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EFFECT OF TEMPERATURE ON LUBRICATING OIL AND POLY(METHYL METHACRYLATE) ADDITIVE

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ABSTRACT: This paper presents the evaluation of Poly(Methyl Methacrylate) or PMMA additive used in Iraqi lubricating oils to improve the characteristics of gasoline engine lubricants. Primarily, the viscosity with viscosity index improvement, represent the indicators for the evaluation of this type of additives under the influence of engine temperature.

The lubricants used in this work, after manual addition of PMMA, were prepared by mixing the Iraqi base oils of grades 150H & 60H (equal amounts of each type) with percentages 100%, 90%, 80%, and 75%, respectively. These prepared mixtures of lubricating oils – additives were operated 4 hrs in engine of type "air cooled, 4-stroke, single cylinder, gasoline engine 3kw". The tests, were conducted for lubricant temperature during engine running, oil viscosity, viscosity index, and weight of debris (not analytic), on each sample of prepared lubricants.

The results confirmed that the most suitable lubricating oil for gasoline engine; either in summer or winter; was the mixture of 25% PMMA with 75% mixed base oil, with difference percentage not exceeds more than 6% between these two seasons, since it has lower increment of viscosity and lower VI decrease, with the presence of low amount of the debris (weight percent). This debris can indicate damages to the engine components, for long time engine operation. Finally, the benefits involved that the PMMA was low affected with the increase of engine temperature, according to its bounded properties.

Keywords: PMMA, Poly(Methyl Methacrylate), gasoline engine, engine temperature, oil mixtures-additives, lubricants consumption.

INTRODUCTION

The cars involved gasoline engines were used many types of lubricants with various components. These lubricants are contained different types of chemical materials known as "additives". Some of these additives were affected by the engine temperature which leads to make the quality of selected lubricant decreases and the oil become un useful for this engine, in a few time of running. Where the gasoline engine temperature is higher than the other engines like diesel, depending on the variation of engine speed (i.e. the no. of rpm per period of operation). For this reason, and for prolong engine life, requires the use of lubricating oil additives appropriate to achieve those requirements (1).

Mineral oils, used oils type in this research, are also relatively stable to thermal decomposition in the absence of oxygen, but at temperatures over about 330 °C, dependent on time, mineral oils will decompose into fragments, some of which polymerise to form hard insoluble products. While, some additives are more liable to thermal decomposition than the base oils, e.g. extreme pressure additives; and surface temperature may have to be limited to temperatures as low as 130 °C [2].

The aim of the present work to evaluate PMMA, used as improvement additive for some oil characteristics, which is done when oil temperature during engine running, oil viscosity, viscosity index, and weight of debris are measured. The relations between improvements and lubricants, under engine running, are showed in order to determine the ability of these improvements to enhance the characteristics of used lubricants.

BASICS & THEORIES

In engine tribology, oil is required especially at the piston ring and cylinder liner interface to provide hydrodynamic or mixed lubrication in order to reduce friction and prevent seizure as well. In addition to lubrication, oil also operates as medium that transports and removes heat from the piston and the ring-liner interface [1, 3].

The lubricant consumption mechanisms contribute to total oil consumption from the piston-ring-liner system during engine operation. Whether one or the other mechanism dominates depends mostly on the engine design specific oil transport rates, engine operating parameters, and lubricant properties. The oil must traverse a complex course before being transported into the combustion chamber, as indicated in Figure (1) [4].

Some important functions of lubricant oil for an engine are adherence to the solid surfaces, resistance when being squeezed out from between the surfaces even under the extreme forces in between engine components and not requiring excessive force to shear adjacent liquid layers [5].

The formation of a hydrodynamic lubrication film at the interface between the piston rings and cylinder liner is expected while the internal combustion engine is in operation [6]. However, the lubrication regime of the mating surfaces affects the efficiency, durability and emission output of the engine.

The lubricant oil which is usually used in the internal combustion engine will be changed based on its quality and characteristics after a certain time and distance. The high quality lubricant oil will lubricate, protect, cool, clean and seal engines as well as maintain them. Hence, it is capable of reducing friction and wear, which leads to efficient engine operation and long life [6]. It should also be able to removing heat from the engine to prevent it from overheating, avoid deposits and corrosion, disperse soot and sludge, contribute to energy savings and clean combustion, and also help to safeguard the environment. Besides, the effect of the oil viscosity on the frictional behaviors of piston rings also has been investigated by Durga & et al [7]. The oil viscosity affects friction values under conditions of pure hydrodynamic lubrication when the rings are fully flooded. Higher friction values occur at higher viscosity. The suggestions had been made that a slight increase in friction, which has observed at mid-stroke of the piston motion, could be partially caused by high-speed shear. The rings experience a very high contact pressure at mid-stroke, which could lead to oil starvation and thus increasing the friction.

VISCOSITY & VI MODIFIERS

A fundamental characteristic of every fluid is its viscosity. The kinematic viscosity of a fluid is dependent on the external parameters of pressure and temperature. A great number of applications specify viscosity at a defined temperature, in the case of hydraulic equipment at 40 °C and 100 °C, to achieve optimum engine oil pump efficiency [8].

The effect of temperature on a fluid can be illustrated double-logarithmically, whereby the gradient defines the viscosity index. The viscosity index is defined exactly by the gradient between 40 °C and 100 °C.

This simple-to-calculate characteristic has a significant impact on lubrication technology and is practically a standard feature of every specification. The viscosity index defines molecular structure and has been exactly described for defined molecules [(9)].

In the simplest of cases, a desired viscosity index can be achieved by mixing fluids with corresponding VIs. Usually, however, the viscosity requirements of modern lubricant specifications can be met only by addition of viscosity modifiers (VMs) also known as viscosity index improvers (VIIs).

As opposed to those present in low-molecular base fluids, viscosity modifiers have a polymer nature [(10)]. These molecules are described as being chain-like molecules whose solubility depends on chain length, structure and chemical composition [(11)].

As a rule, the base oil solubility of these polymer chains deteriorates as the temperature falls and improves with increasing temperature so that an increase in viscosity induced by viscosity modifiers also increases the viscosity index. In 1958 Selby, published a descriptive explanation of the mechanism of VMs [(12)]. Because of poor solubility at low temperatures the chain-like VM molecules form coils of small volume and as the temperature is increased these molecules expand and unravel, resulting in an increasing beneficial effect on high-temperature viscosity.

The absolute increase in viscosity and the VI depends on the type, the molecular weight and the concentration of viscosity modifiers in the formulation [(13)]. In practice and depending on the projected application, molecular weights of 15 000 to 250 000 g mol^{-1} for PAMAs, are used. Concentrations are usually between 3 and 30% (w/w). As a result of their high molecular weight, viscosity modifiers are always dissolved in a base fluid.

Apart from their thickening effect which is schematically illustrated in Figure (2) as a function of molecular weight, shear stability serves as a second characteristic [(14)]. According to Figure (3), increasing molecular weight reduces shear stability if the polymer concentration remains constant.

The reason for this effect is mechanically – or thermally – induced chain degradation [(15)]. As opposed to Newtonian fluids, whose viscosity is independent of the rate of shear or the velocity gradient, long-chain compounds subject to high shearing are mechanically broken. Depending on the type and duration of the load, a number of different molecular sizes are created. The resulting drop in viscosity is described by the Permanent Shear Stability Index (PSSI) which describes the percentage loss of the contribution of the polymer to the viscosity (viscosity increase by the VM compared with base oil viscosity).

ADOPTED MODIFIER(PMMA)

Poly(Methyl-Methacrylate) or PMMA is a linear thermoplastic, with a glass-transition temperature of approximately 105 °C [(16 – 19)]. PMMA does not typically contain any branches or any cross-links. Chemically, PMMA is very stable [(19, 20 & 21)]. It is unaffected by near-UV or visible light, and is resistant to most acids. PMMA general chemical formula is $[C_6H_{10}O_n]_n$ [(22)], while chemical structure is illustrated in Figure (4) [(23)].

In addition, PMMA is an amorphous thermoplastic which is optically transparent, unaffected by moisture, and offers a high strength-to-weight ratio. Common trade names of acrylic include Plexiglas, Lucite, and Acrylite [(24)].

In other words, PMMAs have the ability to contribute relatively little viscosity at colder temperatures such as those that might be encountered at equipment start-up, but have a much higher contribution to viscosity at hotter temperatures at which equipment tends to operate. This desirable behavior enabled oil formulators to prepare multigrade oils that could meet a broader range of operating-temperature requirements. The positive enhancement of VI ensured the future success of PMMAs [(25, 26)].

GENERAL PROPERTIES & APPLICATIONS OFPMMA

Acrylics offer high light transmittance with a Refractive Index of 1.49 and can be easily heat-formed without loss of optical clarity. Prolonged exposure to moisture, or even total immersion in water, does not significantly effect the mechanical or optical properties of acrylic. Most commercial acrylics have been UV stabilized for good weather ability and resistance prolonged sunlight exposure. Acrylics are unaffected by aqueous solutions of most laboratory chemicals, by detergents, cleaners, dilute inorganic acids, alkalies, and aliphatic hydrocarbons. However, acrylics are not recommended for use with chlorinated or aromatic hydrocarbons, esters, or ketones.

Acrylic is an economical, general purpose material used in a wide variety of applications, including: Store fixtures and displays, lenses and lighting fixtures, light pipes, windows and skylights, sight gauges, furniture, outdoor signs, and sculpture (24).

PMMA is better described as a viscoelastic material, as the viscosity of PMMA depends on the shear rate (i.e. the zero-shear viscosity). The viscosity of PMMA is also strongly related to the molecular weight distribution. Over the entanglement length, the viscosity has the following relationship (23, 27):

$\eta 0 = K\ Mw\ a$ (1)

In equation (1), $\eta 0$ is the zero-shear viscosity, Mw is the weight average molecular weight, and K and a are empirical constants. For almost all polymers, a is in the range of (3 to 4). In particular, for PMMA, a = 3.4 (27).

A summary of the material properties of PMMA is presented in Table (1) (23, 24). Where many of these properties vary with the molecular weight distribution, in particular chemical and mechanical properties. Additionally, films less than 100 nm may exhibit changes in the glass-transition due to surface effects (28, 29). The tacticity of the polymer can have even more dramatic effects. Additionally, many properties exhibit an unusually high temperature dependence due to PMMA's large coefficient of thermal expansion. For example, the density of PMMA varies from 1.195 g/cm^3 at 0 °C to 1.150 g/cm^3 at the glass-transition temperature (17).

The information contained in Table (1) are typical values intended for reference and comparison purposes only. They should not be used as a basis for design specifications or quality control. All values at 73 °F (23 °C) (24).

PRACTICAL WORK

MATERIALS

PMMA Quantity

The expensive cost of PMMA, as commercial product, makes the use of this modifier so restricted. Therefore, the amounts of PMMA were 10%, 20%, and 25% weight percentages. Also, these percentages adopted according to the vision of thermal degradation for polymer when use it as modifier in lubricants used in gasoline engines and cracking carbon chain of polymer according to shear, resulting the debris obtained in engine crankcase.

Prepared Mixed Base Oil

The lubricants used in this work were mixed Iraqi base oils of grades 150H & 60H and of type mineral oils, where H means high viscosity index (30). Equal amounts, volume percentage of each grade, were mixed and let to rest for 12 hrs to produce homogeneous base oil with certain specifications to achieve the requirements of this research.

Test Lubricants

The amounts of prepared mixed base oil, added to modifier, were 100%, 90%, 80%, and 75% weight percentages. These amounts were mixed with PMMA and let to rest for 24 hrs to produce the final homogeneous lubricants to use in the test for evaluation process of PMMA, as shown in Table (2).

EGUIPMENTS

a. Refractive Index device

This device used to measure the R.I. to test the homogeneity of both the base oil mixture and prepared test lubricants (AR700 USG Refractometer, Reichert, Florida U.S.).

b. Mixer

Chengxing ZGF-112M mixer with 15000 rpm is used to blending the base oils of grades 150H & 60H to produce mixed base oil and to blending mixed base oil with PMMA for 2 hrs in order to get homogeneous product for each one.

c. Mercury Thermometer

This mercury laboratory thermometer with range 0 – 150 °C is used to measure the engine temperatures during operation.

d. Viscometer

Cannon-Fenske Routine viscometer with size No. 150 is used to measure the kinematic viscosity for each prepared lubricants.

ENGINE CHARACTERISTICS

A single-piston portable gasoline engine, operated by pulling the rounding rope over the pulley, named "air cooled, 4-stroke, single cylinder, gasoline engine 3kw", as shown in Figure (5). This engine is used to operate the prepared test lubricants for 4 hrs. Where the time of operation are determined according to the equivalent of pulley movement. The engine features are as follow:-

1. The 3kw portable gasoline generator utilizes 9hp 4-stroke gasoline engine.
2. It is designed with large mufflers, so it has low running noise.
3. Equipped with control panel, so the 3kw portable gasoline generator is easy to operate.
4. It is mounted with two handles and two wheels, and so it is easy to move.
5. Our 3kw portable gasoline generator can supply uninterrupted quality electrical power.

TECHNICAL PARAMETERS OF PORTABLE GASOLINE GENERATOR 3kw

Table (3), shows the engine operation characteristics, as follow:

Experiments Procedure

The experiments were done in adopted engine (TW3500W(E)), at summer and winter, for the prepared lubricants coded L1, L2, L3 and L4, respectively. Engine was operated under various speeds with range (1500 to 3600) rpm for time equal to 4 hrs for each type of prepared lubricants. This time is determined according to the equivalent of pulley movement in order to determine the distances, must be achieved for each tests lubricants, and equivalent to time of engine operation, as shown in Table (4).

The engine was run for four hours for each oil sample. The engine was run for 60 minutes for each engine speed, start with 1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm, and lastly 3600 rpm. The temperatures for the each lubricant were detected by mercury laboratory thermometer located at the oil sump, and then obtained manually each 10 minutes. Then, after the lubricant was tested, analysis on its viscosity, viscosity index and debris were carried out, and will be studied in order to obtain the properties of the lubricant and the effects to the engine components. The temperature, viscosity, viscosity index, and debris were conducted in accordance to the following:

a. Kinematic Viscosity

The kinematic viscosity was evaluated according to ASTM D445-83, for each prepared lubricant using Cannon-Fenske Routine viscometer at 40 °C and 100 °C before and after operation.

b. Viscosity Index VI

The viscosity index was evaluated according to ASTM D2270-79 and IP 226/80 before and after operation.

c. Temperature

The engine temperature was measured each 10 minutes by using mercury laboratory thermometer from start point of engine operation to the final point of running time, for each prepared lubricants.

d. Debris

The debris is measured before and after operation for each prepared lubricants with weight percentages by using weighing scale (balance), after separation from prepared lubricants by let to rest for 24 hrs to precipitation completely.

RESULT & DISCUSSION

The prepared lubricants were the same used in both summer and winter experiments, for the main purpose to determine the optimum sample under various engine conditions, especially the engine temperature and its effects on the characteristics of these lubricants. Therefore, there are two kinds of experiments which are as follow:

Summer Results

The temperatures were measured for each sample of prepared lubricants. Where the readings were recorded every 10 minutes for a period of 60 minutes each sample run. Also, each sample has been run under both the limits of the specific velocities of the engine (i.e engine speeds). Figures (6, 7, 8, & 9), are shown the behaviours of lubricant temperature for the samples with various durations of adopted engine operation in summer season. These behaviours represented that, the durations of engine operation when increase according to the engine speeds (i.e 1500 to 3600) rpm the temperature of the engine will increase automatically. Where the engine start with temperature 28 °C and warm above 120 °C. So, this will lead to make the lubricant sample suffer from the change of engine's conditions and this will also lead to change the lubricant characteristics. Finally, these changes mean that the added PMMA will lower degradation automatically appear in the measured values of viscosity and viscosity index and lead to replace the lubricant with short period of use in the engine.

The variation of temperatures with various engine speeds (i.e 1500 to 3600) rpm is shown in Figure (10). This variation is obtained the excellent and optimum type of lubricant samples used in the engine in summer season that is L4. Also, the behaviours of lubricants in this figure are show that the various speeds in engine lead to increase engine temperature automatically. This change in temperature will effect on PMMA added to samples and this will effect on its efficiency in engine, especially in summer season.

The viscosity measurements in summer season for each sample were shown the various values before and after operation in the adopted engine, as shown in Table (5). These values indicated that the amounts of PMMA, added to each sample, were not affected very much but the optimum one is the sample L4. This means that, the increase of the amount of PMMA added to the lubricant is the increase in the enhancement of lubricant itself. So, the increase in the amounts represents the increase in viscosity too.

The VI measurements in summer season for each sample were shown the various values before and after operation in the adopted engine, as shown in Table (6). These values indicated that the amounts of PMMA, added to each sample, were not affected very much but the optimum one is the sample L4. This means that, the increase of the amount of PMMA Added to the lubricant is the increase in the enhancement of lubricant itself. So, the increase in the amounts represents the decrease in VI too.

The debris in test lubricants represents the consumption and corrosion of engine internal parts in addition to the degradation of additives like PMMA, primarily. So, this parameter is considered as the indicator for two cases, the first case is the engine life whiles the second case, the important one in this research, is the stability of PMMA with engine temperature variation. Table (7), is shown the measured amounts of debris, in summer season, and its effect on both the engine and the PMMA in prepared lubricants, where the optimum one is the sample L4. Although, that these values are measured with a procedure adopted by the researchers and not scientifically signed.

The debris amounts, as shown in Table (7), is represent the interpretation to the behaviour of PMMA in lubricants as modifiers, because its shown that the more amount of PMMA added the more life for engine and lower failure of lubricant characteristics and this is the aim of modifiers uses to enhancement the lubricants scientifically.

Winter Results

The temperatures were measured for each sample of prepared lubricants. Where the readings were recorded every 10 minutes for a period of 60 minutes each sample run. Also, each sample has been run under both the limits of the specific velocities of the engine (i.e engine speeds). Figures (11, 12, 13, & 14), are show the behaviours of lubricant temperature for the samples with various durations of adopted engine operation in winter season. These behaviours represented that, the durations of engine operation when increase according to the engine speeds (i.e 1500 to 3600) rpm the temperature of the engine will increase automatically. Where the engine start with temperature 18 °C and warm above 100 °C. So, this will lead to make the lubricant sample suffer from the change of engine's conditions and this will also lead to change the lubricant characteristics. Finally, these changes mean that the added PMMA will lower degradation automatically appear in the measured values of viscosity and viscosity index and lead to replace the lubricant with short period of use in the engine.

The variation of temperatures with various engine speeds (i.e 1500 to 3600) rpm is shown in Figure (15). This variation is obtained the excellent and optimum type of lubricant samples used in the engine in winter season that is L4. Also, the behaviours of lubricants in this figure are show that the various speeds in engine lead to increase engine temperature automatically. This change in temperature will effect on PMMA added to samples and this will effect on its efficiency in engine, especially in winter season.

The viscosity measurements in winter season for each sample were shown the various values before and after operation in the adopted engine, as shown in Table (8). These values indicated that the amounts of PMMA, added to each sample, were not affected very much but the optimum one is the sample L4. This means that, the increase of the amount of PMMA Added to the lubricant is the increase in the enhancement of lubricant itself. So, the increase in the amounts represents the increase in viscosity too.

The VI measurements in winter season for each sample were shown the various values before and after operation in the adopted engine, as shown in Table (9). These values indicated that the amounts of PMMA, added to each sample, were not affected very much but the optimum one is the sample L4. This means that, the increase of the amount of PMMA Added to the lubricant is the increase in the enhancement of lubricant itself. So, the increase in the amounts represents the decrease in VI too.

The debris in test lubricants represents the consumption and corrosion of engine internal parts in addition to the degradation of additives like PMMA, primarily. So, this parameter is considered as the indicator for two cases, the first case is the engine life whiles the second case, the important one in this research, is the stability of PMMA with engine temperature variation. Table (10), is shown the measured amounts of debris, in winter season, and its effect on both the engine and the PMMA in prepared lubricants, where the optimum one is the sample L4. Although, that these values are measured with a procedure adopted by the researchers and not scientifically signed.

The debris amounts, as shown in Table (10), is represent the interpretation to the behaviour of PMMA in lubricants as modifiers, because its shown that the more amount of PMMA added the more life for engine and lower failure of lubricant characteristics and this is the aim of modifiers uses to enhancement the lubricants scientifically.

The Best Condition of Sample

The engine conditions in summer and winter are different, but these conditions are different with percentage not exceeds more than 6% between these two seasons.

Figures (16 & 17), are shown the chosen sample (L4) both in summer and winter. These figures could be considered as the pointers to the optimum determination, because it is shown the differences in engine temperature measurement with the durations of engine operation and speeds of engine, respectively. As a result, these figures also show the optimum sample (L4) between summer and winter and it was the sample used in summer is higher affected by temperature than the sample used in winter, but the amount of debris for this sample in summer is lower than in winter, also the viscosity and VI changes in summer is more reasonable than the changes in winter, so L4 in summer is the optimum lubricant than the lubricant L4 in winter.

Finally, the optimum L4 in summer; in addition to L4 in winter; means that, this lubricant is more efficient and more resistance to various engine conditions and this in turn means that this weight percentage of PMMA (25%) is the optimum percentage to prevent or decrease the affection of PMMA against the variation of conditions in gasoline engines, so it's the optimum modifier for lubricants at all.

CONCLUSIONS

This search included the following conclusions:

1. The main conclusion is that the PMMA is lower affection by engine conditions, especially the engine temperature, so it could be the optimum modifier for lubricants.
2. The prepared test lubricants is more efficient in gasoline engines, if it are prepared very well, and according to the mechanisms and rules of lubrication tribology, scientifically.
3. The amounts of modifiers additives which are added to prepared test lubricants should be adopted very well, in addition to the base oils used in order to give the good behaviour of lubrication in engine with lower degradation or cracking of modifiers themselves.
4. The differences between the behaviours of the same lubricant used in engine either in summer or winter are not different very much but with low percentage not exceed 10%, also this lubricant is could be the optimum in summer than in winter.
5. The efficiency of lubrication for lubricant is increase when the different types of additives are mixed with each others to add it to the base oils, like antioxidant, detergent and others, where the PMMA is used as viscosity modifier only.

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Table (1): Typical Properties of PMMA [23, 24].

ASTM or UL test	Property	Acrylic
PHYSICAL		
D792	Density (lb/in³) (g/cm³)	0.043 1.18
D570	Water Absorption, 24 hrs (%)	0.3
MECHANICAL		
D638	Tensile Strength (psi)	8,000 - 11,000
D638	Tensile Modulus (psi)	350,000 - 500,000
D638	Tensile Elongation at Break (%)	2
D790	Flexural Strength (psi)	12,000 - 17,000
D790	Flexural Modulus (psi)	350,000 - 500,000
D695	Compressive Strength (psi)	11,000 - 19,000
D695	Compressive Modulus (psi)	-
D785	Hardness, Rockwell	M80 - M100
D256	IZOD Notched Impact (ft-lb/in)	0.3
THERMAL		
D696	Coefficient of Linear Thermal Expansion (x 10-5 in./in./°F)	5 – 9
D648	Heat Deflection Temp (°F / °C) at 264 psi	150-210 / 65-100
D3418	Melting Temp (°F / °C)	265-285 / 130-140
-	Max Operating Temp (°F / °C)	150-200 / 65-93
C177	Thermal Conductivity (BTU-in/ft²-hr-°F) (x 10-4 cal/cm-sec-°C)	3.9 1.2
UL94	Flammability Rating	-
ELECTRICAL		
D149	Dielectric Strength (V/mil) short time, 1/8" thick	400
D150	Dielectric Constant at 60 Hz	4.0
D150	Dissipation Factor at 60 Hz	0.05
OPTICAL		
-	Light Transmission, minimum (%)	92
-	Refractive Index	1.48-1.50

Table (2): Prepared Test Lubricants**.**

No.	Mixed Base Oil (wt%)	PMMA (wt%)	Lubricant Code	SAE Compatibility
1	100	0	L1	SAE 30
2	90	10	L2	SAE 30
3	80	20	L3	SAE 30
4	75	25	L4	SAE 30

Table (3): The Engine Operation Characteristics.

Model		TW3500W(E)
Generator	**Type**	Air cooled, 4stroke, single phase, gasoline
	Rated Output	2.8kw
	Max. Output	3.0kw
	Voltage (V)	110V220V
	Frequency (Hz)	50HZ/60Hz
Engine	**Engine Model**	173FB
	Engine Type	Air cooled, 4-stroke, single cylinder, gasoline engine
	Fuel	Unleaded Gasoline
	Displacement (CC)	196
	Engine Speed (rpm)	9.0HP/(1500rpm, 2000rpm, 2500rpm, 3000rpm) Max. 3600rpm
	Engine Starting System	Manual starting/electric starting
	Fuel Tank Capacity (L)	17L
	Oil Capacity (L)	1.1L
	Operating Noise Level (7m)	70dB(A)
Unit	**Weight**	N.W.: 45kgs G.W:48
	Dimension	650*515*530mm
		150pcs/20'ft container
		Pulley Diameter 6 in
MOQ	**30 Units**	–

Table (4): Distance According to TW3500W(E) Engine Speed.

No.	Engine Operation Time (hrs)	Engine Speed (rpm)	Distance (km/hr)
1	4	1500	42.5
2	4	2000	56.6
3	4	2500	70.7
4	4	3000	84.8
5	4	3600	102

Table (5): Prepared Test Lubricants Viscosity, Summer Results.

No.	Lubricant Code	Viscosity (CSt) at 40 °C Before Test	Viscosity (CSt) at 100 °C Before Test	Viscosity (CSt) at 40 °C After Test	Viscosity (CSt) at 100 °C After Test
1	L1	71.34	10.33	63.52	6.84
2	L2	116.52	13.17	105.86	11.64
3	L3	143.22	18.57	137.14	16.66
4	L4	159.33	21.17	154.87	19.13

Table (6): Prepared Test Lubricants VI, Summer Results.

No.	Lubricant Code	Viscosity (CSt) at 40 °C Before Test	VI Before Test	Viscosity (CSt) at 40 °C After Test	VI After Test
1	L1	71.34	96.35	63.52	83.81
2	L2	116.52	105.64	105.86	99.45
3	L3	143.22	117.27	137.14	114.38
4	L4	159.33	121.55	154.87	120.72

Table (7): Prepared Test Lubricants Debris Amounts, Summer Results.

No.	Lubricant Code	Debris (Wt. %) Before Test	Debris (Wt. %) After Test
1	L1	1.21	5.61
2	L2	2.64	6.72
3	L3	4.54	8.25
4	L4	6.11	10.86

Table (8): Prepared Test Lubricants Viscosity, Winter Results.

No.	Lubricant Code	Viscosity (CSt) at 40 °C Before Test	Viscosity (CSt) at 100 °C Before Test	Viscosity (CSt) at 40 °C After Test	Viscosity (CSt) at 100 °C After Test
1	L1	75.25	12.24	64.31	7.71
2	L2	119.65	15.42	107.74	12.30
3	L3	147.91	20.77	140.53	16.82
4	L4	161.34	23.38	154.28	21.05

Table (9): Prepared Test Lubricants VI, Winter Results.

No.	Lubricant Code	Viscosity (CSt) at 40 °C Before Test	VI Before Test	Viscosity (CSt) at 40 °C After Test	VI After Test
1	L1	75.25	97.60	64.31	85.64
2	L2	119.65	106.56	107.74	101.11
3	L3	147.91	118.84	140.53	115.54
4	L4	161.34	122.35	154.28	121.16

Table (10): Prepared Test Lubricants Debris Amounts, Winter Results.

No.	Lubricant Code	Debris (Wt. %) Before Test	Debris (Wt. %) After Test
1	L1	1.21	6.15
2	L2	2.64	7.34
3	L3	4.54	9.64
4	L4	6.11	11.48

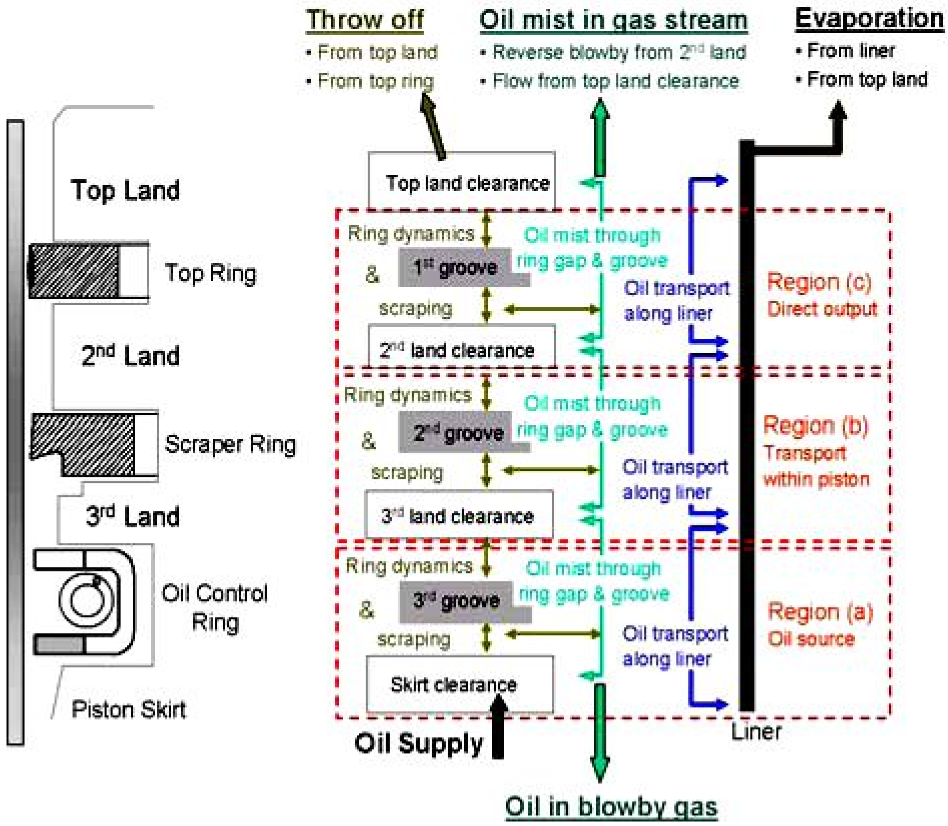

Fig.(1): Oil Transport in The Clearances of The Piston-Ring-Liner System (4).

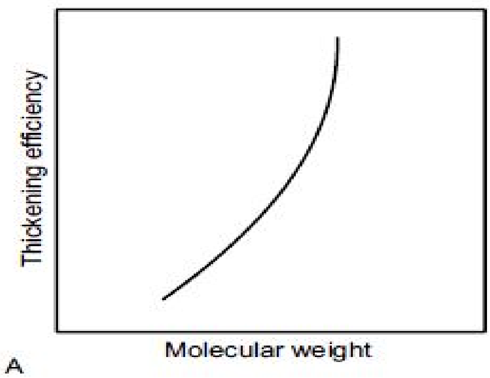

Fig.(2): Thickening Efficiency (14).

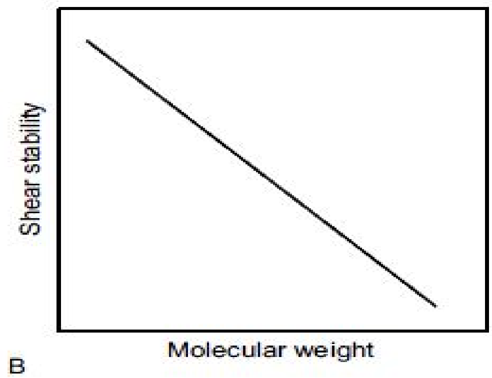

Fig.(3): Shear Stability of VMs (14).

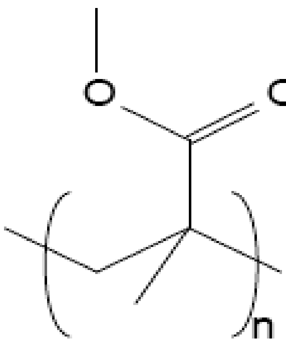

Fig.(4): Schematic Illustration of The Chemical Structure of PMMA (23).

Fig.(5): Portable Gasoline Generator 3kw.

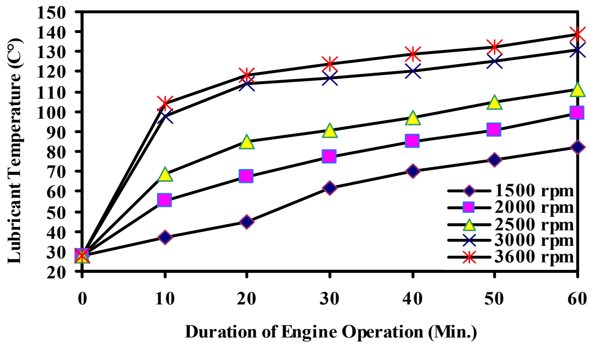

Fig.(6): Sample No. 1 (L1).

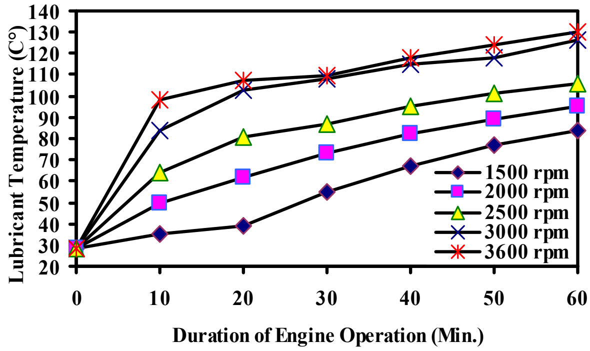

Fig.(7): Sample No. 2 (L2).

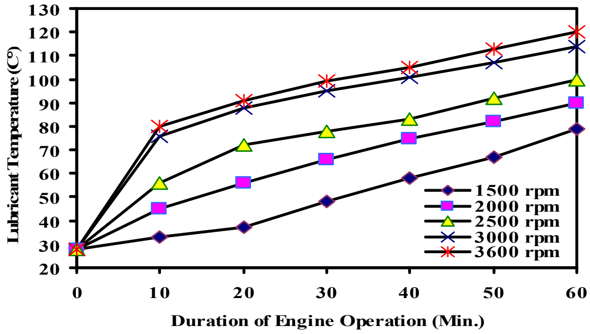

Fig.(8): Sample No. 3 (L3).

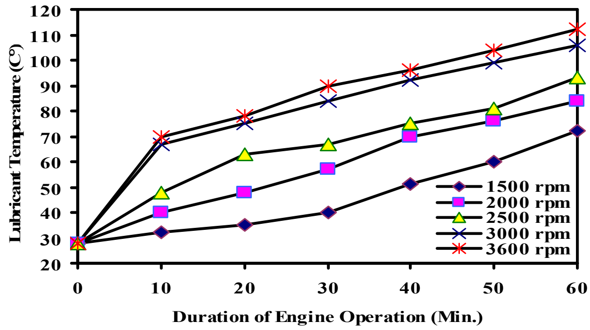

Fig.(9): Sample No. 4 (L4).

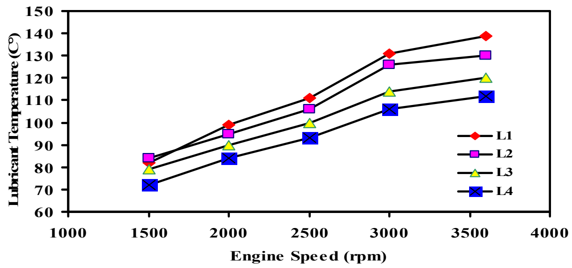

Fig.(10): The Variation of Temperature with Various Engine Speeds to Determine The Excellent and Optimum Lubricant in Summer Season (L4).

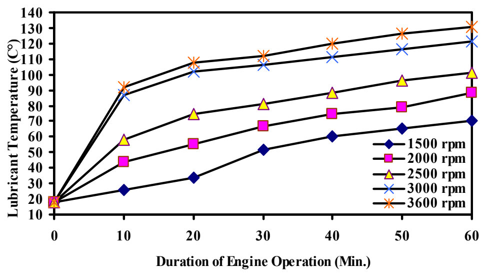

Fig.(11): Sample No. 1 (L1).

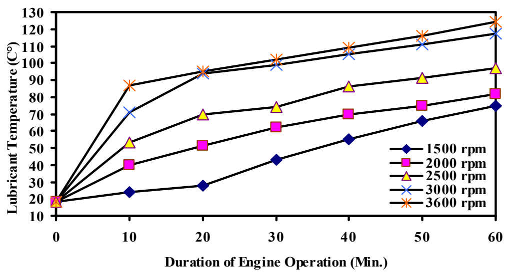

Fig.(12): Sample No. 2 (L2).

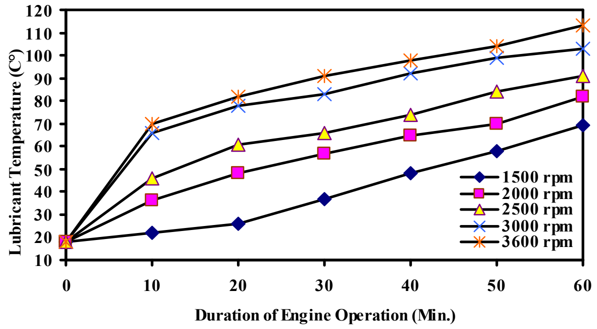

Fig.(13): Sample No. 3 (L3).

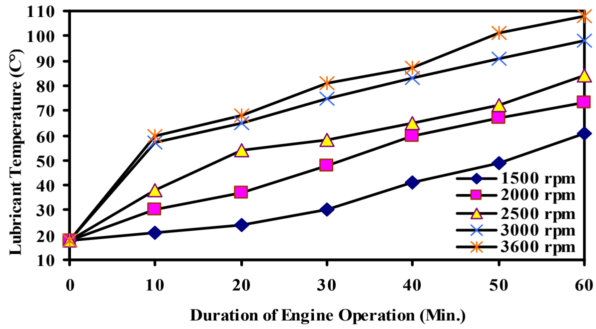

Fig.(14): Sample No. 4 (L4).

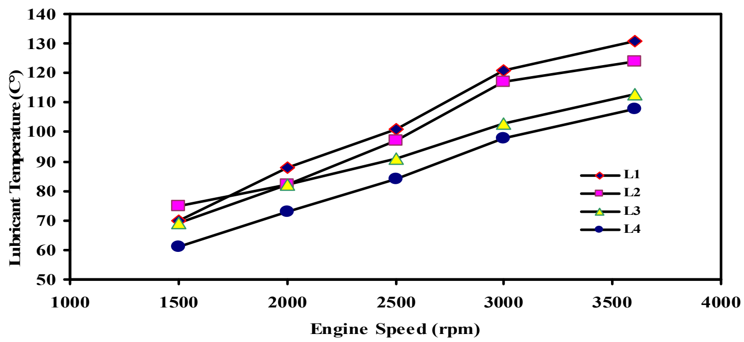

Fig.(15): The Variation of Temperature with Various Engine Speeds to Determine The Excellent and Optimum Lubricant in Winter Season (L4).

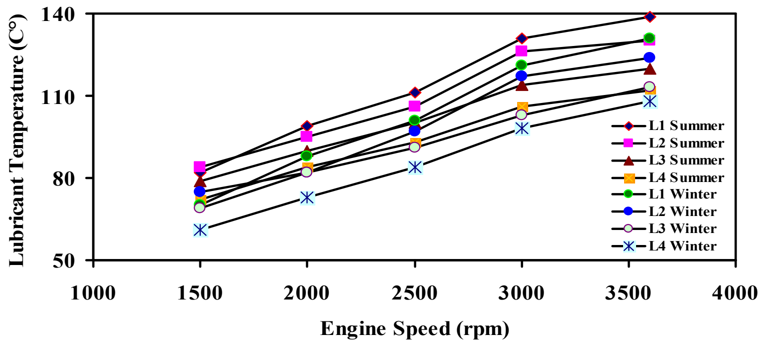

Fig.(16): Lubricant Temperature (°C) Vs. Engine Speed (rpm) for All Samples, Optimums behaviour.

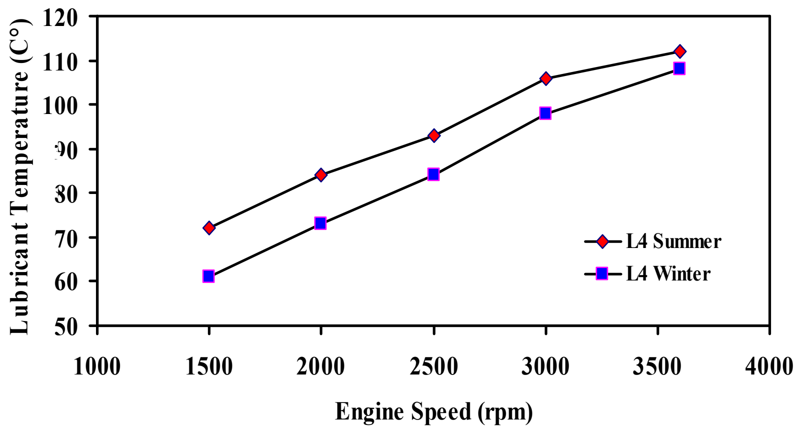

Fig.(17): Lubricant Temperature (°C) Vs. Engine Speed (rpm) for Optimum L4, in Summer and Winter.

تأثير درجة الحرارة على زيت التزييت وعلى مضاف البولي (ميثايل ميثاكريليت)

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الخلاصة

يتناول هذا البحث تقييم مضاف البولي (ميثايل ميثاكريليت) أو PMMA المستخدم في زيوت التزييت العراقية لتحسين خواص زيوت محرك البنزين، وبالدرجة الأولى تحسن اللزوجة ومؤشر اللزوجة، والتي هي مؤشرات لتقييم هذا النوع من المواد المضافة وتحت تأثير درجة حرارة المحرك.

وكانت الزيوت المستخدمة في هذا البحث، بعد إضافة الـ PMMA يدوياً، قد حضرت بواسطة مزج الزيوت الاساس العراقية بدرجات H١٥٠ و H٦٠ (كميات متساوية من كل نوع) وبنسب مئوية ١٠٠٪، ٩٠٪، ٨٠٪، و ٧٥٪، على التوالي. ان هذه الامزجة من زيوت التزييت – والمضافات المحضرة قد تم تشغيلها لمدة ٤ ساعات في محرك من نوع "مبرد بالهواء، ٤ اشواط، ذو اسطوانة واحدة، محرك بنزين ٣ ك. واط". وتمأجر اء فحوصات قياس درجة حرارة الزيت أثناء تشغيل المحرك، واللزوجة، ومؤشر اللزوجة، ووزن الحطام (لم يتم تحليل عناصرها)، اكا نموذج من الزيوت المحضرة.

وأكدت النتائج أن زيت التزييت الأكثر ملائمة لمحرك البنزين، سواء في الصيف أو الشتاء، كان الخليط المتكون من ٢٥% من مضاف الـ PMMA مع ٧٥٪ من زيوت الاساس الممزوجة، مع نسبة اختلاف لا تتجاوز أكثر من ٦٪ بين هذين الموسمين،و أنه كان ذو زيادة قليلة من اللزوجة ومؤشر لزوجةأقل انخفاضاً ، مع وجود كمية قليلة من الحطام (نسبة وزنية). ان هذا الحطام يمكن أن يشير إلى حدوث أضرار لمكونات المحرك، لتشغيل المحرك لوقت طويل. أخيراً ، فإن الفوائد التي ظهرت بان مضاف الـ PMMA كان ذو تأثر منخفض مع زيادة درجة حرارة المحرك، وفقاً لخصائصه المحددة.