Mathematical Modeling of Motor Oil Life and Lubrication Degradation Rate

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ABSTRACT

The paper is trying to give information about motor lubricant oil its grades according to relatively international standard. The paper suggested that due to poor oil personnel experience in Sudan lubricant oil choosing and change shows less effectiveness. The objectives of this study are to give the condition of maintaining correct time for the motor oil changing and the suitable oil type that helps to optimize lubricant cost and performance for motor engine. For that the process of fixing motor oil type and changing duration is done by using a mathematical model that has a direct relation to economical concepts and machine technical condition. The study used a data of an experimental work done by Honda International Company for an engine oil to fix its duration interval. Also the paper shows that the machine lubricant industry specifications, its general grades and machine manufacturer directions are very confusable. They are in a constant state of change; therefore the printed information's may not reflect the latest specifications. So from the side of motor oil users and engine manufacturer they are asked to update continuously their information. The paper is suggested that an international effort should be done extremely in the field of lubricant oil quality control and to give lubricant oil personnel considerable training to insure suitable oil and safety timing for machine oil changing. No doubt this leads to lengthen machine time life duration, helps to lessen machine wearing, car failure, environmental risk and to minimize maintenance cost.

Paper is suggested that all new car engines should be provided with the oil life monitoring systems that notify the driver when an oil change is required.

KEYWORDS: Engine oil, Oil type, Machine load, Trip duration, Temperature rate, Extreme operating conditions.

INTRODUCTION

Lubricant oil undergoes thermal breakdown due to high operating temperature. When this occurs, the oil becomes less effective as a lubricant and without a good lubricant parts of the engine rub together and wear each other out. Lubricant oil also contains additives that have the ability to neutralize acids. Over time, these additives get used up and stop being effective. Finally, oil can absorb water, dust and combustion byproducts and also hold them in suspension. Eventually, the oil gets saturated with this stuff and can't absorb any more. Then that stuff remains in the engine and can cause corrosion [1].

The dirty oil doesn't do the job as well as fresh oil does. The additives in dirty oil boil out, contaminants form in the crankcase and eat metal parts and water collects over time and forms sludge. The oil holds more and more abrasive particles of metal suspended in it, and these particles wear away the parts of the engine that the oil is supposed to protect [2].

Therefore motor oil should be changed at regular reasonable intervals. Generally for motor oil personnel in Sudan the reasonable amount of time — or mileage — between oil changes is a problematic issue.

In general, changing the vehicle's oil is one of the most important things that can be done to avoid bringing large cost of maintenance later on. However, there's a lot of controversy about exactly when engine oil gets old and how often it should be replaced with new oil in Sudan service locations. Because there are many factors at work – like driving regime, the condition and age of the engine, the external environment at loading or driving , and stop-and-go versus highway driving – are the exact factors that determine the oil change. Most owners' manual recommendations for oil and filter changes vary from 3,000 to 10,000 miles.

Generally the oil technician in Sudan recommending for the change of oil and filter can be every 5,000 miles, without consideration of the machine age and operation condition. That is the best estimate as they declared since it's difficult to them to deal with all different car manufacturers' recommendation and different oil producers advices. Anyhow it may be too soon for many people and too late for a few, but for the vast majority; 5,000-mile oil changes will help the engine last to a ripe old age. According to most references and literature the changing of oil generally should be considered more frequently with short interval if:

- The drive like a knucklehead: jackrabbit starts, heavy acceleration or high-speed driving.
- The condition of living where the climate is extremely hot or cold as this is in case of Sudan.

- The operation or driving is often on dirt roads as in most remote area of Sudan
- If the engine is old and burns oil. More than 85% of Sudan automobile fleet is manufactured before 2013.
- If the engine is frequently carrying heavy loads

So according to Sudan case car operations condition very often subjected to the upper cases. Anyhow the general advise if possible it's a must to read the car owner's manual to locate the correct interval. Some car manufacturers suggest that oil change every 7,500 miles or more, but that's based on optimum operating conditions, and the car manufacturers are the ones who get to sell the new vehicle if the old one wears out prematurely and this service is not exist in Sudan. Although new vehicles can run longer on the same oil than older ones can and improvements in motor oil have extended its efficiency over longer periods of oil time change technicians still ignoring these facts in Sudan. Therefore some car owners insisted to be on the safe side and to change their oil every 5,000 miles or every six months. If the case of a freeway driver who goes on a lot of long journeys as buses between cities and at high speeds he can probably extend the oil change interval, but on anyhow in this case even newest vehicles, are not to be advised to go longer than 3,000 miles between changes in case of Sudan condition. Generally under any circumstances, go farther than the manufacturer's recommended maximum interval between oil changes is not recommended.

In Sudan generally when asked about oil change, the technician's answers such as every 3000, 5000, 7500 miles, or when the vehicle's oil monitors (if exists) indicates that this service is necessary. It is no wonder consumers are confused because in fact, there is no general interval that applies to most vehicles. The operating conditions generally in Sudan can be considered as "extreme operating conditions" because of a lot of stop-and-go driving in cities or rush-hour traffic, make a lot of short trips each day and leave the car parked not to long enough time to have the engine cool down between them, and don't often get up to high speeds on a highway, the engine rarely gets hot enough to evaporate the water that forms in the crankcase and builds up sludge in the engine. Other extreme conditions are when the drive in very hot weather or in areas with a lot of blowing dust or dirt, or tow or haul heavy loads all the time, in any of these circumstances, the change of oil as often as every 1,000 to 3,000 miles. On new vehicles, the following of the manufacturers' recommendations for extreme use is important.

The engine won't last as long as it could without proper frequent change. Oil serves many crucial functions, and clean oil performs those functions better than dirty oil. Oil is relatively cheap, and changing the oil every 5,000 miles is a very cheap insurance policy against major repairs down the road but this carry an environmental risk.

When oil change is suggested for about 3000 mile, which is very often in Sudan service workshops the following facts should be also taken in considerations:

- Oil requires complex additives and detergents to help prevent corrosion and sludge buildup
- Additives allow oil to flow freely at extremely cold temperatures while also providing protection under extremely hot temperatures
- Testing shows that at 3000 miles the oil itself still lubricates, but the depletion of critical additives may no longer allow the oil to offer the same protection on and to get the benefits
- Longer intervals may benefit the environment, but perhaps at the expense of engine life
- Re-refined oils offer an alternative for motorists with concerns about the environment since it shorten the quantity of used oil
- Re-refined oils use the remaining lubricating qualities of used oil, and replenish the depleted additives to create oils that meet the quality of new oil.

The car's filters are important to the longevity of the car and interior comfort. So for maximizing the car investment this will be by replacing filters regularly.

The oil filter traps contaminants, allowing the oil to flow through the engine unrestricted. The fuel filter separates harmful contaminants that may cause problems with carburetors or intricate fuel injectors. The air filter traps dirt particles, which can cause damage to engine cylinders, walls, pistons and piston rings. The air filter also plays a role in keeping contaminants off the airflow sensor (in fuel-injected cars). The cabin filter helps trap pollen, bacteria and dust that may find their way into a car's ventilation system [3].

Filters are normal wear items that require regular checks and replacement. Factors that affect replacement intervals include: mileage, driving habits, driving and road conditions, type of filter, vehicle type. The symptoms that appear for filters performance that need replacement are: poor gas mileage, hesitation while accelerating and musty odor in the cabin.

Synthetic oils, such as the popular Mobil 1, are stretching oil change intervals, leaving the 3,000-mile mark in the dust. "The great majority of new vehicles today have a recommended oil change interval greater than 3,000 miles [4][5].

Oil experts and car manufacturers are solidly on the side of the less-frequent oil changes that these formulation changes make possible. "If customers always just stayed with the 3,000-mile recommendation, consumers, would be "throwing away good oil."

The main objectives of this study are:

a) To insure proper intervals for motor oil changing.
b) To guarantee a suitable type of motor oil according to machine function.
c) To extract mathematical model for oil changing interval in Sudan condition.
d) To make authorities to pay attention for engine oil waste and its environmental effect.
e) To enforce people to use the latest technology of motors like using oil life monitor systems and recycling of waste oil.

MATERIALS AND METHODS

Motor oil sample

Motor oil, engine oil, or engine lubricant is any of various substances that are used for lubrication of internal combustion engines which power cars, motorcycles, lawnmowers, engine-generators, and many other machines. The main function of motor oil is to reduce wear on moving parts; it also cleans, inhibits corrosion, improves sealing, and cools the engine by carrying heat away from moving parts.

Motor oils are derived from petroleum-based and non-petroleum-synthesized chemical compounds. Motor oils today are mainly blended by using base oils composed of hydrocarbons, polyalphaolefins (PAO), and polyinternal olefins (PIO), thus organic compounds consisting entirely of carbon and hydrogen. The base oils of some high-performance motor oils contain up to 20% by weight of esters.

In engines, there are parts which move against each other, and the friction wastes the useful power by converting the kinetic energy to heat. It also wears away those parts, which could lead to lower efficiency and degradation of the engine. This increases fuel consumption, decreases power output, and can lead to engine failure. Lubricating oil creates a separating film between surfaces of adjacent moving parts to minimize direct contact between them, decreasing heat caused by friction and reducing wear, thus protecting the engine. In use, motor oil transfers heat through convection as it flows through the engine by means of air flow over the surface of the oil pan, oil cooler and through the buildup of oil gases evacuated by the Positive Crankcase Ventilation (PCV) system [6][7].

In petrol (gasoline) engines, the top piston ring can expose the motor oil to temperatures of 160 °C (320 °F). In diesel engines the top ring can expose the oil to temperatures over 315 °C (600 °F). Motor oils with higher viscosity indices thin less at these higher temperatures.

Coating metal parts with oil also keeps them from being exposed to oxygen, inhibiting oxidation at elevated operating temperatures preventing rust or corrosion. Corrosion inhibitors may also be added to the motor oil. Many motor oils also have detergents and dispersants added to help keep the engine clean and minimize oil sludge build-up. The oil is able to trap soot from combustion in itself, rather than leaving it deposited on the internal surfaces. It is a combination of this, and some singeing that turns used oil black after some running.
Rubbing of metal engine parts inevitably produces some microscopic metallic particles from the wearing of the surfaces. Such particles could circulate in the oil and grind against moving parts, causing wear. Because particles accumulate in the oil, it is typically circulated through an oil filter to remove harmful particles. An oil pump, a vane or gear pump powered by the engine, pumps the oil throughout the engine, including the oil filter. Oil filters can be a full flow or bypass type.

In the crankcase of a vehicle engine, motor oil lubricates rotating or sliding surfaces between the crankshaft journal bearings and rods connecting the pistons to the crankshaft. The oil collects in an oil pan, or sump, at the bottom of the crankcase. In some small engines such as lawn mower engines, dippers on the bottoms of connecting rods dip into the oil at the bottom and splash it around the crankcase as needed to lubricate parts inside. In modern vehicle engines, the oil pump takes oil from the oil pan and sends it through the oil filter into oil galleries, from which the oil lubricates the main bearings holding the crankshaft up at the main journals and camshaft bearings operating the valves. In typical modern vehicles, oil pressure-fed from the oil galleries to the main bearings enters holes in the main journals of the crankshaft. From these holes in the main journals, the oil moves through passageways inside the crankshaft to exit holes in the rod journals to lubricate the rod bearings and connecting rods. Some simpler designs relied on these rapidly moving parts to splash and lubricate the contacting surfaces between the piston rings and interior surfaces of the cylinders. However, in modern designs, there are also passageways through the rods which carry oil from the rod bearings to the rod-piston connections and lubricate the contacting surfaces between the piston rings and interior surfaces of the cylinders. This oil film also serves as a seal between the piston rings and cylinder walls to separate the combustion chamber in the cylinder head from the crankcase. The oil then drips back down into the oil pan [7].

Motor oil may also serve as a cooling agent. In some constructions oil is sprayed through a nozzle inside the crankcase onto the piston to provide cooling of specific parts that undergo high temperature strain. On the other hand, the thermal capacity of the oil pool has to be filled then the oil has to reach its designed temperature range before it can protect the engine under high load. This typically takes longer than heating the main cooling agent like water or mixtures thereof — up to its operating temperature. In order to inform the driver about the oil temperature, some older and most high performance or racing engines feature an oil thermometer.

Due to its high viscosity, motor oil is not always the preferred oil for certain applications. Some applications make use of lighter products such as WD-40, when lighter oil is desired or honing oil if the desired viscosity needs to be mid-range.[6]An example is lubricating oil for four-stroke or four-cycle internal combustion engines such as those used in portable electricity generators and "walk behind" lawn mowers. Another example is two-stroke oil for lubrication of two-stroke or two-cycle internal combustion engines found in snow blowers, chain saws, model air planes, gasoline powered gardening equipment like hedge trimmers, leaf blowers and soil cultivators. Often, these motors are not exposed to as wide service temperature ranges as in vehicles, so these oils may be single viscosity oils [8].

In small two-stroke engines, the oil may be pre-mixed with the gasoline or fuel, often in a rich gasoline oil ratio of 25:1, 40:1 or 50:1, and burned in use along with the gasoline. Larger two-stroke engines used in boats and motorcycles may have a more economical oil injection system rather than oil pre-mixed into the gasoline. The oil injection system is not used on small engines used in applications like snow blowers and trolling motors as the oil injection system is too expensive for small engines and would take up too much room on the equipment. The oil properties will vary according to the individual needs of these devices. Non-smoking two-stroke oils are composed of esters or polyglycols. Environmental legislation for leisure marine applications, especially in Europe, encouraged the use of ester-based two cycle oil.

Synthetic oils

Synthetic lubricants were first synthesized, or man-made, in significant quantities as replacements for mineral lubricants (and fuels) by German scientists in the late 1930s and early 1940s because of their lack of sufficient quantities of crude for their (primarily military) needs. A significant factor in its gain in popularity was the ability of synthetic-based lubricants to remain fluid in the sub-zero temperatures of the Eastern front in wintertime, temperatures which caused petroleum-based lubricants to solidify owing to their higher wax content. The use of synthetic lubricants widened through the 1950s and 1960s owing to a property at the other end of the temperature spectrum, the ability to lubricate aviation engines at temperatures that caused mineral-based lubricants to break down. In the mid-1970s, synthetic motor oils were formulated and commercially applied for the first time in automotive applications. The same SAE system for designating motor oil viscosity also applies to synthetic oils. A common problem encountered when people began switching to synthetic oils was leakage. Owners of cars, especially older and vintage automobiles, found that their cars, that did not leak using conventional oils, suddenly had leaks all over with the synthetic oils. This remains a problem, although it has encouraged many vintage car owners to investigate newer technology oil seals for their engines so that they can take advantage of the properties of synthetic oils. Synthetic oil makers have not addressed the leakage problem in a forthright manner, and this has caused suspicion by many consumers that synthetic oils are merely another overpriced oil scam [9].

Synthetic oils are derived from Group III, Group IV, or some Group V bases. Synthetics include classes of lubricants like synthetic esters as well as "others" like GTL (Methane Gas-to-Liquid) (Group V) and polyalpha-olefins (Group IV). Higher purity and therefore better property control theoretically means synthetic oil has better mechanical properties at extremes of high and low temperatures. The molecules are made large and "soft" enough to retain good viscosity at higher temperatures, yet branched molecular structures interfere with solidification and therefore allow flow at lower temperatures. Thus, although the viscosity still decreases as temperature increases, these synthetic motor oils have a higher viscosity index over the traditional petroleum base. Their specially designed properties allow a wider temperature range at higher and lower temperatures and often include a lower pour point. With their improved viscosity index, synthetic oils need lower levels of viscosity index improvers, which are the oil components most vulnerable to thermal and mechanical degradation as the oil ages, and thus they do not degrade as quickly as traditional motor oils. However, they still fill up with particulate matter, although the matter better suspends within the oil and the oil filter still fills and clogs up over time. So, periodic oil and filter changes should still be done with synthetic oil; but some synthetic oil suppliers suggest that the intervals between oil changes can be longer, sometimes as long as 16,000-24,000 km (10,000–15,000 mile) primarily due to reduced degradation by oxidation.

Tests show that fully synthetic oil is superior in extreme service conditions to conventional oil, and may perform better for longer under standard conditions. But in the vast majority of vehicle applications, mineral oil based lubricants, fortified with additives and with the benefit of over a century of development, continues to be the predominant lubricant for most internal combustion engine applications.

Bio-based oils existed prior to the development of petroleum-based oils in the 19th century. They have become the subject of renewed interest with the advent of bio-fuels and the push for green products. The development of canola-based motor oils began in 1996 in order to pursue environmentally friendly products. A review on the status of bio-based motor oils and base oils globally, as well as in the U.S, shows how bio-based lubricants show promise in augmenting the current petroleum-based supply of lubricating materials, as well as replacing it in many cases.

The USDA National Center for Agricultural Utilization Research developed an Estolide lubricant technology made from vegetable and animal oils. Estolides have shown great promise in a wide range of applications, including engine lubricants. Working with the USDA, a California-based company Biosynthetic Technologies has developed high performance "drop-in" biosynthetic oil using Estolide technology for use in motor oils and industrial lubricants. This biosynthetic oil American Petroleum Institute (API) has the potential to greatly reduce environmental challenges associated with petroleum. Independent testing not only shows biosynthetic oils to be among the highest-rated products for protecting engines and machinery; they are also bio-based, biodegradable, and non-toxic and do not bioaccumulation in marine organisms. Also, motor oils and lubricants formulated with biosynthetic base oils can be recycled and re-refined with petroleum-based oils. The U.S.-based company Green Earth Technologies manufactures bio-based motor oil, called G-Oil, made from animal oils[9].

Other additives

In addition to the viscosity index improvers, motor oil manufacturers often include other additives such as detergents and dispersants to help keep the engine clean by minimizing sludge buildup, corrosion inhibitors, and alkaline additives to neutralize acidic oxidation products of the oil. Most commercial oils have a minimal amount of zinc dialkyldithiophosphate as an anti-wear additive to protect contacting metal surfaces with zinc and other compounds in case of metal to metal contact. The quantity of zinc dialkyldithiophosphate is limited to minimize adverse effect on catalytic converters. Another aspect for after-treatment devices is the deposition of oil ash, which increases the exhaust back pressure and reduces fuel economy over time. The so-called "chemical box" limits today the concentrations of sulfur, ash and phosphorus (SAP).

There are other additives available commercially which can be added to the oil by the user for purported additional benefit. Some of these additives include:EP additives, like zinc dialkyldithiophosphate (ZDDP) additives and sulfonates, preferably calcium sulfonates, are available to consumers for additional protection under extreme-pressure conditions or in heavy duty performance situations. Calcium sulfonates additives are also added to protect motor oil from oxidative breakdown and to prevent the formation of sludge and varnish deposits. Both were the main basis of additive packages used by lubricant manufacturers up until the 1990s when the need for ashless additives arose. Main advantage was very low price and wide availability (sulfonates were originally waste byproducts). Currently there are ashless oil lubricants without these additives, which can only fulfill the qualities of the previous generation with more expensive basestock and more expensive organic or organometallic additive compounds. Some new oils are not formulated to provide the level of protection of previous generations to save manufacturing costs. Lately API specifications reflect that some molybdenum disulfide containing additives to lubricating oils are claimed to reduce friction, bond to metal, or have anti-wear properties. MoS_2 particles can be shear-welded on steel surface and some engine components were even treated with MoS_2 layer during manufacture, namely liners in engines they were used in World War II in flight engines and became commercial after World War II until the 1990s. They were commercialized in the 1970s (ELF ANTAR Molygraphite) and are today still available (Liqui Moly MoS_2 10 W-40, www.liqui-moly.de). Main disadvantage of molybdenum disulfide is anthracite black color, so oil treated with it is hard to distinguish from soot filled engine oil with metal shavings from spun crankshaft bearing.In the 1980s and 1990s, additives with suspended PTFE particles were available, e.g., "Slick50", to consumers to increase motor oil's ability to coat and protect metal surfaces. There is controversy as to the actual effectiveness of these products, as they can coagulate and clog the oil filter and tiny oil passages in the engine. It is supposed to work under boundary lubricating conditions, which good engine designs tend to avoid anyway. Also, Teflon alone has little to no ability to firmly stick on a sheared surface, unlike molybdenum disulfide, for example. Various extreme-pressure (EP) additives and antiwear additives are available.Many patents proposed use perfluoropolymers to reduce friction between metal parts, such as PTFE (Teflon), or micronized PTFE. However, the application obstacle of PTFE is insolubility in lubricant oils. Their application is questionable and depends mainly on the engine design — one that cannot maintain reasonable lubricating conditions might benefit, while properly designed engine with oil film thick enough would not see any difference. PTFE is a very soft material, thus its friction coefficient becomes worse than that of hardened steel-to-steel mating surfaces under common loads. PTFE is used in composition of sliding bearings where it improves lubrication under relatively light load until the oil pressure builds up to full hydrodynamic lubricating conditions. EP additives may be incompatible with some motorcycles which share wet clutch lubrication with the engine.

Lubricant oil Properties:

Most motor oils are made from a heavier, thicker petroleum hydrocarbon base stock derived from crude oil, with additives to improve certain properties. The bulk of typical motor oil consists of hydrocarbons with between 18 and 34 carbon atoms per molecule. One of the most important properties of motor oil in maintaining a lubricating film between moving parts is its viscosity. The viscosity of a liquid can be thought of as its "thickness" or a measure of its resistance to flow. The viscosity must be high enough to maintain a lubricating film, but low enough that the oil can flow around the engine parts under all conditions. The viscosity index is a measure of how much the oil's viscosity changes as temperature changes. A higher viscosity index indicates the viscosity changes less with temperature than a lower viscosity index.

Motor oil must be able to flow adequately at the lowest temperature it is expected to experience in order to minimize metal to metal contact between moving parts upon starting up the engine. The pour point defined first this property of motor oil, as defined by ASTM D97 as "... an index of the lowest temperature of its utility ..." for a given application. Oil is largely composed of hydrocarbons which can burn if ignited. Still another important property of motor oil is its flash point, the lowest temperature at which the oil gives off vapors which can ignite. It is dangerous for the oil in a motor to ignite and burn, so a high flash point is desirable. At a petroleum refinery, fractional distillation separates a motor oil fraction from other crude oil fractions, removing the more volatile components, and therefore increasing the oil's flash point (reducing its tendency to burn)[10].

Another manipulated property of motor oil is its Total base number (TBN), which is a measurement of the reserve alkalinity of oil, meaning its ability to neutralize acids. The resulting quantity is determined as mg KOH/ (gram of lubricant). Analogously, Total acid number (TAN) is the measure of a lubricant's acidity. Other tests include zinc, phosphorus, or sulfur content, and testing for excessive foaming.

The NOACK volatility (ASTM D-5800) Test determines the physical evaporation loss of lubricants in high temperature service. A maximum of 14% evaporation loss is allowable to meet API SL and ILSAC GF-3 specifications. Some automotive OEM oil specifications require lower than 10% [10].

Kinematic Viscosity:

Kinematic viscosity is graded by measuring the time it takes for a standard amount of oil to flow through a standard orifice, at standard temperatures. The longer it takes, the higher the viscosity and thus higher SAE code.

Dynamic Viscosity

Kinematic Viscosity is the ratio of the dynamic viscosity and the fluid density (kg /cubic m) The SI unit of kinematic viscosity is the m^2 / s. The equivalent cgs unit is the stoke (St) which has the unit of cm^2 / s. The unit commonly used is the centistoke(cSt). $1\ m^2 / s = 10^6$ cSt

Absolute Kinematic Viscosity (m^2 / s) = (Pa s) / (kg / m^3)

Saybolt Universal Viscosity

A method of determining a lubrication fluids viscosity is to measure the rate of flow of the fluid through a test device. The rate is measured in seconds the greater the number of seconds the more viscous the fluid. This viscosity is second’s = Saybolt universal Viscosity - seconds.

The SAE has a separate viscosity rating system for gear, axle, and manual transmission oils, SAE J306, which should not be confused with engine oil viscosity. The higher numbers of a gear oil (e.g., 75W-140) do not mean that it has higher viscosity than an engine oil.

Grades:

The Society of Automotive Engineers (SAE) has established a numerical code system for grading motor oils according to their viscosity characteristics. SAE viscosity grading includes the following, from low to high viscosity: 0, 5, 10, 15, 20, 25, 30, 40, 50 or 60. The numbers 0, 5, 10, 15 and 25 are suffixed with the letter W, designating they are "winter" (not "weight") or cold-start viscosity, at lower temperature. The number 20 comes with or without a W, depending on whether it is being used to denote a cold or hot viscosity grade. The document SAE J300 defines the viscometrics related to these grades [10].

Single-grade

Single-grade engine oil, as defined by SAE J300, cannot use a polymeric Viscosity Index Improver additive. SAE J300 has established eleven viscosity grades, of which six are considered Winter-grades and given a W designation. The 11 viscosity grades are 0W, 5W, 10W, 15W, 20W, 25W, 20, 30, 40, 50, and 60. These numbers are often referred to as the "weight" of motor oil, and single-grade motor oils are often called "straight-weight" oils.

For single non-winter grade oils, the kinematic viscosity is measured at a temperature of 100 °C (212 °F) in units of mm^2/s (millimeter squared per second) or the equivalent older non-SI units, centistokes (abbreviated cSt). Based on the range of viscosity the oil falls in at that temperature, the oil is graded as SAE viscosity grade 20, 30, 40, 50, or 60. In addition, for SAE grades 20, 30, and 1000, a minimum viscosity measured at 150 °C (302 °F) and at a high-shear rate is also required. The higher the viscosity, the higher the SAE viscosity grade is.

Multi-grade

The temperature range the oil is exposed to in most vehicles can be wide, ranging from cold temperatures in the winter before the vehicle is started up, to hot operating temperatures when the vehicle is fully warmed up in hot summer weather. Specific oil will have high viscosity when cold and a lower viscosity at the engine's operating temperature. The difference in viscosities for most single-grade oil is too large between the extremes of temperature. To bring the difference in viscosities closer together, special polymer additives called viscosity index improvers, or VIIs are added to the oil. These additives are used to make the oil multi-grade motor oil, though it is possible to have multi-grade oil without the use of VIIs. The idea is to cause the multi-grade oil to have the viscosity of the base grade when cold and the viscosity of the second grade when hot. This enables one type of oil to be used all year. In fact, when multi-grades were initially developed, they were frequently described as all-season oil. The viscosity of multi-grade oil still varies logarithmically with temperature, but the slope representing the change is lessened. This slope representing the change with temperature depends on the nature and amount of the additives to the base oil.

The SAE designation for multi-grade oils includes two viscosity grades; for example, 10W-30 designates common multi-grade oil. The first number '10W' is the viscosity of the oil at cold temperature and the second number is the viscosity at 100 °C (212 °F). The two numbers used are individually defined by SAE J300 for single-grade oils. Therefore, an oil labeled as 10W-30 must pass the SAE J300 viscosity grade requirement for both 10W and 30, and all limitations placed on the viscosity grades (for example, a 10W-30 oil must fail the J300 requirements at (5W). Also, if oil does not contain any VIIs, and can pass as a multi-grade, that oil can be labeled with either of the two SAE viscosity grades. For example, very simple multi-grade oil that can be easily made with modern base oils without any VII is a 20W-20. This oil can be labeled as 20W-20, 20W, or 20. Note, if any VIIs are used however, then that oil cannot be labeled as a single grade.

Breakdown of VIIs under shear is a concern in motorcycle applications, where the transmission may share lubricating oil with the motor. For this reason, synthetic oil or motorcycle-specific oil is sometimes recommended [10][11]. The necessity of higher-priced motorcycle-specific oil has also been challenged by at least one consumer organization.

Environmental effects:

Due to its chemical composition, world-wide dispersion and effects on the environment, used motor oil is considered a serious environmental problem. Most current motor oil lubricants contain petroleum base stocks, which are toxic to the environment and difficult to dispose of after use. Over 50% of the pollution in Sudan's waterways and rivers is from used motor oil. Used oil is considered the largest source of oil pollution in the Sudan harbors and waterways, at 36 million gallons per year, mostly from improper disposal. By far, the greatest cause of motor oil pollution in our rivers comes from drains and urban street runoff, much of which is from improper disposal of engine oil. One gallon of used oil can create an eight-acre slick on surface water, threatening fish, waterfowl and other aquatic life. According to the U.S. EPA, films of oil on the surface of water prevent the replenishment of dissolved oxygen, impair photosynthetic processes, and block sunlight. Toxic effects of used oil on freshwater and marine organisms vary, but significant long-term effects have been found at concentrations of 310 ppm in several freshwater fish species from rivers surrounding Khartoum and as low as 1 ppm in marine life forms at the east of Sudan. Motor oil can have an incredibly detrimental effect on the environment, particularly to plants that depend on healthy soil to grow. There are three main ways that motor oil can affects plants: contaminating water supplies, contaminating soil, and poisoning plants. Used motor oil dumped on land reduces soil productivity. Improperly disposed used oil ends up in landfills, sewers, backyards, or storm drains where soil, groundwater and drinking water may be contaminated [12].

EXPERIMENTAL RESULTS

The experiment is done by Japanese International Automobile Company Honda to fix the degradation of engine oil in general condition that can be applied to Sudan. Engine oil from a Honda gasoline engine was studied. As the antioxidant package in the oil is depleted by oxidation, the intensity of the peroxy radical ($RO_2\bullet$) is considered as signal of increases steadily from zero. This is the induction period of oil degradation. Also, the g-factor of the peroxy radical signal increases slightly as the hydrocarbon chains are broken down [13]. When the oil is approaching the end of its useful life, the intensity of the peroxy radical signal increases dramatically and failure is imminent, as shown in Figure (1).

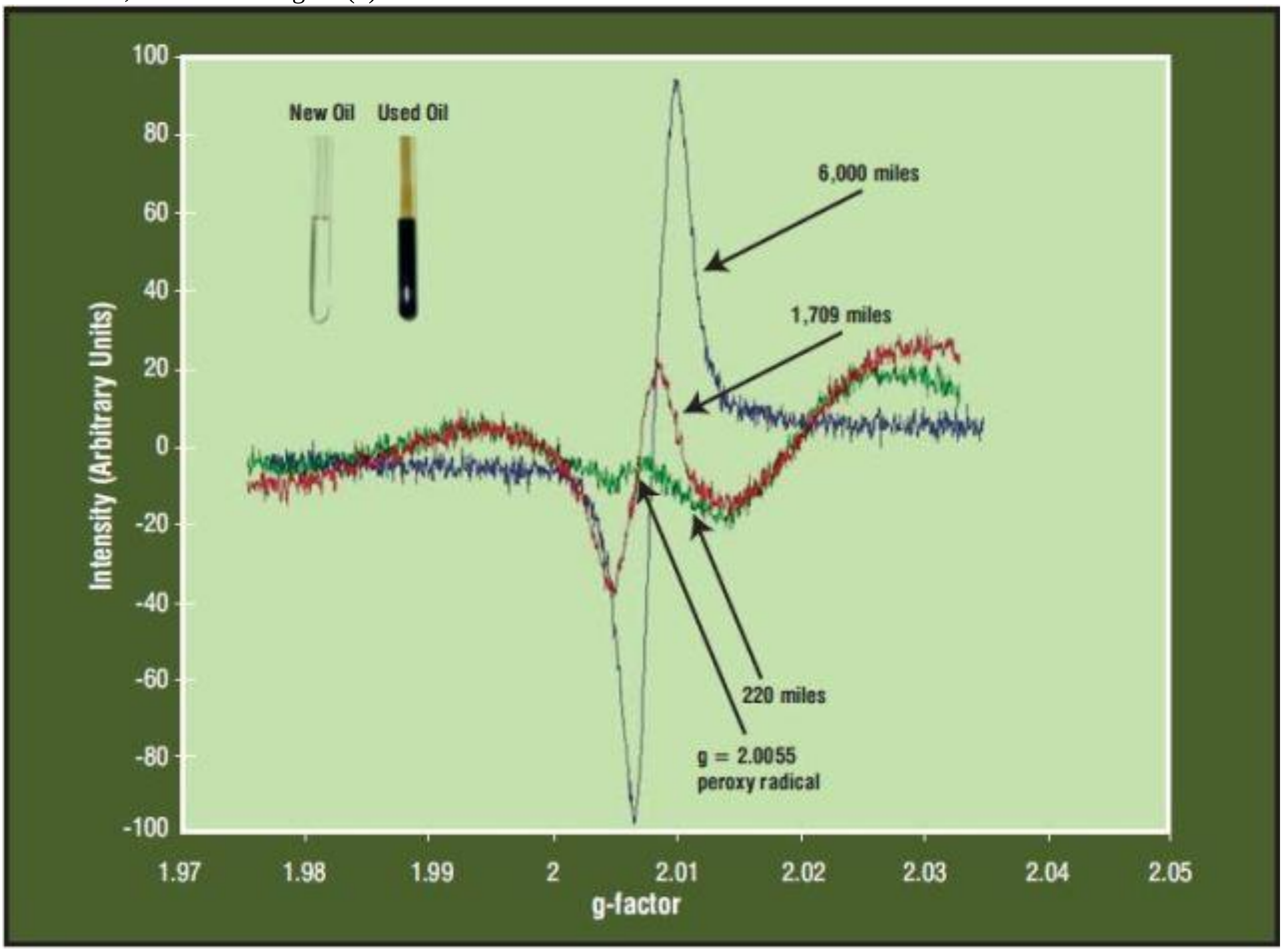

Figure (1)

Peroxy Radical vs Mileage

The oxidation chain reaction can be examined to understand the importance of the peroxy radical in lubricant breakdown. First, free radicals are produced by exposing oil to high temperatures in the presence of oxygen as follows:

$$RH \rightarrow \text{(free radical)} + H\bullet$$
$$RH + O_2 \rightarrow R\bullet \text{ (free radical)} + HO_2\bullet$$

The chain reaction then propagates as:

$$R\bullet + O_2 \rightarrow RO_2\bullet \text{ (peroxy radical)}$$
$$RO_2\bullet + R'H \rightarrow ROOH \text{ (hydroperoxide)} + R'\bullet$$

Normally, antioxidants are added to the base oil, which react with the peroxy radical and render it harmless. However, as the antioxidants in the oil are consumed, the concentration of peroxy radical's increases and breakdown accelerates.

In Figure (2), all of these compounds can be observed experimentally. Cylinder lube oil is used typically once and then burned in the engine. Lube oil feed rates must also be adjusted depending on the concentration of sulfur in the fuel oil, and measurement of the sulfur content of the fuel is of interest to ship operators who seek to minimize operating costs.

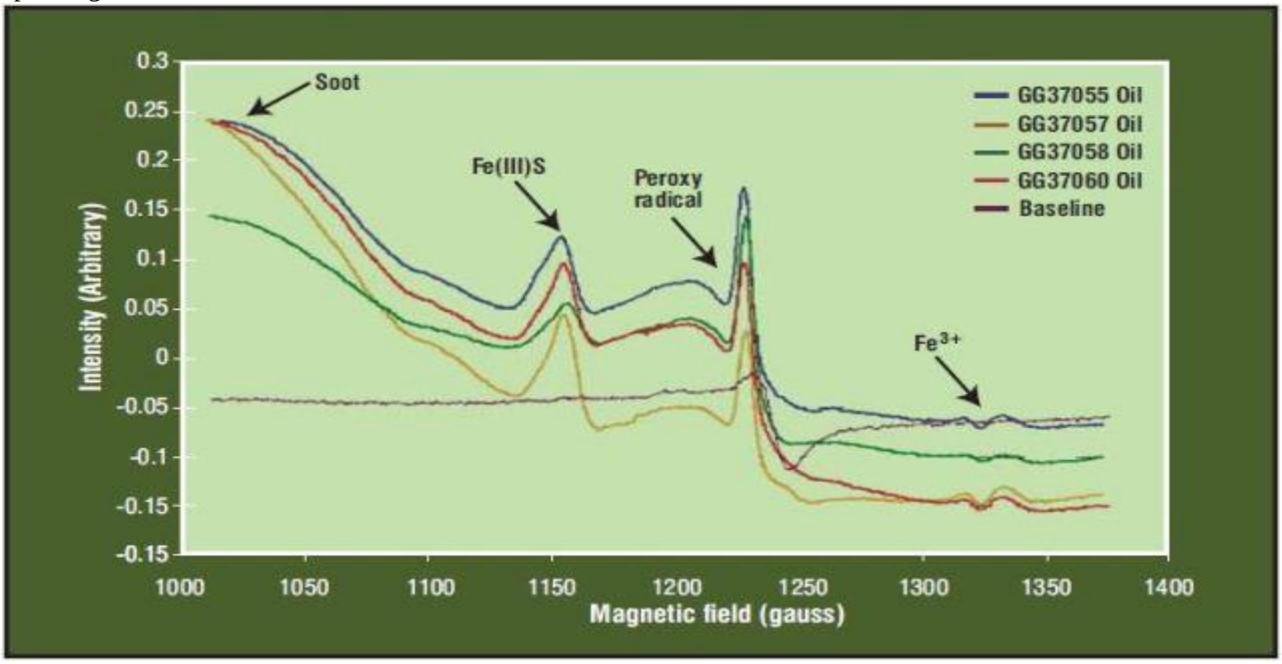

Figure (2)

ESR Spectra of Marine Engine Cylinder Lube Oil Samples

The examples above clearly show the breadth of applications (100-hp gas motors to 75,000-hp marine diesels) where the sensor can be applied. As seen in Figure (2), carbon soot particulates can be readily detected by the spectrometer, both when dissolved in the oil and also from airborne soot. This enables its use to determine the composition and concentration of airborne soot particulates in vehicle or power plant emissions. Just as an oxygen sensor in a gasoline engine is used to adjust the fuel-air mixture to prevent the engine from running too rich, an electro spin resonance airborne soot sensor can be used for adjusting the fuel-air mixture in a diesel engine to prevent excess particulate emissions. This is a very important application as new emissions standards are continually challenging vehicle manufacturers to reduce particulate emissions to lessen environmental risk.

The spectrometer determines intrinsic chemical properties of the oil (concentration of chemical constituents), while other approaches measure physical properties of the oil (such as dielectric constant, viscosity, electrical impedance) and then relate that data to underlying chemical changes in the oil. Another benefit is that the spectrometer gives an absolute reading of the condition of the oil. New oil has a null spectrum; there are no free radicals, carbon or other contaminants present in the oil. The presence of any ESR spectrum clearly shows that contamination is present in the oil.

In addition, the g-factor as in Equation 1 of each free radical is only weakly dependent on temperature because free radicals in oil can be uniquely identified by their g-factors, this enables the user to easily identify any ESR signals with absolute confidence at any operating temperature. The specificity of ESR implies that no compounds other than free radicals or transition metal ions will produce a signal. The technique, therefore, does not exhibit cross factors commonly seen with other sensors.

This application of the spectrometer offers the end-user a new and cost-effective method to ensure compliance with environmental standards. It also enables the user to identify when an engine is running too rich, which severely reduces fuel efficiency [13].

Mathematical Modeling:

Generally in Sudan the car is to follow as the sticker in the window that called for an oil change in 3,000 miles which is essentially the advice given by all quick oil change outlets and dealership service departments and not the 4,000 or 5,000 miles. The quick oil change industry justifies its perpetuation of the 3,000-mile standard by saying that most people drive under "severe" conditions. An oil change company representative said the 3,000-mile recommendation is meant to be just that — a recommendation.

So in this model we would like to find the optimal interval distance for oil changing, in order to minimize the expected cost. It is the case of preventive oil change at a fixed interval. The objective of this mathematical method is to find which policy of oil changing type is the best.

A publication of an article in August 2010, for a 2007 Honda Fit for an oil change to see what might happen to the average car owner indifferent condition of work. The car had an oil type of mobile1. In all cases, an engine oil analysis revealed that the oil could have provided at least the bellow intervals beginning from severe condition to standard normal condition of work with relatively probability values as follows [14].

The probabilities of the oil to lose its validity during the kth interval is pk, is given by the following table (1).
Given the cost of replacing the oil is $132.72, and the cost after break down during an interval will be an average of extra $ 1500.

Distance interval by miles	The probability of oil failure
Less than 2000	0.1
2000-3000	0.1
3000-4000	0.2
4000-5000	0.3
Greater than5000	0.3

Table number (1)

For our problem we have:

Let R_p be the cost of preventive oil changing

Let R_f be the cost of oil changing at a failure of machine engine (R_p+ a loss of output)Let $\overline{P}_k = 1 - P_k = \sum_{i=k+1}^{\infty} p_i$ be the probability the oil lasts (good to use) at least k intervals of mileage.

The expected cost, if we preventively replace the machine oil after n intervals, is

R_p Prob {oil lasts at least n intervals} + R_f Prob {oil fails (bad to use) at nth interval or earlier} = $R_p \overline{P}_n + R_f P_n$ (1)

The expected number of intervals between the oil changes if we preventively replace it after n intervals is

$1\, p_1 + 2p_2 + \ldots + (n-1)p_{n-1} + np_n + n\,\overline{P}_n$ (2)

We can rewrite this expected number of intervals as:

$(p_1 + p_2 + p_3 + \ldots) + (p_2 + p_3 + p_4 + \ldots) + (p_3 + p_4 + p_5 + \ldots) + \ldots + (p_n + p_{n-1} + p_{n-2} + \ldots) =$
$\overline{P_0} + \overline{P_1} + \overline{P_2} + \ldots + \overline{P_{n-1}}$

Since we have an expected cost given by (1) and the number of intervals between these costs is an average given by (2), the expected cost per each given interval if we made an oil change preventively after n intervals of different conditions is given by:

$$C(n) = \frac{R_p\overline{P}_n + R_f(1-\overline{P}_n)}{\overline{P_0} + \overline{P_1} + \overline{P_2} + \ldots + \overline{P_{n-1}}}.$$ [17], [18]

Here we have: R_p = $ 132.72, R_f =$(132.72 + 1500) = $1632.72

$\overline{P_0} = 1$, $\overline{P_1} = 0.9$, $\overline{P_2} = 0.8$, $\overline{P_3} = 0.6$, $\overline{P_4} = 0.9$, $\overline{P_5} = 0$.

C (1) = $(132.72 X 0.9 + 1632.72 X 0.1)/1 =$ 282.72

C (2) = $ (132.72 X 0.8 + 1632.72 X 0.2)/1.9 = 432.72/1.9 = $227.747

C (3) = $ (132.72 X 0.6 + 1632.72 X 0.4)/2.7 = 732.72/2.7 =$ 271.378

C (4) = $ (132.72 X 0.3 + 1632.72 X 0.7)/3.3= 1182.72/3.3 =$ 358.4

C (5) = $ (132.72 X 0. + 1632.72 X 1)/3.6 =$ 453.533

From the cost results we find that it is not suitable to replace the oil before less than 2000 kilometer. The cost increases by 19% between 3000- 4000from the first stage when its 2000. Then it's increases by 32% between 4000-5000. At last it is increases by 26% for greater than 5000. So after 4000 there is an increasing in the cost that represents greatest one in the interval 4000-5000. Therefore the best decision is to replace the oil before the fourth interval 4000-5000.

DISCUSSION

It's clear that oil change is always directly connected with the condition of machine work therefore it's very unsafe to be fixed by untrained personnel. If the machine is not provided by oil time life monitoring system a dialogue should held between car owner and oil dealer personnel, then accordingly the interval can fixed.

RECOMMENDATIONS AND RESULTS

Today's longer oil change intervals may be guaranteed globally and in Sudan only when the following processing due to many references [15][16] and general observations is employed:

- Improved "robustness" of today's oils, with their ability to protect engines from wear and heat and still deliver good fuel economy with low emissions should be used.
- More improved synthetic oil should be advised to be used by automakers
- Tighter tolerances (the gap between metal moving parts) should be used for modern engines.
- Car engine should be provided with the oil life monitoring systems that notify the driver when an oil change is required. They are based on the way the car is driven and the conditions it encounters. Sixteen of 34 carmakers now use oil life monitoring systems in their 2013 model-year vehicles; this should be considered in Sudan when new cars are to be imported.
- Regular oil changes can help improve the performance and fuel economy of cars, truck, or SUV. Many vehicles in Sudan are older model, manufactured without or before the creation of the Oil Life Monitoring System, require oil changes at 3,000-mile intervals.
- However, advances in engine technologies, newer models have a much longer range between oil changes
- Oil certified service technician dealer generally should be expertly trained to understand how vehicle uses its oil and how he monitors oil life.
- Oil chemistry and engine technology have changed tremendously in recent years, but car owners would never know it from the quick-change behavior. Driven by an outdated 3,000-mile oil change commandment, they are unnecessarily spending millions of dollars and spilling an ocean of contaminated waste oil.
- The majority of automakers today call for oil changes at either 7,500 or 10,000 miles, and the interval can go as high as 15,000 miles in some cars. Yet this wasteful cycle continues largely because the automotive service industry in Sudan, while fully aware of the technological advances, continues to preach the 3,000-mile gospel as a way to keep the service bays busy. As a result, even the most cautious owners are dumping their engine oil twice as often as their service manuals recommend.
- After interviews with oil experts, mechanics and automakers, one thing is clear: The 3,000-mile oil change is a myth that should be laid to rest. Failing to heed the service interval in the owner's manual wastes oil and money, while compounding the environmental impact of illicit waste-oil dumping.
- Part of the blame for this over-servicing lies in our insecurities about increasingly complicated engines that are all inaccessible to the average mechanics and driver, while in some vehicles, the only thing an owner can easily access is the oil cap.
- Sophisticated vehicles owners maybe have some feeling that they're taking care of their vehicles if they change their oil more often.
- The 3,000-mile myth is also promoted by the quick-lube industry's "convenient reminder" windshield sticker. It is a surprisingly effective tool that prompts us to continue following a dictate that into our heads that it's our duty to change the oil every 3,000 miles — or the car will pay the price. But as former service advisors put it, the 3,000-mile oil change is "a marketing tactic that dealers use to get you into the service bay on a regular basis. Unless you go to the drag strip on weekends, you don't need it.
- Car dealers' service departments are also guilty of incorrectly listing the mileage for the next oil change. We've seen them recommend a 3,000-mile oil change on a car with a 10,000-mile interval and also list a 5,000-mile recommendation on a car that has a variable oil change schedule.
- Because busy car owners seldom read their owner's manuals, most have no idea of the actual oil change interval for their cars. And so they blindly follow the windshield reminder sticker, whether it's an accurate indicator of the need for an oil change or not. The argument that most people drive under severe conditions is losing its footing, however.
- About the only ones that really need a 3,000-mile oil change are the quick-lube outlets and dealership service departments. In their internal industry communications, they're frank about how oil changes bring in customers. "Many people...know when to have their oil changed but don't pay that much attention to it," said an article in the National Oil and Lube News online newsletter. "Take advantage of that by using a window sticker system [and] customers will be making their way back to you in a few short months."
- **Today's oil goes the distance** while the car-servicing industry is clear about its reasons for believing in the 3,000-mile oil change, customers cling to it only because they're largely unaware of advances in automotive technology. Among 2013 models, the majority of automakers call for oil changes at either

7,500 or 10,000 miles based on a normal service schedule, more than double the traditional 3,000-mile interval. The longest oil change interval is 15,000 miles for all Jaguar vehicles. The shortest oil change interval is 5,000 miles in some Hyundai and Kia models with turbo engines and Toyota vehicles that call for non-synthetic oil. Toyota has been shifting its fleet to 10,000-mile oil change intervals using synthetic oil.

- Micro-ESR signifies a fundamental advance in the state-of-the-art of chemical sensor technology. Despite the enormous breadth of applications of electron spin resonance spectrometry; there have been no fundamental advances in the core design of the spectrometer until now.

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