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An Investigation on Physical and Chemical Properties of Lubricant Used in Diesel Engine

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Abstract

Lubrication is one of the most important parameter of internal combustion engine which plays a vital role to prevent engine deterioration. This research investigated physical and chemical properties of lubricants used in diesel engines. The objective of this research is to measure and compare the condition of used lubricants based on its properties. In this work, several samples of used lubricants have been taken from two different engine types, namely: engine A group and engine B group. All samples were chosen so wisely to vary ages of oil. In total seven samples were from engine A group and five samples from engine B group. The physical and chemical properties of all samples were measured on the basis of three categories; wear condition, oil condition and contamination. All the samples were analyzed using respective ASTM standard method. To visualize the obtained results, it has been plotted in to the graphs and charts. The result shows wear condition of the lubricants has mixed effect. Wear condition of total metal has been found to be higher when there is higher oxidation in lubricant. Similarly lowering in viscosity of lubricant has been observed with increase in engine operation time causing more wear. Moreover it is also observed that wear condition getting worsen with high engine speed. It can be noted that physical and chemical properties of lubricant are significantly interrelated to each other.

Keywords*:* Lubricant, Wear condition, Contamination.

1. Introduction

Diesel engines are increasingly used in passenger cars due to their high efficiency and performance in comparison with its counterpart petrol engine. Modern diesel engine uses direct injection system, which consists of a high pressure pump, pressure storage (common-rail) and a set of injectors. A gear pump is used as pre-feed for the fuel supply to the high pressure pump. These systems including gear pump allow injecting the diesel fuel, compressed up to 2000 bar (and even more in the future), into the combustion chamber of the diesel engine in order to increase the specific engine power. Simultaneously, fuel consumption and greenhouse gases are reduced [1].
However, a direct consequence of this high pressure is the high contact pressure and temperature at different tribological contacts involved in the diesel injection systems. In diesel injection systems, diesel fuel is not only used as combustion fuel, but also as a lubricant. Diesel fuel has become poorer in terms of anti-wear elements such as sulfur and aromatic contents. Therefore, the lubricating properties of diesel fuel have drastically decreased [2-4]. Decreasing diesel fuel lubricating properties, combined with increasing contact pressure and temperature, can lead to adhesive wear in, e.g., steel/steel tribological systems, which can – in worst cases – result in component failure. An option to solve this problem in these critical tribological contacts in diesel injection systems is the application of coatings, which reduce wear and at the same time extend the lifetime of the entire injection system [5].

Major functions of lube oil include cooling, friction reduction, and wear control. The lube oil develops lubricating film between moving surfaces, which reduces friction and wear. However, the engine oil is a depository of impurities. These are in the form of solid, liquid, and gaseous contaminants. If uncontrolled, these contaminants can build up to excessive levels. High levels of lubricant contamination cause wear of mechanical components as well as breakdown of the lube oil. The result is performance degradation, reduced engine life, and short oil service life [6-8].

In this research, the comparative study of physical and chemical properties has been done for twelve different samples taken from two engine groups. Different aged lubricant sample were chosen to see the wearing effect of the engine. The results were compared in terms of wear condition, oil condition and contamination. Where, wear condition represents the present of total metal particle like iron, aluminum, copper, chromium, oil condition evaluates the properties like viscosity, oxidation, and contamination measures presence of soot.

2. Material and Methods

In this research, twelve different types of used lubricant have been taken from two engine groups, namely group A and group B. The detail of engine specification of each engine group is shown in Table. 1.

Table. 1 Engine specification

Engine parameter	**A Group**	**B Group**
1. Displacement volume	1,499 cc	2,000 cc
2. Compression ratio	14.8	16.3
3. Maximum Power	105/4000 (hp/rpm)	184/4000 (hp/rpm)
4. Maximum Torque	280/1,500-2,500 (Nm/rpm)	380/1,750-2,750
5. Engine oil	SAE 0W-30	SAE 5W-30

Seven lubricant samples were taken from group A car where five samples from group B car. Those samples were named as A1 to A7 for group A car and B1 to B5 for group B. The detail of engine age and lubricant age for each sample is shown in Table.2 below. Those lubricant samples which have equal value of car age and oil age are termed as run in condition. Here, A1, A2, A3, A4 and B1 haven't changed their engine oil since the vehicle started to driven.

Table. 2 Age of tested lubricant sample

S.N.	Lubricant/car sample	Engine age (km)	Lubricant age (km)
1.	A1	1,980	1,980
2.	A2	6,275	6,275
3.	A3	9,993	9,993
4.	A4	11,237	11,237
5.	A5	19,046	9,362
6.	A6	19,500	9,800
7.	A7	19,779	9,811
8.	B1	3,479	3,479
9.	B2	30,597	20,014
10.	B3	47,827	16,383
11.	B4	72,180	12,914
12.	B5	106,921	23,878

These samples were tested in standard lab to measure individual physical and chemical properties. To quantify the lubricant condition, the result has been categorized in three sub division namely; wear condition, oil condition and contaminations. The standard used and the measured properties are shown in Table. 3 below.

Table. 3 Test properties and methods

Physical/Chemical properties		Testing standard	Unit
Wear condition	Iron	ASTM D6595	PPM
	Aluminum		
	Copper		
	Chromium		
	Tin		
	Nickel		
	Lead		
Oil condition	Viscosity	ASTM D445	cSt
	Oxidation	E2412M	Abs
Contamination	Soot	E2412M	% W

3. Result and Discussion

3.1 Wear condition analysis

Wear condition analysis covers presence of external particles in lubricating oil which primarily comes from both dynamic and static engine components during engine operation [3]. Dynamic component represents those engine components which are in motion during engine operation, e.g. piston, piston ring, fuel pump, filter, plunger, connection rod, inlet and exhaust valve etc. In other hand static components represents those engine components which do not move during operating condition of engine, e.g. fuel pump injector housing, fuel tank, fuel filter, fuel line, cylinder liner etc. In general both the dynamic and static components are metallic in nature. When the engine operates, movement of dynamic components over static component accomplish by causing wear. Those wear particles are thus washed and suspended in lubrication oil. The wear condition analysis of used lubricating oil is very useful to predict wear rate, element source, and engine condition which are always under motion with each other as well as static component [7]. Based on the analysis done in this research, the major metallic components found are discussed and compared individually in each lubrication sample.

"Fig.1" illustrates the presence of wear particle in all lubricant samples. Which shows presence of iron is predominant followed by copper and aluminum. However other particles like lead, nikel and chromium are very negligible. The reason of higher number of iron and copper particles are due to the utilization of it in manufacturing of major engine components.

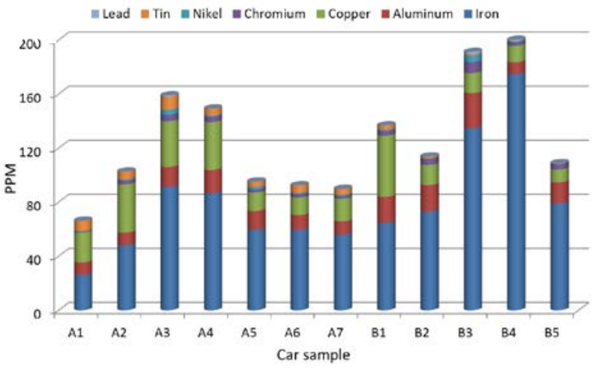
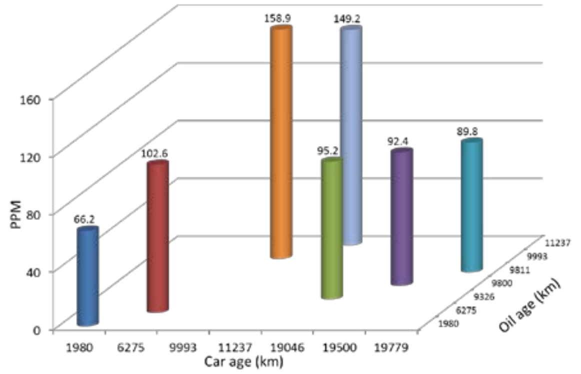
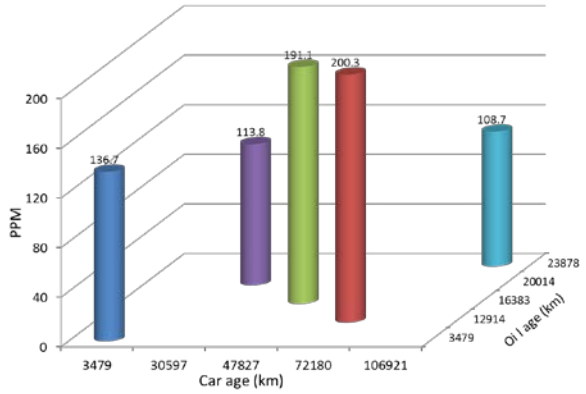


Fig. 1 Total metal wear in lubrication sample

"Fig. 2" shows total wear element for group A and group B. The comparison has been made with reference to car age and oil age respectively. The result shows higher number of wear particles for sample with shorter car age. Conversely it can be noted that longer the oil age higher will be the number of wear particle. However, two cars from group B shows high number of wear particles although the car age is longer. With the available data only, it is hard to point out reason behind higher number particles in certain sample with longer car age and shorter oil age. However, theoretically it is obvious to see higher number of wear particles in lubricant in case of car in run-in condition [9].



(a)



(b)

Fig. 2 Total wear metal presence in lubricant
(a) Group A, (b) Group B

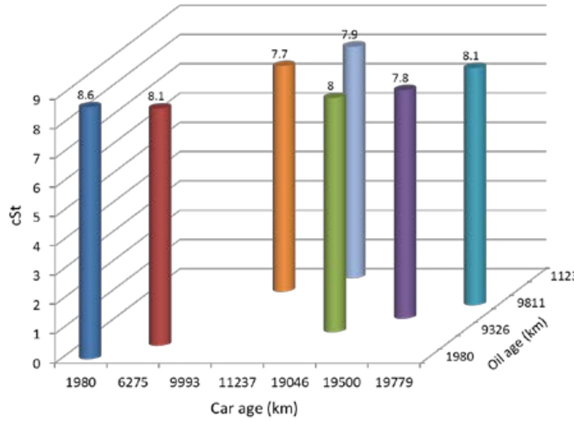
3.2 Oil Condition

Oil condition analysis is a process that involves a sample of Lubricants oil, whether virgin or used. It examines oil condition, the physical and chemical properties e.g. viscosity, Total Base Number, Oxidation and Nitration value. Presence of these contaminants degrades quality of lubricant drastically. The study shows viscosity and oxidation has higher effects on lubricant. So, in this study only the viscosity and oxidation has been studied and presented. The experimental results observed in this research are presented below.

3.2.1 Viscosity

Viscosity of lubricating oil is the most important property which affects the wear rate of various engine components. The viscosity value must be within the specified range. Viscosity is inversely proportional to temperature, thus higher the temperature, the viscosity value drop causing the lubricant layer thin. Which may cause two mating part in contact ultimately causing excessive wear.

"Fig. 3" shows the viscosity of all lubricant samples comparing with its engine age vs oil age. It can be notice that, the value decreases slightly with longer use of oil. Although in spite of having large difference in oil age, there is not so much variation in viscosity value. This may be due to the higher measurement temperature. It might be seen noticeable difference if the measuring temperature is lower.



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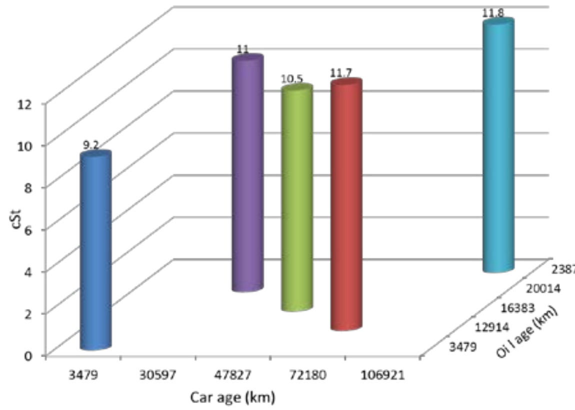


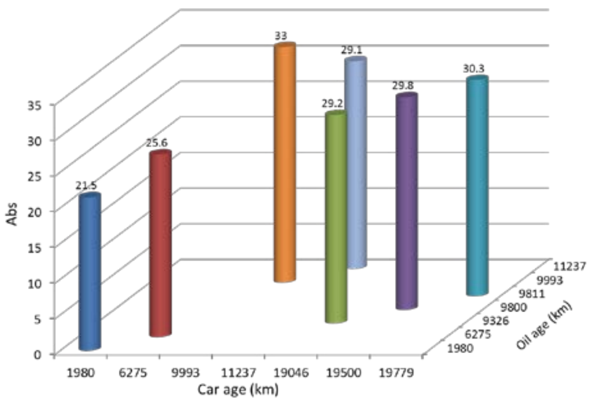
(b)

Fig. 3 Viscosity of lubricant samples
(a) Group A, (b) Group B

3.2.2 Oxidation

Oxidation is a complex primary chemical degradation process in the base oil. It can be defined as the chemical breakdown of the base oil molecules with oxygen as reagent where the principle source of oxygen is air. At lower temperatures (up to about 150 ºC) the pattern of oxidation reactions may differ substantially from those at high temperatures[10].

"Fig.4" represents the oxidation values observed for all lubricant samples. For group A it can be clearly seen that the oxidation value is getting higher with longer oil age and car age. However the trend is not clear in case of group B lubricants. As stated above, oxidation is a complex properties which is not affected only due to the longer use of lubrication, the presence of oxygen in combustion process may also plays a great role to increase its value. Moreover, higher oxidation value is not preferred for better lubrication. The increased oxidation value of lubrication may causes ionic exchange between metal components and hence increased in wear.



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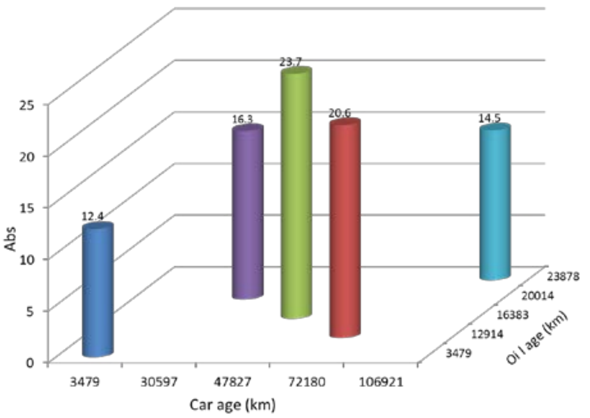
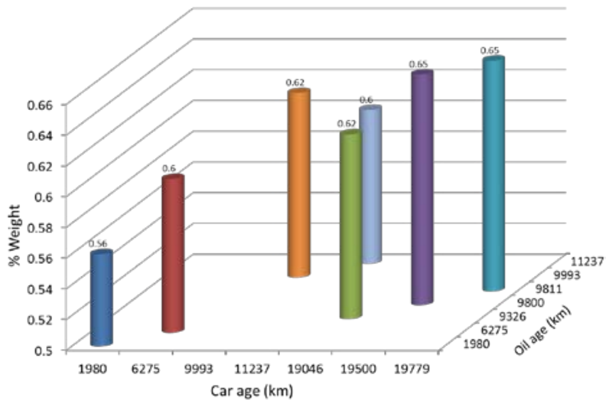


(b)

Fig. 42 Effect on Oxidation value of lubricants with engine age and oil age (a) Group A, (b) Group B



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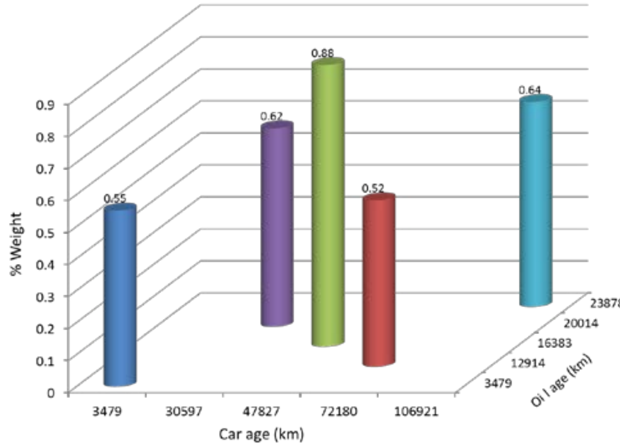

(b)

Fig. 5 Soot contamination present in lubricants (a) Group A, (b) Group B

3.3 Contamination

Diesel engine lubricant contamination is a major cause of engine component wear, leading to loss of engine performance and life. In addition, contamination accelerates breakdown of the engine lube oil, reducing its useful service life. Contaminant particles the size of or larger than the dynamic lubricant oil films separating moving component surfaces cause a major portion of diesel engine wear. The size of these harmful particles is 20 microns and smaller [11].

3.3.1 Soot

Internal combustion engines produce soot as a result of incomplete fuel combustion. Ideally, complete combustion in a cylinder would only produce carbon dioxide and water, but no engine is completely efficient. Soot occur because of the way that fuel is injected and ignited, soot formation occurs more commonly in diesel than in gasoline engines. The fuel and air mixture in diesel engines typically do not mix as thoroughly as they do in gasoline engines. This creates fuel-dense pockets that produce soot when ignited. While the majority of soot easily escapes through the exhaust, some gets past the piston rings and ends up in the oil [12].

"Fig. 5(a)" shows the level of soot measured from all lubricant samples for group A and has been compared in terms of engine age and oil age. It can be clearly observed that the soot particles are gradually increasing with longer engine and oil age. However "Fig. 5(b)" shows the value is fluctuating with longer engine age but the soot value is noticeably higher in case of longer oil age. It is clear that, soot particles generated during combustion get washed by lubricant, which contaminates it and the value gets increased after prolong use of same engine oil.

4. Conclusion

This research has been performed by collecting the lubricant used in normally operated engines. The study has been done based on physical and chemical properties of obtained lubricants. However, the driving manner is not included, which also effects on engine wear. The physical and chemical properties of the lubricant have quite significant relation to cause wear to the internal combustion engine. After completion this experimental analysis, the following conclusion can be drawn.

1. The wear condition results obtained during this experiment shows, iron, copper and aluminium are the major wear components in

comparision to other components. This may be due to most of dynamic components are made of iron, copper and aluminium.

2. Group B lubricants showed higher number of wear particles as compared to group A lubricants. It may be due to the difference in compression ratio, displacement volume.
3. The data from oil condition analysis shows, degradation of viscosity is the major issue for all tested sample with compared to other properties and it degrades with longer use of lubricant. However, oxidation value not in similar pattern with increased engine age and oil age because its compled chemical feature.
4. The analysis of contamination in lubricant has been made to compare presence of soot in both lubricant groups. The result showed that higher percentage of soot with longer use of lubricant. It illustrates that the soot produced in diesel combustion is washed away with lubricant causing degradation to the lubrating efficiency.

5. Acknowledgement

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