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Deterioration in Physical Engine Oil Properties after Different Trip Length

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ABSTRACT

Fresh engine oils or engine lubricants lose some of their properties during service, engine lubricant deterioration leads to change in oil properties, which ultimately have effect on engine overall performance. Therefore, it is very crucial to specify used engine lubricants at various conditions to check the performance and ability of used oils, which in turn protects engine parts and designs new formulations to produce better type of engine oil or improve the existing oil. In this study, most significant parameters such as kinematic viscosity, flash and fire points were chosen to find out physical properties deterioration in engine oil properties. The oil samples were multigrade fully synthetic with SAE gradation 10W-30 grand Eco drive is used in 5 different passenger cars. Having information about these properties are crucial chemical and physical behaviors of engine oils and for keeping its lifecycle. The results of the study show that after using it for more than 10,000 km, 10W-30 Delta NL motor oil brand (special synthetic with API SL) oil properties such as viscosity at cold ignition, 40 °C and 100 °C dropped 22.92%, 23.61% and 26.13% respectively. In addition, both flash point and fire point decreased 15.6% and 14.22%%, respectively, from the base properties. According to the test results this type of engine oil can be used for 10,000 km.

1. INTRODUCTION

Engine oil is a type of liquid used in Internal Combustion Engines (ICE) for lubrication in different types of vehicles and passenger cars. For many purposes lubricants which is used in engines, but main functions of motor lubricant are to decrease friction between moving parts by separating and reducing wear to protect them. Additionally, fresh engine oils used to clean the engines from varnish and sludges that produced by dispersants. It also cools the engines by carrying heat away from hotter spots generated by friction and burning of air fuel mixture inside the engine to the sump. Other functions of oil are; improving sealing of piston rings and neutralizes acids that initiate with oxidation of the oils and from fuel when mixed with lubricants [1]. The rate of degradation depends on duration of oil usage, cycle time and vehicle engine conditions[2][3]. A few necessary characteristics of engine oils involve reducing the high boiling point, friction, ideal kinematic viscosity, resistance to oxidation, thermal stability and corrosion delays [4]. For protecting moving parts from wear and tear, every engine lubricant forms a thin layer on the surface of the moving parts and internal engine body. The boundary lubricating film on the surface parts prevent any contacts between sliding surfaces [5]. Temperature has direct influence on the lubricants, oxidation of the lubricants occurs when temperature increases. When the rate of oxidation in the oil rise, degrades the lubricants quality and makes several consecutive problems for lubrication system such as slugs, resins and corrosive acids formed with rising in oil temperature [6]. Sealing is used in some parts of the engine to prevent engine oil from leak, so the lubricants need to have the characteristic to protect the seals from damage while lubricated by the engine oil during operation. All lubricants contain special additives or anti-corrosion to protect engine from corrosion, which is another function of the lubricants [7]. The Society of Automotive Engineers (SAE) reported that there are many levels of properties and different sorts of lubricants. For instance, lubricants with synthetic grade are the excellent kind and can be produced from non–petroleum or petroleum compounds of the chemical elements [8].

Different standard tests are used to analyze lubricant condition in an engine oil system after remaining it for different length trips or before using, such as follows;

1.1 Kinematic Viscosity

Viscosity is a unit of measurement of a fluid's resistance to flow at a certain temperature. The most basic parameters for evaluating conditions of internal combustion engine's oil are the viscosity [9][10][11]. Every vehicle manufacturer advises their customers to choose the correct engines oil viscosity to their engines by using the engine's specific owner's manual. Moreover, every engine oil must keep its properties under different engine working conditions. For example, when engine running under load with high engine temperature or at low temperature at starting or at cold weather, minimal changes occur in oil viscosity and other lubricant properties during engine running. To choose the oil viscosity, SAE oil grade can be used, and it is the same across the globe [12]. The SAE has set up a viscosity arrangement for internal combustion lubricant to label the lubricant viscosity. According to the SAE, for example 10W-30 internal combustion engine lubricant, the W in viscosity grade means the lubricant is suitable for using in winter, number '10' which comes before W is the first level in the SAE oil grade represents the oil flow rate at cold engine condition (at cold start), the higher the first number the lower flow rate at cold engine condition. The number '30' which comes after W represents the lowest kinematic viscosity requirement at optimal operating temperature condition for protecting engine from damage [13]. According to [14], for the gasoline engines the highest tolerance permissible decrease in viscosity up to 30% is acceptable. Further, in the study of [15], the maximum acceptable change for engine oil viscosity is 25%. A decrease in viscosity occurs due to an increase of fuel in the oil content, while increasing viscosity usually occurs due to contamination, oxidation or nitration [16]. Oil viscosity directly affected by the change in temperature. [3], studied the relationship between temperature and viscosity, they used Japan-made Totachi international oil SAE 0W-20 in 10 different used engines. The results show that for fresh oil the viscosity decreased to 8.0 cSt at 100 ℃. Also, for an engine oil used at cold ignition its viscosity reduced from 36.8 to 5.86 cSt at 100 ℃ after 10,000 Km. In the work of [17], three different engine lubrication oil (10W-30) were used. In the test, they rotated the viscometer according to the ASTM D445. According to their results, viscosity has an inverse relationship with the temperature. Thus, the viscosity of engine lubrication increases with any decrease in the temperature. Another research was conducted by Kaleli and Yavasliol,[16], which two different types of engines were used. Lubrication engine oil with SAE 20W-50 was used to determine the oil condition after using it. The findings in the lubricants claimed that after 15,000 km, the kinematic viscosity of the lubricants decreased from 160.16 cSt to 103.02 cSt at 40 ℃, and the viscosity of the engine lubricants lowered from 18.09 cSt to 13.24 cSt at 100 ℃. Lubricants have the influence on the rates of the wear and the rate of wear inside the engine increases at the cold start. Using the wrong oil viscosity is one of the factors that damages the engines. For instance, when the engine starts, if a wrong oil with high viscosity is used in the engines which needs low viscosity oil grade instead, then during starting, the ability of the oil pump decreases and unable to push the required amount of the engine oil to the above moving parts of the engine. If the oil reaches the upper engine parts too late, then the rate wear arises [3].

1.2 Flash point and fire point

Flash and fire points are two other factors for determining the engine lubricants property. According to the ASTM D92, flash point of the engine oils is the lowest temperature at which the vapors of the engine's lubricant start to ignite or to catch fire when it is exposed to a naked fire or spark source under the conditions of certain laboratories of the test [18]. The reason for decreasing the flash point of any engine lubricants is the penetration of fuel and accumulation of volatile products in the engine oil [19]. There are two methods in the laboratory to specify the flash and fire points of the engine lubricants. Pensky-Martens Closed Cup is one of the methods which is used to determine or calculate both flash and fire points. This method is used in those types of fuels, which have low rates of inflammability, in the Pensky-Martens method a closed container is used to analyze the flash and fire points of the fuel or lubricant during the test [20]. Open Cleveland Method or open flash point is another method, which is used to calculate flash and fire points. This method is used with those types of fuels or lubricants that have a high rate of inflammability (above 100 ℃), in this method an open container is used to determine the flash point and fire point during the test [20]. After flash point temperature, if heating to the lubricant continues to increase, then the kinetic energy of the lubricant helps the vapors to be released fast enough to produce a fire for a minimum of 5 s. This temperature of the fuel or lubricants is called the fire point. Typically, for every lubricant the flash point temperature is lower from the temperature of the fire point. According to the Researchers [16], after 10,000 Km the flash point of the lubricant that used (20W-50 engine oil type) decreased from 204 °C to 128 °C.

2. METHODS AND MATERIALS

In this study, passenger car 10W-30 Delta NL motor oil brand (special synthetic with API SL) synthetic grand Eco drive, which designed for high-tech four cycle gasoline and diesel engines, was used in Nissan Sunny with the same engine sizes and different production years. The characteristics of the fresh oil used by this work are shown in Table 1 and physical characteristics are presented Table 2.

Table 1: Shows SAE 10W-30 Delta NL motor oil brand (special synthetic with API SL) performance grade properties

Performance grade properties
API SL
Fully synthetic
ACEA A3/B3
Low fuel consumption
Fast cold start
Strong resistance against oxidation

Table 2: Shows SAE 10W-30 Delta NL motor oil brand physical characteristics

Properties	Units
Kinematic viscosity at 40 ℃	69.90 cSt
Kinematic viscosity at 100 ℃	11.10 cSt
Flash point	218 ℃
Density at 15 ℃	0.865 Kg/L
Pour point	-30 ℃
Sulphate ash	% 1.02

The 10W-30 Delta NL motor oil brand (special synthetic with API SL) synthetic grand Eco drive samples were taken directly from the passenger car sumps and all kept in clean closed bottles and stored in room temperature condition until the day of analysis. The samples were collected in Darbandikhan car services, Sulaymaniyah, Iraq. The kinematic viscosity for the engine oil samples measured after they have been filtered, the used filter was stainless steel which its mesh size was 50 microns. this is to avoid any error occurs with the presence of impurities such as agglomerated or tiny particles that were produced by the friction between moving and non-moving engine parts. In the scope of this work, KV1000 kinematic viscosity bath (conformed to ASTM D445) with a variable limit control was used to determine kinematic viscosity of the taken engine oil samples. Koehler viscometer was used in this study, the Koehler viscometer was manufactured according to the ASTM D446 and calibrated against fully traceable ISO 17025 certified standards. To analyze the flash and the fire points of the used lubricant samples, an Open Cleveland method was used, NCL 120, Normes: ASTM D92, ISO 2592, Ip 36 was used for finding the flash point and fire point of 10W-30 Delta NL oil samples. To show the flash and fire point temperature, a thermometer was used with a 300 ℃ measuring range. The experimental works conducted at Petroleum laboratories of Kurdistan institute. Kurdistan institute located in Sulaymaniyah province-Iraq. Table 3 in this study shows information about the 10W-30 Delta NL motor oil brand (special synthetic with API SL) synthetic grand Eco drive samples and the vehicles utilized by this work.

Table 3: Shows information about used vehicles and the rate of oil trip length in this study

Model	Made	Engine	Engine No.	Production Year	Vehicle Odometer	Trip Length (Km)
Sunny	Nissan	1.5	1	2018	12357-13432	1075
					13432-23479	10047
			2	2017	26150-28174	2024
					28174-37205	9031
			3	2019	8342-11376	3034
					11376-19392	8016
			4	2017	23547-27613	4066
					27613-34645	7032
			5	2016	38275-43403	5128
					43403-49519	6116

3. RESULTS

The results of the current study for Delta NL motor oil brand (special synthetic with API SL), the kinematic viscosity, flash point and fire point of the used oil for different types of passenger vehicle engines are shown in Table 4. The values of the findings were modelled by using a general liner function formula. The general formula is presented below:

$$Y(x) = Kx + q \qquad (1)$$

Figure 1 shows the valued formula for counting the kinematic viscosity of used Delta NL motor oil brand (special synthetic with API SL) in different gasoline engines at 100 °C:

$$v(s) = -0.2555\,.\,s + 11.015\ [cSc; Km] \qquad (2)$$

Figure 2 shows the valued formula for counting the kinematic viscosity of used Delta NL motor oil brand (special synthetic with API SL) in different gasoline engines at 40 °C:

$$v(s) = -1.7055\,.\,s + 71.196\ [cSc; Km] \qquad (3)$$

Figure 3 shows the valued formula for counting the kinematic viscosity of used Delta NL motor oil brand (special synthetic with API SL) in different gasoline engines at cold ignition:

$$v(s) = -1.7268\,.\,s + 79756\ [cSc; Km] \qquad (4)$$

Where v is kinematic viscosity and s is trip length. According to the test results, kinematic viscosity decreased at different temperature (100 °C, 40 °C, and cold ignition) with increasing the distance of the trip length as presented in Figure 1, Figure 2, and Figure 3. Test of the kinematic viscosity was repeated two times and the average of the test results were taken. Further, according to the test results in, Figure 4 and Figure 5, both flash point and fire point for the engine oil decreased with increasing. This difference is significant if compared with fresh lubricating oil. Moreover, with increasing in the trip length of the vehicles, the rate of volatile impurities rises.

Additionally, in order to obtain an accurate result for the flash point and fire points the tests have been repeated three times and the average was recorded. To get the oil of a vehicle engine with passing 10 thousand kilometres, we nearly need six months. for this reason, to make the project faster I have taken five vehicle engines as samples of the study which their production years are very close to each other.

Table 4: Shows information about Kinematic viscosity, flash point, fire point of the used engine oil samples

Oil Condition	Engine No.	Trip Length (Km)	Viscosity at cold Ignition	Viscosity (cSt) 40°C	Viscosity (cSt) 100°C	Flash point °C	Fire point °C
Pure Oil		0	77.45	69.9	11.10	218	232
Used Oil	1	1075	76.3	67.7	10.6	212	229
	2	2024	74.5	66.1	10.2	207	225
	3	3034	73.1	64.9	9.7	201	223
	4	4066	71.8	62.3	9.6	199	219
	5	5128	69.3	60.9	9.3	197	217
	5	6116	67.4	58.6	9.1	194	213
	4	7032	66.2	57	8.9	193	212
	3	8016	64.7	55.7	8.9	190	207
	2	9031	62.9	54.1	8.7	186	202
	1	10047	59.7	53.4	8.2	184	199

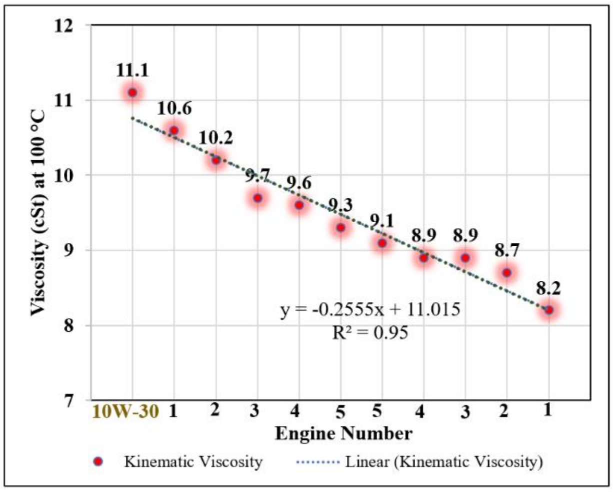

Figure 1: Change in kinematic viscosity at 100 °C

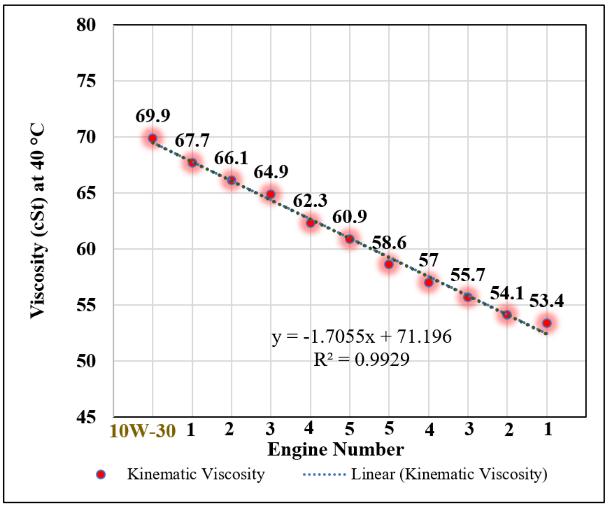

Figure 2: Change in kinematic viscosity at 40 °C

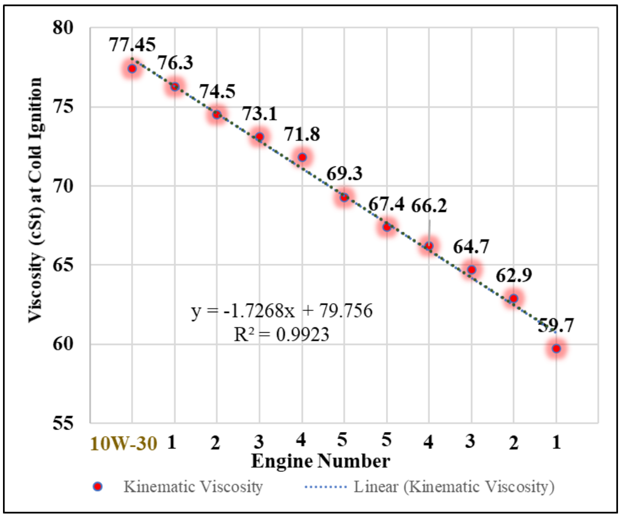

Figure 3: Change in kinematic viscosity at cold ignition

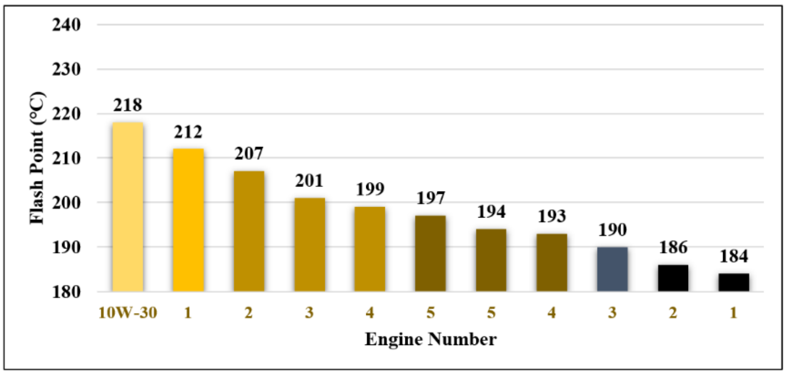

Figure 4: Change in flash point

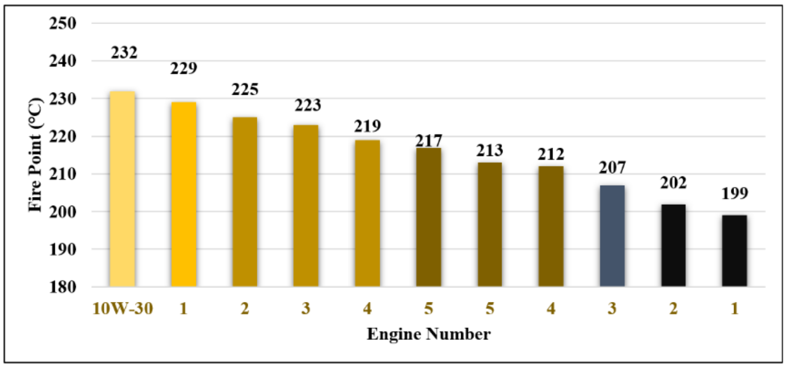

Figure 5: Change in fire point

4. DISCUSSION

There are different types of oil with different qualities of engine lubricants used in internal combustion engines.

According to the SAE international standards of oils, the viscosity of oils can be separated, at cold weather or at engine starts, thick oil with high viscosity transferred from the sump by the oil pump will experience hardship if compared to the thin oils with low viscosity.

As presented in Figure 1 the viscosity of the used engine lubricant at 100 °C decreased from 11.1 cSt to 8.2 cSt when the trip length of the vehicle increased, and the percentage by which the viscosity is decreased is 26.13%. According to Figure 2, with increasing the trip length, the viscosity of the used engine oil at 40 °C lowered from 69.9 cSt to 53.4 cSt, the rate of the lowering is 23.61%. Also, the viscosity at cold ignition shown in Figure 3. According to the results, the viscosity decreased from 77.45 cSt to 59.7 cSt, it was decreased by the percentage of 22.92%.

Another method to determine the rate of decrease in properties of the engine oil is flash point or fire point. In the lab an electrical heater was used to increase the temperature of 50 mL of the lubricating oil in a special cup, a special thermometer fitted with the heating tool to measure temperature increase. In the front panel of the NCL 120 there are an energy regulator to regulate the rate of heating. Additionally, a flame source on the NCL 120 was used to ignite the appeared vapor on the special cup with increasing the temperature of the used engine oil, a flame source was moved every 2 °C of rising temperature on the thermometer, according to the results in Table 4, the flash point of used oil lowered continuously form 1000 km to 10,000 km, the flash point of an used oil was 218 °C as shown in Table 2 decreased to 184 °C, as shown in Figure 4, which means the rate of the decrease in flash point is 15.6% comparing to its properties. Presence of contaminants in the used engine oil causes reduction or decrease in flash point.

With increasing the trip length, fire point decreased as shown in Table 4, fire point is another property that can be used to determine the rate of engine oil deterioration. Increasing impurities inside the used engine oil reduces the fire point, the fire point of the oil before using was 232 °C as shown in Table 4. The fire point of the used oil after 10,000 km decreased to 199 °C, as shown in Figure 5, the rate of the decrease was 14.22%.

5. CONCLUSION

10W-30 Delta NL motor oil brand (special synthetic with API SL) was used in five different engines, the rate of deterioration in the engine oil properties was analyzed. The study focused on the change in most important of engine oil properties, these properties are viscosity, flash point and fire point, these properties decreased in every engine with increasing in trip length. According to the test results in the experimental work, used engine oil properties degraded with increase in trip length, the test results for both flash point and fire point show that after 10,000 km the flash point decreased 15.6% of its quality. Also, the fire point of the used oil decreased 14.22% of its quality. The viscosity at 100 °C, 40 °C and cold ignition decreased 26.13%, 23.61%, and 22.92%, respectively. It is very important to have information about engine oils used in car services in Kurdistan to help drivers choose the best type of engine oil for their cars and to protect engines from any damages produced by bad quality of engine oils.

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