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Optimization of Different Grades Engine Oil Viscosity

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Abstract: *Mechanical engine is a complexmachine; it consists of a hundreds of moving parts. The parts of the mechanical engine are operated under a wide temperature ranges and pressure. Engine oil is used in all machines to reduce friction and control wear, so oil conditions and specifications controls the friction any wear behavior in any engine, viscosity is one of oil specifications, it shows the amount of forces between oil particles. A complete simulation of engine oil according to its viscosity is done in this study, through the experiment data a mathematical formulas for different engine oils grades are created. Engine oils 10W-40, 5W-30, and 20W-50 are selected for testing and simulation because these types are widely used in Kuwait market for engines. The SVM 3000 viscosity measuring unit is used to measure viscosity and density of engine oils 10W-40, 5W-30, and 20W-50, optimization techniques in MATLAB software are used so the minimum values of viscosity are created.*
Key words: *Oil, Engine, Viscosity, Temperature, Optimization.*

I. INTRODUCTION

1.1 Engine oil general information [11]

Motor oil or engine oil is formed from petrochemicals, the origin of oil in general from animal, vegetable, or petrochemical. The basic types of engine oil are [1]:

- Engine oil (10W-40, 4W-30, and 20W-50).
- Gear oil (80W-90, and 75W-90).
- Automatic transmission fluid.
- Special application oil.

The purpose of using oil in engines and rotating machineries is lubrication, lubrication means adding a layer of oil or film between the surfaces to prevent metal to metal contact also oil helps in cooling and heat transfer processes [2].

Multi-grades engine oil is used today for all seasons, in the past they car owners used engine oil in winter and oil for summer season [2]. One example of multi-grade engine oil is 10W-40, the letter W means winter, not weight or watt or anything else and the other numbers show that the oil has maximum viscosity at low temperature, the lower W number the better oil cold starting performance for example 5W is better than 10W [1].

Viscosity is the most important parameter of engine oil, viscosity shows shear force or resistance to motion, and it depends on temperature and speed [3]. Engine oil should be capable of flowing at low temperatures; oil rotates under the oil pump action around the engine in a fraction of a second at start-up and must protect engine components at high temperatures without evaporating or carbonizing and maintain adequate oil pressure.[5] Engine oil must cover the following points:

• Lubricate engine parts and reduce wear.
• Reduce friction.
• Protect against corrosion mechanism.
• Keep engine parts clean and free of oxidizing.
• Minimize combustion chamber deposits.
• Cool engine parts.
• Seal combustion pressures.
• Resist foaming.
• Aid fuel economy.
• Permit easy starting.

The SAE refers to Society of Automotive Engineers, the SAE number is measured in Centistoke (cst) at 100^{o}C [3], Centistokes measures the fluid resistance to motion. The oil grades with viscosity ranges are SAE 20 = 5.6

to less than 9.3cst, SAE 30 = 9.3 to less than 12.5cst, SAE 40 = 12.5 to less than 16.3cst, SAE 50 = 16.3 to less than 21.9cst, and SAE 60 = 21.9 to less than 26.0cst.
The factors effect on the oil operating period for different types of engines is [4]:
• Individual engine equipment status.
• Tolerance scatters.
• Operating conditions.
• Duty profile.
• Fluids and lubricants.
• Miscellaneous assembly materials based on wear status of the engine components.
API this standard for passenger cars, two categories. S = Petrol and C = Diesel, most oils carry both petrol (S) and diesel (C) specifications [11].

Figure (1): API classifications for car passenger engine oil (http://www.pqiamerica.com/apiserviceclass.htm)

Table (1): Specifications of the up to date engine oil [11].

SG	Introduced 1989 - has much more active dispersant to combat black sludge.
SH	Introduced 1993 - has same engine tests as SG, but includes phosphorus limit 0.12%, together with control of foam, volatility and shear stability.
SJ	Introduced 1996 - has the same engine tests as SG/SH, but phosphorus limit 0.10% together with variation on volatility limits
SL	Introduced 2001 - all new engine tests reflective of modern engine designs meeting current emissions standards.
SM	Introduced November 2004 - improved oxidation resistance, deposit protection and wear protection, also better low temperature performance over the life of the oil compared to previous categories.

The engine oil operation temperature different from grade to another, the temperature range for each grade is shown in figure (2).

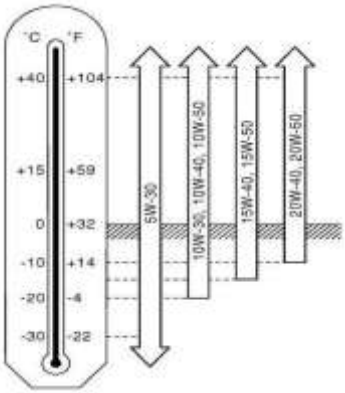

Figure (2): Engine oil grades with temperature. (http://www.navara.asia).

1.2 Optimization Techniques

Optimization is an act, process, or methodology of making something as fully perfect, functional, or effective as possible, specifically in the mathematical procedures as finding the maximum or minimum of a function. The polynomial equation in general consists constants a[i] and variables x^i, the polynomial function f(x) for n terms (1<i<n):

$$f(x) = \sum_{i=0}^{n} k_i x^i \dots\dots\dots\dots (1)$$

$$f(x) = k_o + k_1x + k_2x^2 + k_3x^3 + \cdots + k_nx^n \ldots\ldots\ldots\ldots\ldots\ldots (2)$$
$$f_{min,max} = f(x_{min}, x_{max}) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The critical points for polynomial of one variable are:

$$\frac{\partial f}{\partial x} = 0, \frac{\partial(k_o + k_1x + k_2x^2 + k_3x^3 + \cdots + k_nx^n)}{\partial x} = 0 \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

II. LITERATURE REVIEW[11]

Engine oil basic parameter is viscosity, there are many methods for measuring engine oil viscosity, and these techniques are classified to static and dynamic test. In static test the viscosity is measured based on the oil conditions for example oil temperature but in dynamic technique the apparatus can apply load and torque on sample to simulate different operation conditions. [6] they used dynamic testing method to measure viscosity of different types of engine oil, the tested oils are used in four stroke motorcycle engine, the tested oils are 10W-40 standard type, semi-synthetic type, and synthetic type, the temperature range during experiment from -5^{o}C to 115^{o}C, the experiment results are used to create mathematical formula for each type of oil.

The effect of mixing new and old engine oils is presented [7], the study shows the effect of adding old oil to new oil and adding new oil to old oil, in this study blends of the new and the usedengine oil are created, the temperature range of -10^{o}C to +60^{o}C during experiment, the results shows engine oil viscosity with temperature for different mixing percentages.

In their study [8] they focused on a comparative of four methods of recycling the used lubrication oils, the studied techniques are acid/clay treatment, distillation/clay, acid treatment, and activated charcoal/clay treatment method, the tests are done on recycled oil based on the main oil parameters, the tested parameters are flash point, pour point, specific gravity, metal contents, viscosity and Sulphur contents, the study results showed that viscosity increased from 25.5 for used lube oil to 86.2 for distillation, 89.10 for acid/clay treatment and 80.5 is for activated/clay treatment. This is compared with 92.8 cs for fresh lube oil.

For oil recycling of waste engine oils [9] by acetic acid treatment, the treatment oil engine oil process was developed for automotive engines applications, the process take place at room temperature after treatment process two layers were separated from oil, the first layer is a transparent dark red colored oil and the second layer is a black dark sludge at the bottom of the container. The results showed the treated engine oil viscosity compared with new oil from the same grade.

Tribo-mechanical characteristics of technical systems are monitored using special techniques [10], the various physical, chemical and tribological methods are used in wear monitoring and diagnosis, they used tribological tests that are part of the oil analysis and to access the condition of the system, the study results depend on the tribological characteristics of engine oil (Mercedes O 345, PUCH 300GD and PINZGAUER 710M) , also a tribological characteristics change of oil for engine and gear transmission lubrication are presented based on the experimental results.

III. ENGINE OIL MODELING

The experiment is done in pervious paper [11] for old and new engine oils, the selected oils are 5W-30, 10W-40, and 20W-50. The oil samples are taken from cars workshop in Kuwait, the test is done in collage of technological studies in PAAET (public Authority of Applied Education and Training-Kuwait).Old engine oils are selected after 5000km and 10000km travelling period. Table (2) shows new and old engine oil specifications.

Table (2): The selected engine oil specifications[11].

New Engine Oil	Old Engine Oil
5W-30	5W-30 (5000km)
10W-40	10W-40 (10000km)
20W-50	20W-50 (10000km)

The oil and new engine oil viscosity is mathematically simulated in sixth order polynomial using Excel software, the mathematical equation is in the form:

$$\mu = a_o + a_1T + a_2T^2 + a_3T^3 + a_4T^4 + a_5T^5 + a_6T^6$$

Table (3): The sixth order polynomial coefficients [11].

Engine oil	a_o	a_1	a_2	a_3	a_4	a_5	a_6
10W-40 (New)	231.74	3.9958	-0.7215	0.0228	-0.0003	$2x10^{-6}$	$-7x10^{-9}$
10W-40 (Old)	612.13	-40.954	1.3408	-0.0252	0.0003	$-2x10^{-6}$	$4x10^{-9}$
20W-50 (New)	1740.60	-112.42	3.3932	-0.0583	0.0006	$-3x10^{-6}$	$7x10^{-9}$
20W-50 (Old)	1237.7	-74.135	2.0887	-0.0338	0.0003	$-2x10^{-5}$	$4x10^{-9}$
5W-30 (New)	366.91	-18.794	0.4541	-0.0061	$5x10^{-5}$	$-2x10^{-7}$	$2x10^{-10}$
5W-30 (Old)	293.07	-12.497	0.2078	-0.0007	$-2x10^{-5}$	$3x10^{-7}$	$-1x10^{-9}$

IV. OPTMIZATION RESULTS

The optimization technique shows the minimum viscosity of engine oil and minimum temperature, the technique is applied for new and used engine oils. MATLAB software shows graphical plot of oil viscosity with temperature also it shows the minimum numerical values of engine oil viscosity and temperature. Minimum values of viscosity and temperature of new engine oil 10W-40 are 104.4215mPa.sec and 39.2736^{o}C, figure (3) shows viscosity curve with temperature for new engine oil 10W-40.

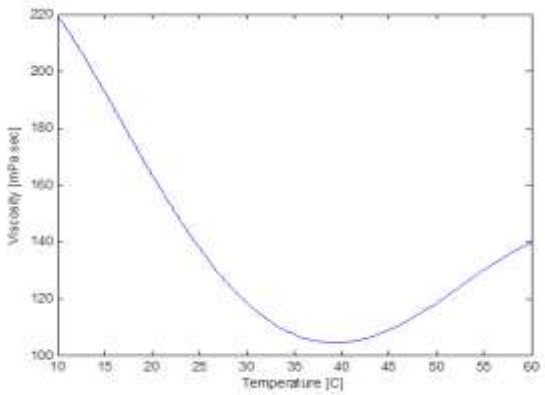

Figure (3): Viscosity of Engine oil 10W-40 vs. temperature.

For new engine oil 5W-30 the minimum values of viscosity and temperature are 66.8957 mPa.sec and 40.9076^{o}C, figure (4) shows viscosity curve with temperature for new engine oil 5W-30.

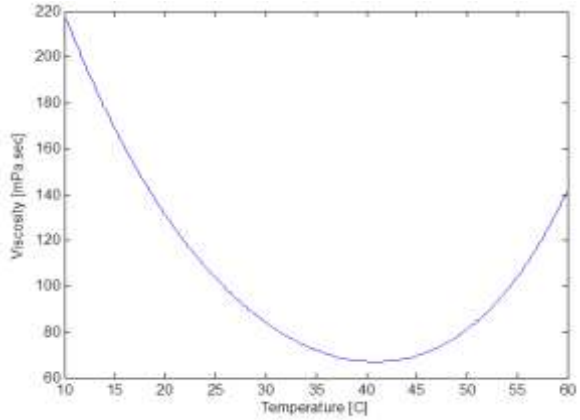

Figure (4): Viscosity of Engine oil 5W-30 vs. temperature.

For new engine oil 20W-50 the minimum values of viscosity and temperature are 198.3505 mPa.sec and 41.2930^{o}C, figure (4) shows viscosity curve with temperature for new engine oil 20W-50.

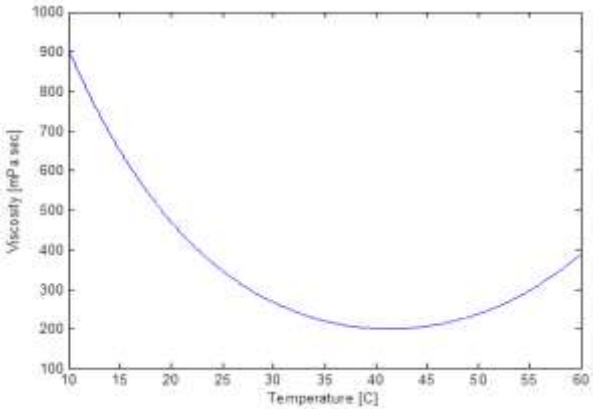

Figure (5): Viscosity of Engine oil 20W-50 vs. temperature.

V. CONCLUSIONS

Engine oil is made from petrochemicals with different grades, the most important specification of engine oil specifications list is viscosity, and mathematical models of different grades engine oil (10W-40, 5W-30, and 20W-50) are used based on pervious paper. The optimization technique is used to show the minimum value of viscosity of engine oil also temperature of minimum viscosity is found. As shown in the study results the temperature of minimum viscosity for all engine oil grades (10W-40, 5W-30, and 20W-50) approximately around 40^{o}C.

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