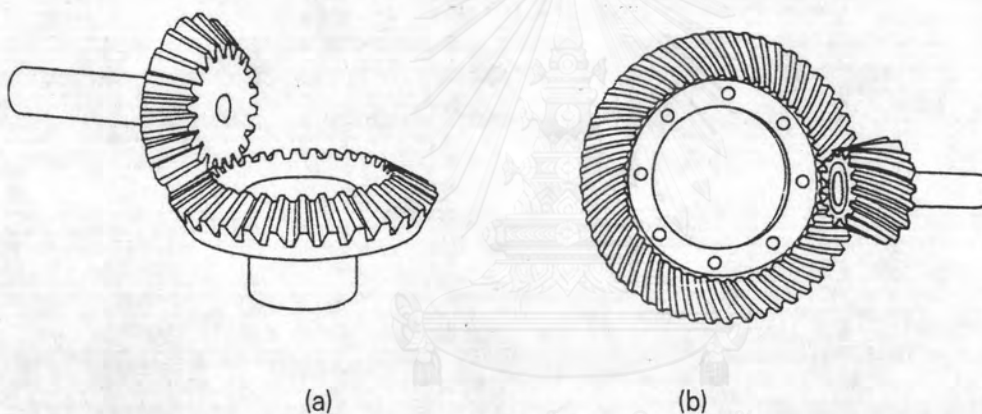


Figure 1.4 (a) A simple bevel gear.

(b) A spiral bevel gear.

*Spiral bevel gears* have curved teeth set at an angle to radical lines, as can be seen in Figure 1.4 b. As before, one end of a tooth comes into mesh before the other end of the previous tooth has disengaged.



#### 1.2.4 Worm gears

The worm gears (Figure 1.5), essentially a development of the skew gear, is used where shafts are at right angles and where the required reduction in velocity is large. One characteristic of the worm gear is that the relative speeds of the two components are not necessarily defined by their diameters because the pitch of the worm is the decisive factor. Another characteristic is that a high reduction worm gear cannot transmit drive from the larger wheel to the smaller.

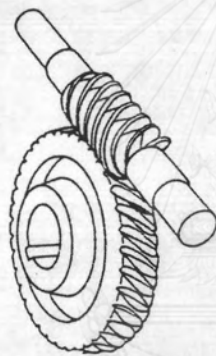


Figure 1.5 A worm gear.

#### 1.2.5 Hypoid gears

In hypoid gears (Figure 1.6), some of the characteristics of the worm gear are combined with some of the characteristics of the spiral bevel gear. The axles are offset and the equivalent cones do not have a pure motion but rather a combination of rolling and sliding.

The advantages of hypoid gears are that the pinion and its teeth can be made

longer and stronger for a given ratio and in automotive applications permits the lowering of the propeller shaft. Also, a quietness of operation characterizes the hypoid axle set.[4-5]

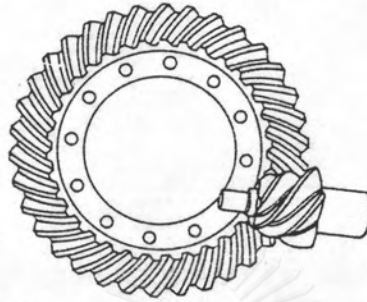


Figure 1.6 A hypoid gear.

### 1.3 Gear oil lubricants

In any metal-working operation, damage to surfaces can be caused when surfaces rub against each other, and high friction can also cause excessive loss of power. Lubrication provides the vital function of separating the contacting surfaces of the gear teeth by an easily sheared film which reduces friction, improves efficiency, and extends the useful life. In addition, lubrication may also provide cooling and flushing of the gear tooth surfaces, corrosion protection, and chemical modification of the surface material. These lubrications are given in Figure 1.7.

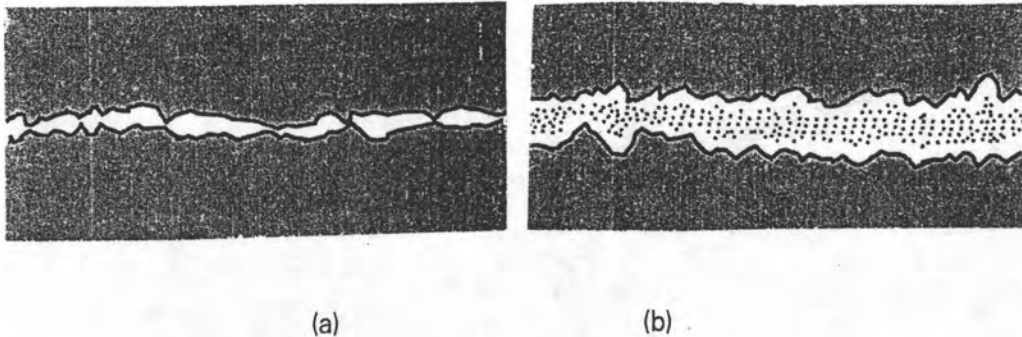


Figure 1.7 (a) Boundary lubrication : metal-to-metal contact performance essentially dependent on boundary film.  
 (b) Hydrodynamic lubrication : fluid film lubrication-surface separated by lubricant film. [6]

Generally, gear oils can be divided into two general classes, automotive and industrial. Their details are described as follows;

The automotive applications require strong EP performance to satisfy hypoid gear requirements while the industrial applications have historically been much less severe. Since the late 1960's, the EP requirements of industrial gear oils have increased substantially. Expanded production has required higher loading and higher temperatures, and these conditions have in turn demanded lubricants offering greater EP protection and improved thermal stability.

Steel mill operations have especially placed severe demands upon the lubricant and well balanced EP packages are now the rule rather than the exception. Formulated packages are required to satisfy both low speed operations running under heavy loading and high speed operations involving shock loading. Sulfur and phosphorus are the usual ingredients in



packages since sulfur protects under high speed conditions while phosphorus protects under low speed/high torque operations. [7]

In addition to good carrying capabilities, the following properties are important in industrial gear oils:

- Good oxidation and thermal stability.
- Ability to separate water. (demulsibility)
- Good rust and corrosion protection.
- Satisfactory worm gear performance.
- Ability to retain performance after long periods of storage or use.
- Free from toxicity. [7]

To cope with the various operating conditions, there are three main types of oil:

- Straight mineral oils
- Compounded oils
- Extreme pressure oils

Straight mineral oils are petroleum oils which do not contain additives to enhance their properties. They are generally used where operating conditions are moderate. Their ability to keep surfaces separated, and so reduce friction and wear, depends largely on their viscosity. The viscosity of gears are similar to those of bearings, in that: Heavier loads (and slower speeds) require high viscosity oil. Lighter loads (and higher speeds) require low viscosity oil.

Compounded oils are blends of fatty and mineral oils, because straight mineral oils become unable to withstand the load and can no longer keep surfaces sufficiently separated. The load-carrying ability of mineral oils can be improved by addition of fatty oils. The fatty oils can be either vegetable oils (like rapeseed and groundnut oils) or animal oils (like whale oil).

Extreme pressure oils are used when operating conditions are too severe for straight mineral oils or compounded oils. These are generally mineral oils reinforced with chemical additives. [5]

### 1.3.1 Base oils

Several types of base stocks are available for formulating industrial gear oils:

- Naphthenic low VI (0-50 VI)
- Conventionally refined HVI paraffinic (80-110 VI)
- Hydrotreated HVI paraffinic (80-110 VI)
- Synthetic (100-166 VI)

The high viscosity index associated with paraffinic oils is generally preferred for premium quality industrial gear oil applications because of the tolerance for wide temperature ranges. Maintenance of a continuous lubricant film is also important to the load carrying capabilities of lubricants and very low viscosities could lead to failures in field service. The desired viscosity can usually be obtained by combining a heavy bright stock with a light neutral oil in the proper ratios. The same additives may show a different response in different base stocks.

Synthetic lubricants are receiving attention where temperature extremes demand a high viscosity index and thermal stability. Principle classes of synthetic lubricants include 1) polyolefins, 2) diesters, 3) polyglycols, 4) halogenated hydrocarbons, 5) phosphate esters, and 6) silicon type polymers. The polyolefins and esters appear to be receiving the greatest attention for industrial gear applications.

The viscosity of the oil must allow the formulation of an adequate protective film under the existing conditions of load, speed and temperature. Lower viscosity gear oils are usually chosen for high speed operations where contact periods between teeth or meshing gears are minimal and where loading is light. Heavier oils are more suitable to low speed/high load operations where contact periods are longer. [7]

### 1.3.2 Additives

Lubricant additive is a material which imparts a new or desirable property not originally present in the fluid or reinforces a desirable property already possessed in some degree by the fluid [8]. Additives used in formulating industrial gear oils can be divided into two general classes : chemically inert additives and chemically active additives.

#### 1.3.2.1 Chemically inert additives.

These additives affect a physical characteristic of the lubricant, namely viscosity, pour point, demulsibility and foaming tendency, as described in detail as follows;

### Viscosity index improvers.

Viscosity index (VI) improvers can alter the natural viscosity temperature relationship of an oil. VI improvers are generally polymeric materials which tend to thicken the oil more at high temperatures than at low temperatures. When cold, the polymers are coiled up into small round particles and offer little resistance to the bulk oil flow. When the temperature rises, the polymers uncoil to form long string like fibers which restrict the free flow of the oil, giving rise to a higher effective viscosity. VI improvers are polyisobutylenes, polyacrylates, polymethacrylates and ethylene-propylene copolymers.

### Pour point depressants.

Lubricating oils containing straight chain paraffinic hydrocarbons tend to form wax crystals at low temperatures and these crystals form lattice structures which impede the flow of the oil. Pour point depressants are structurally similar to VI improvers but are usually of a much lower MW. These materials are believed to function by interfering with the lattice like structure of the wax crystals. Typical examples are polymethacrylates, wax alkylated naphthalenes, wax alkylated phenols and poly (alkyl phenol) ethers.

### Foam inhibitors.

The foam inhibitors are chemicals added to increase the rate of destruction of air bubbles which are formed when lube oils are severely agitated. These materials have very limited solubility in most mineral oils and creating discontinuities within the oil film surrounding the air bubbles or by lowering the bulk surface tension of the oil. Polymers of silicon and oxygen called polysiloxanes are commonly employed as foam inhibitors, although acrylate type polymers have also been effective.

### Demulsifiers.

Chemicals which enhance the water separating characteristics of lubricating oils are called demulsifiers. These materials have partial solubility in both water and oil phase. Some materials are trialkyl phosphates, polyethylene glycols, alkyl amines, and carboxylic acids.

#### 1.3.2.2 Chemically active additives.

These additives produce their effect through some kind of chemical reaction either within the lubricant or on a metallic surface. They protect the lubricant from oxidative and thermal degradation, prevent rusting and corrosion of metal parts, and reduce wear and prevent scoring due to metal to metal contact. Important examples of the additives are following;

#### Extreme-pressure agents.

These chemicals contain sulfur, phosphorus, chlorine and heavy or transition metals. They react with sliding metal surfaces under the influence of heat and pressure to form compounds of the metal and these compounds exist as a film on the metal surface which reduces frictional heat and prevents welding and scoring. Some of the materials are sulfurized olefins, sulfurized esters, phosphate and thiophosphate esters, zinc dialkyl dithiophosphates and chlorinated paraffins.



### Friction modifiers.

Friction modifiers often called "slipperiness agents" generally consist of a long linear hydrocarbon chain and a small polar entity. Unlike EP agents, these materials do not react chemically with the metal surface but rather become adsorbed on that surface. The adsorbed molecules become aligned in a regular pattern and act to reinforce the fluid film. Typical examples include fatty acids, esters, alcohols, and amines. Sulfurized derivatives often serve a dual function as EP agent and friction modifier.

### Oxidation inhibitors.

When oils are oxidized, unstable materials called peroxides are formed. The peroxides quickly decompose to form other materials which are more susceptible to oxidation. The whole process is a chain reaction which is accelerated by increased temperatures and which is catalyzed by certain metals. The final products of oxidation are sludges, gums, varnishes, lacquers, and acidic materials, none of which are beneficial to a lubricant system. Oxidation also causes the viscosity of the lubricant to increase. Some of the chemicals typically used to inhibit oxidation are : hindered phenols, aromatic amines, sulfurized olefins, thiazoles, zinc dithiophosphates, and dithio carbamates.

### Rust Inhibitors

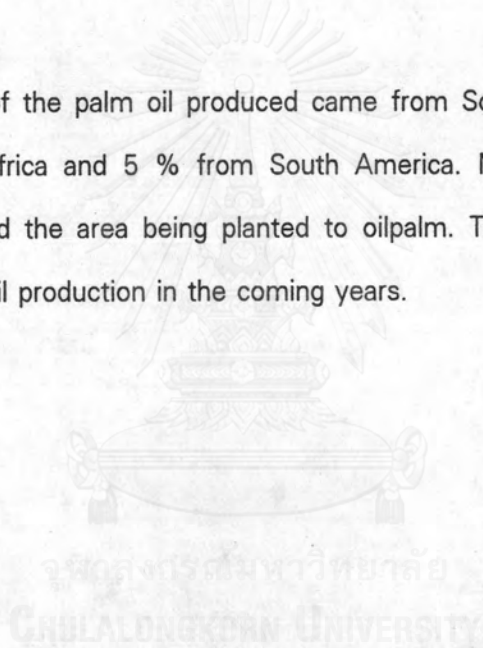
Rust inhibitors are usually highly polar compounds with only a limited solubility in oil. They function by adsorption on the metal surface to form a thin protective film which effectively excludes air and water. The types of chemicals used as rust inhibitors in industrial gear oils are : fatty amines, fatty amides, oxazolines, imidazolines, phosphoric

acid esters, and carboxylic acids. [7-8]

#### 1.4 Palm oil.

Of all oil-bearing plants, the oil palm produces the most oil per unit area, with current production amounting to 5 to 7 tonnes of oil per hectare. In 1980, palm oil became the world's second most important vegetable oil after soybean. Production had increased in a spectacular manner, more than double during the decade from 1970 to 1980.

In 1977, 78 % of the palm oil produced came from South-East Asia (Malaysia and Indonesia); 17 % from Africa and 5 % from South America. More recently, Malaysia and Indonesia have accelerated the area being planted to oilpalm. This evolution will result in a distinct increase in palm oil production in the coming years.



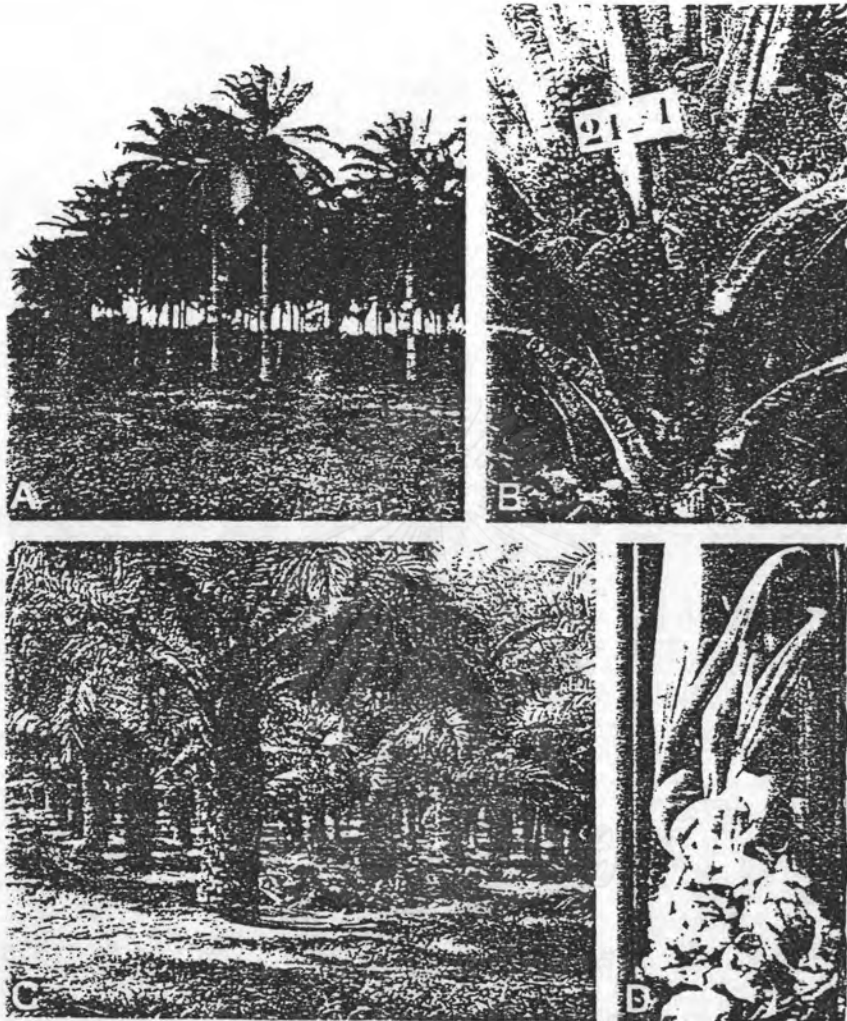


Figure 1.8 Oil palm. (A) Adult oil palm plantation

(B) An oil palm crown bearing unripe bunches

(C) Plantation of a dwarf variety

(D) Young plantlets in a tube for in vitro mass propagation

#### 1.4.1 Origin and systematics.

The oil palm, *Elaeis guineensis* Jacq., (Figure 1.8) originated in Africa where its natural habitat is in the humid tropics, 15° on either side of the equator. The plant is a monocotyledon of the order Spadiciflorae of the Palmae family, and is a member of the Coconut tribe. In addition to the oil palm, the genus *Elaeis* includes two other species of American origin, that of *E. oleifera* (H.B.K.) Cortes. (*E. melanococca*), which is easily crossed with *E. guineensis* in spite of its different origin, and *E. odora* Trinal, a less well-known species of secondary importance. [9]

The oil palm can reach when growing wild an height of 15 to 25 m. On estates it grows much slower and its trunk reaches an height of 3 to 4 m. in its 12th year. An adult palm is bearing about 30 leaves, 4 to 6 meters long. The inflorescences appear in cycle alternately males and females. There is in each leaf axial a female or a male inflorescence. But some are abortive. The female inflorescence or bunch has an avoid shape, it carries 100 to 150 finger-like structures having 8 to 12 flowers. The bunch will be ripe six months after the flowers have been pollinated. It will weight 10 to 25 kilos sometimes even more.

There are an average of 1,000 to 1,500 fruits per bunch. A fruit, having also an avoid shape, is composed of:

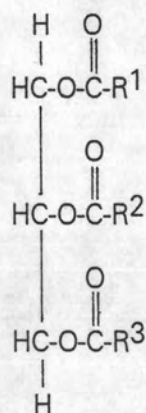
- the epidermis      rich in carotene
- the pulp            more or less fibrous and of a thickness  
varying from 2 to 10 mm. from which  
palm oil is obtained.
- the seed            A composed of a very hard shell of 1/2

to 5 mm. thickness enclosing the kernel which albumen will give the kernel oil. [10]

#### 1.4.2 Formation and characteristics.

Chemically, the word "fat" is coming to be used to cover vegetable oils and fats whether they are in the solid or liquid state, though in normal parlance the word oil is applied to a fat when it is in the liquid state.

Fats have been defined as the esters of fatty acids with the trihydric alcohol glycerol, and they must be distinguished from other simple lipids like the waxes which are esters of fatty acids with high molecular weight, straight chain alcohols. The triglyceride fats, which predominate in plant and animal fats have the following general formula:



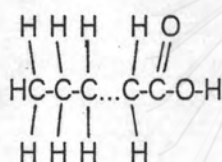
where  $R^1, R^2$  and  $R^3$  represent the hydrocarbon chains of fatty acid radicals.

Fatty acid may also combine with glycerol to form mono- or di- glyceride when only one or two of the hydroxyl groups of the glycerol will be in fatty acid combination. However these occur naturally only in fats which have become partly hydrolysed. When more than one fatty

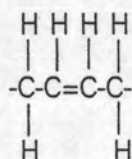


acid radicals are involved, as in tri- or di-glycerides, these may be alike or different. There are many different naturally occurring fatty acids.

Naturally occurring vegetable fats are mixtures of fats. Their characters are taken largely from the fatty acids which predominate in them and from the arrangement of these fatty acids in the triglycerides. The fatty acids are hydrocarbon chains in which two hydrogen atoms are attached to all or the majority of carbon atoms within the chain. The carbon atom at one end of the chain has three hydrogen atoms attached to it and the one at the other end is attached to a carbonyl group to give the general structure, as shown below:



Fatty acids of this general formula are saturated fatty acids as they have the full number of hydrogen atoms attached to the carbon atoms of the chain. In unsaturated fatty acids there are one, two or three double bonds between carbon atoms which then have only single hydrogen atoms attached to them, in the following manner:



Double bonds can occupy different positions in the chain, thus giving rise to different isomers. Furthermore, there are also geometric isomers (the *cis*- or the *trans*- forms) according to whether portions of a molecule joined by a double bond extend in the same or opposite

directions.[11]

#### 1.4.3 Properties.

Palm oil varies in color from orange-yellow to deep orange according to the colour of the original fruit[12]. At ambient temperatures in temperate climates, palm oil is solid. In tropical countries such as Malaysia palm oil is a fluid with a small fraction present in crystalline form. The melting of palm oil is gradual over a range of temperatures from 25 °C to 50 °C. Palm oil is in reality a mixture of oils and isomers of the same oil. [11]

The colour of the oil is due to a mixture of carotene and xanthophyll in the proportion of three parts of carotene to one part of xanthophyll. The colour of the oil is not permanent, a bleaching effect taking place on standing for a long period, especially if the oil is exposed to light. The presence of these fat-soluble pigments, more particularly carotene, is interesting from the point of view of the nutritive value of the oil, on account of the relationship existing between carotene and vitamin A, a fat-soluble vitamin. As is well-known, vitamin A is considered to be associated with bodily growth and vigour.

From a chemical point of view, palm oil is classified as a vegetable fat. Some of the physical and chemical constants as determined for samples of local oil is shown in Table 1.1

The acidity of palm oil is expressed in terms of palmitic acid, being present in the mixed fatty acids to the extent of approximately 40 percent. The percentage composition of the mixed fatty acids in palm oil is shown in Table 1.2

Table 1.1 Physical and chemical properties of palm oil.[12]

<b>Oil</b>	
Specific gravity at 99.5 °C (water at 15 °C = 1)	0.860-0.861
Saponification value	201.0-202.5
Iodine value (Wijs)	50.3-52.2
Acidity (palmitic acid per cent.)	4.2-5.8
<b>Fatty Acids</b>	
Solidifying point (Titer value)	44.9-46.3 °C
Mean molecular weight	270-271
Iodine value (Wijs)	52.5-54.2

Table 1.2 The composition of the mixed fatty acids in palm oil. [10]

<b>Unsaturated acids</b>	
Oleic	39-52
Linoleic	6-10
<b>Saturated acids</b>	
Palmitic	32-45
Stearic	3.7-5.5
Myristic	0.6-1.6

International specification organisations are getting together to try to agree on firstly an international method of analysis and a specification for crude palm oil from the producing country. Without satisfactory methods of analysis which are the same internationally, no specification can work. Organisations such as IUPAC, ISO and the standards institutes in various countries are working to this end. Two special grades of palm oil have been suggested a special quality and a standard quality. The characteristics and specific requirements are shown in Table 1.3

Table 1.3 Quality characteristic requirements of palm oil.[11]

<i>General characteristic requirements</i>	
<i>Colour</i>	The colour shall be bright, clear orangy-reds at a temperature of 50-55 °C.
<i>Odour and taste</i>	The colour and taste shall be free foreign and rancid odour and taste.
<i>Total carotenoids</i>	The total carotenoids for <i>E. guineensis</i> shall be in the range 500 -1000 mg/Kg.
<i>Quality requirements</i>	The material shall be of two qualities, namely, Special Quality and Standard Quality.  The material shall conform to the requirements shown below.



Table 1.3 Quality characteristic requirements of palm oil.(continued)

<i>Specification requirements for palm oil (at time of shipment)</i>			
		<i>Requirements for:</i>	
<i>Item</i>		<i>Special</i>	<i>Standard</i>
<i>Number</i>	<i>Specifications</i>	<i>Quality</i>	<i>Quality</i>
(i)	FFA (max) %	2.5	5.0
(ii)	Moisture content (max) %	0.15	0.15
(iii)	Impurities (max) %	0.02	0.02
(iv)	Peroxide value (max) meq/kg	6	
(v)	Anisidine value (max)	6	
(vi)	Bleachability (min)	Residual colour in	
	3% Tonsil optimum FF	5 1/2" Lovibond cell:	
	at 150 °C	2 Red	
		20 Yellow	
	1 hr under carbon dioxide		
(vii)	Metal content :		
	Copper ppm (max)	0.2	
	Iron ppm (max)	3.5	

#### 1.4.4 Extraction

The fresh fruit bunches arrive from the field at a reception area and then are transported to a hopper. Fruit cages of special design for use in the sterilisation are filled from the hopper, and these cages have a capacity of 2 1/2 tonnes of bunches. Fresh fruit bunches are sterilised for the following reasons:



- (i) to destroy the enzymes responsible for the development of FFA
- (ii) to coagulate the nitrogenous and mucilaginous matter to prevent the formation of emulsions in the crude oil and
- (iii) to loosen the fruit from the bunch so that stripping of the fruit is not difficult.

Sterilising is carried out for a period in order to ensure that the enzyme responsible for the development of the fatty acid is destroyed. It is necessary to ensure that the air is swept out of the steriliser so that the correct temperature is obtained and also to avoid some oxidation of the fruit. After sterilising, the fruit is stripped from the bunch in a drum thresher. The empty bunches are burnt in an incinerator and the ash used as a valuable fertiliser with a high potassium content.

The most important process in the extraction of the oil is the digestion of the fruit. The fruit is fed into an elevator from the thresher and then to a worm conveyor which distributes the fruit to the digester. The crude oil from the press is passed over vibrating screens where the larger fibre particles are removed. Oil is fed to a crude oil tank where the sand and dirt are allowed to settle. The crude oil is pumped through a pre-heater and a continuous clarification tank. In this tank approximately 90 % of the pure oil is settled out. The pure oil continues to a centrifuge where the impurities are removed and the moisture content reduced. The oil is passed through a continuous vacuum drier and then stored in bulk ready for shipment. [11]

In the manufacturing [10] the factory is a complex industrial plant. The manufacturing process is shown in Figure 1.9

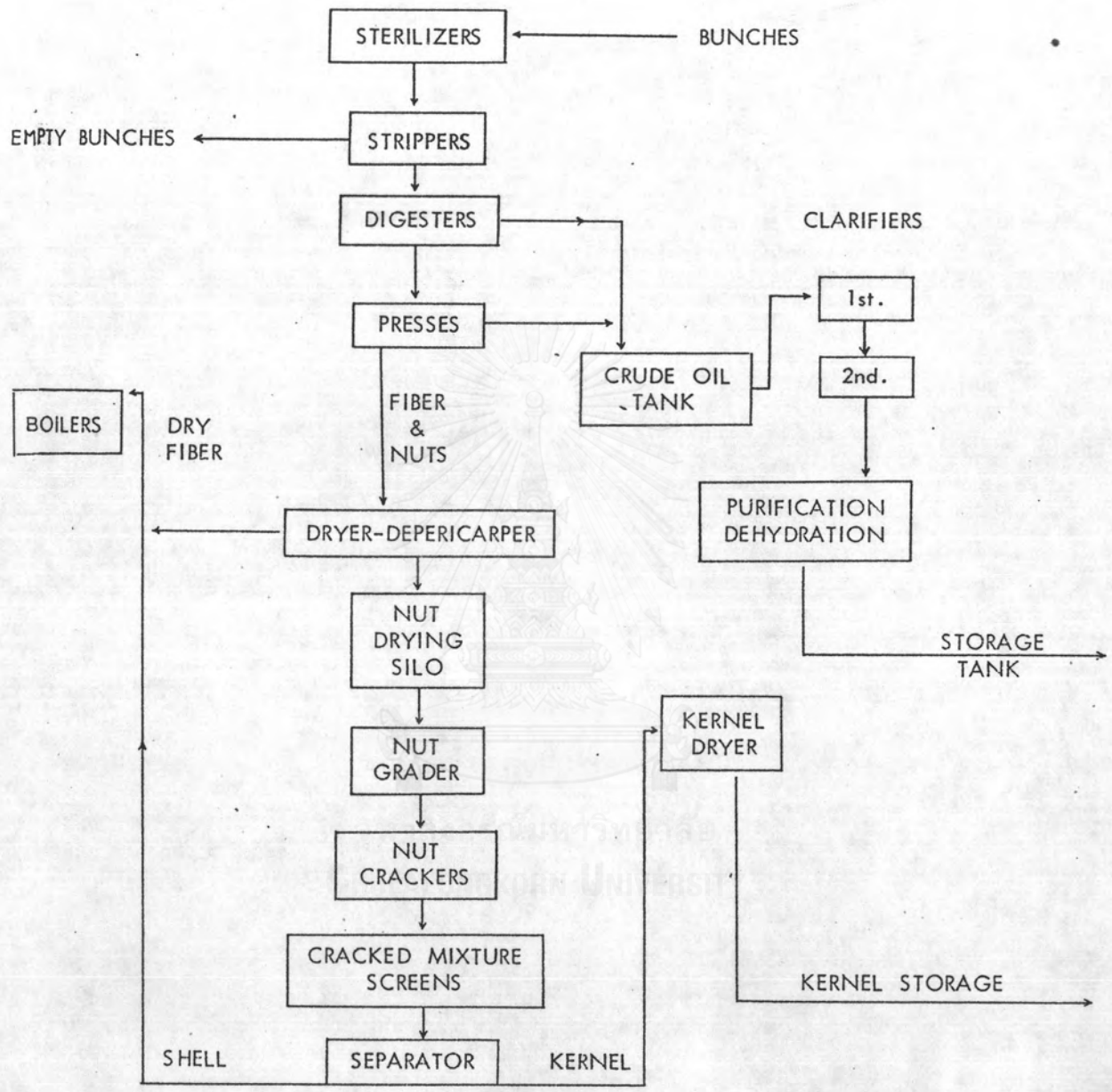


Figure 1.9 Factory diagram.

#### 1.4.5 Industrial Applications

The particular applications which palm oil finds in industry depend principally upon the acidity of the oil. The uses of palm oil may be summarised as follows:

(a) *Soap-making* For this purpose, the acidity of the oil is of relatively minor importance, the medium and lower grades of palm oil being suitable. If such grades of oil are employed, there will be a considerable reduction in the yield of glycerine, a by-product of importance in soap manufacture. Increasing amounts of high-grade palm oil are now being used in the manufacture of soap, particularly toilet soap.

(b) *Candles.* Palm oil owes its application in the candle industry to the comparatively high melting point of the fatty acids present as glycerides in the oil. The use of palm oil for manufacture of candles is unlikely to increase on account of the competition which the oil must meet from mineral waxes, such as paraffin wax.

(c) *Edible purposes.* As far as can be ascertained, palm oil is being used to a slightly increased extent both in the manufacture of edible fats and in the preparation of vegetable butters and margarine. For such purposes, palm oil of low acidity is required in order to reduce refining losses to a minimum. Briefly, the process can be divided into three parts, namely;

- (1) Bleaching the oil (Decolorisation)
- (2) Removal of acidity (Neutralisation)
- (3) Removal of odour and taste (Deodorisation)

(d) *Tin-plating* Palm oil is used extensively, especially in the United States of America, for tin-plating, that is tin-coated iron. For this purpose the oil should be of good quality, the acidity, calculated as palmitic acid less than 7 per cent., the combined moisture and dirt contents not exceeding 1 percent.

(e) *Greases*. Palm oil is used to a small extent in the manufacture of heavy greases, for example, axle greases for locomotives, also wagon grease. The application of palm oil in this connexion is unlikely to extend on account of the use of mineral greases for such purposes. In the preparation of palm oil greases, the oil, if of low grade, is usually mixed with lime or other alkali to reduce its acidity, thereby preventing corrosion of metal. The corrosion would be likely to occur if oil containing a high proportion of free fatty acid was used.

(f) *Fuel*. Palm oil has been used as a fuel for internal combustion engines with satisfactory results, although its use in this connexion is likely to remain restricted to those countries in which palm oil can be produced more cheaply than imported mineral oil. The oil must be of good quality, free from moisture and dirt. A special carburettor is necessary to atomize the oil, which must be maintained liquid in the supply tank.[12]

### 1.5 Objectives for this study

The objectives of this work are to synthesize sulfurized palm oil as a lubricant additive for industrial gear oil and to study the efficiency of the sulfurized palm oil lubricant as described in the following:

1. Synthesis of sulfurized palm oil by using various chemical conditions followed by study of the major conditions that influence the quality of the total sulfur in products. The conditions investigated are;

- Reaction temperature in a range of 150-220 °C
- Reaction time in a range of 2-10 hrs.
- Concentration of sulfur in a range of 3-20 %w

2. Study of the physical properties of sulfurized palm oil with base including

- % total sulfur
- viscosity
- solubility
- pour point
- flash point and
- copper corrosion

3. Study of the extreme-pressure properties of sulfurized palm oil in various conditions including

- Amount of sulfurized palm oil
- Viscosity of base oil
- Concentration of sulfurized palm oil