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Evaluation and Optimization of Poly-aromatic Cationic Surfactant as Additive for Mineral base Oil

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Abstract— *In this research, evaluation and optimization of poly- aromatic cationic surfactant as modifier for base mineral oil. Different weight percent from this modifier was added to base mineral oil and assessed. Physicochemical properties mineral base oil and blended oil were carried out. The rheological behaviors of base mineral oil with and without modifier were investigated at different temperatures using Programmable Rheometer LADV-III Ultra-System. Yield stress and dynamic viscosity for these blended oils were determined. Optimization and modeling of the obtained data concerning dynamic viscosity was studied which the predicting of these data with different temperatures. It was found that the rheological behavior of these oils show Newtonian flow. The results revealed that the rheological behavior and pour point of base oil with and without poly-aromatic cationic surfactant depend on a large extant on the contents of the components in the base oil. It was concluded that the poly-aromatic cationic surfactant can be used as rheological and pour point modifier to such base mineral oil. The predicted of viscosity mineral base oil blank or with additive poly-aromatic cationic surfactant at temperature 130, 160 and 190^{o}C using Trend line modelingwhich as blended base oil samples show the poly- aromatic cationic surfactant is suitable as rheological modifier.*

Keywords—Mineral base Oil, viscosity, Poly-aromatic, and LADV-III.

I. INTRODUCTION

A lubricant is a substance that is used between two surfaces of moving materials to reduce the friction generated between them. There are many types of lubricants, including gases, liquids, solids, and grease. Among them, liquid lubricants are most often used. Liquid lubricants are mixtures that consist of about 90% base fluids and less than 10% chemical additives. The base fluids act as a lubricant primarily by separating the fluid layer from the moving surfaces and should easily remove any generated heat. The base oil, usually referred to as mineral oil, meets these requirements; thus, it is typically used as the base fluid(1, 2).

To improve the quality, lube oil always contains different types of additives are mixed to the lube oil to impart a new and desirable property which was not originally present in the oil. Sometimes additives amplify the property already present to some degree in the oil(1,2). The quantity and quality of the additives depend on the nature of the base oil and also on the purpose of their use. Types of additives are antioxidants, detergents and dispersants, corrosion inhibitors, viscosity index improvers (VIIs) and pour point depressants (PPDs), etc. of them VIIs and PPDs are the very important ingredients in modern lubricants.In addition, viscosity is a very important property of a lubricant(3,4).The viscosity of a liquid is a measure of its resistance to flow. High viscosity oil is less fluid than the one of low viscosity. At higher temperatures, the oil tends to thin out and flow more readily and vice versa(5). The change in viscosity with the variation of temperature is expressed by a parameter known as viscosity index (VI). Higher viscosity index of oil means the viscosity of the oil does not vary much with the variation of temperature. Viscosity modifiers (VMs) are added to the lubricating oil to improve the VI of the oil(2).

The rheological properties such as fluidity of the oil at low temperature, viscosity, and variation of viscosity with temperature govern the performance of lubricant base oils. To have effective performance at low as well as at high temperatures, an engine lubricant should be fluid at low temperature and should have minimum variations of its viscosity with temperature (2).

This has directed modern lubrication science toward the development of a new type of polymer additives with multifunctional activity and ability to improve their dispersant in addition to the control of viscosity properties(6.7,8).

Introducing the ability of dispersant into a polymer additive demands a carefully engineered incorporation of a strongly polar functional group to the main polymer backbone. The

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most commonly employed functional groups are amines, alcohols, or amides (8-10). Such formulated polymer additives will have the ability to keep insoluble combustion debris and oil oxidation products dispersed in the oil, which will prevent their deposition on the main part of the engine(11). This will have a direct effect on minimizing harmful engine exhaust emissions, increasing engine life, and controlling oil consumption by maintaining clean engine operation (12).

II. VISCOSITY AND MODELING EQUATIONS

The simplest of this rheology is the Newtonian viscous fluid. To under-stand the assumptions let us restrict attention to the determination of a viscous stress tensor at x, t, which depends only upon the fluid properties within a fluid parcel at that point and time. It is reasonable to assume that the forces dues to the rheology of the fluid are developed by the deformation of fluid parcels, and hence could be determined by the velocity field (12). The Newtonian viscous fluid is one where the stress tensor is linear in the components of the velocity derivative matrix, with a stress tensor whose specific form will depend on other physical conditions (13).

Dynamic viscosity or absolute viscosityis a measure of a fluid's resistance to deformation under shear stress. For example, crude oil has a higher resistance to shear than water. Crude oil will pour more slowlythan water from an identical beaker held at the same angle. This relative slowness of the oil implies a low "speed" or rate of strain(5,13).

The symbol used to represent viscosity is (μ).To understand the physics of viscosity, it is useful to refer back to solid mechanics and the concepts of shear stress and shear strain. Shear stress, $\tau$is the ratio of force/area on a surface when the force is aligned parallel to the area. However, the shear stress on a fluid element is proportional to the rate (speed) of strain, and the constant of proportionality is the viscosity (5, 13):

{Shear stress} = {Viscosity} × {Rate of Strain}

The rate of strain is related to the velocity gradient by(ϕ= *dV/ dy*), so the shear stress (shear force per unit area) is

$$\tau = \mu \frac{dV}{dy} \qquad Eq.\ 1$$

Where *V* is the fluid velocity and *y* is the distance measured from the wall. The velocity distribution shown is characteristic of flow next to a stationary solid boundary, the shear stress decreases with distance from the boundary. From Eq. (1) it can be seen that the viscosity μ is related to the shear stress and velocity gradient.

$$\mu = \frac{\tau}{dV/dy} = \frac{N/m^2}{(m/s)/m} = N.s/m^2\ Eq.2$$

A common unit of viscosity is the *poise,* which is 1 dyne-s cm^2 or $0.1 N\cdot s/m^2$. The viscosity of water at 20°C is one centipoise (10^{-2} poise) or $10^{-3} N\cdot s/m^2$. The unit of viscosity in the traditional system islbf· s/ft^2.

III. EXPERIMENTAL WORK

First of all, Poly-aromatic cationic surfactant was prepared and structure confirmed on the basis of the presented method by to Omar et al. (1-2). The purity of this compound is about 94.85% with molecular weight 4500 gm/mol. This compound was evaluated as rheological modifier using base mineral oil and its effect of concentration was investigated by using 1.0 wt. %, 2.0wt. % and 3.0 wt. %.Second one; Mineral base oil was kindly supplied by Co-operative petrol. The characteristics of this base oil were carried out according to ASTM methods. Then, the evaluation of the poly-aromatic surfactant was as the rheological modifier for mineral base oil. The profile dynamic viscosity - shear rate of base oil contains the tested polymer was investigated at temperature 40, 70 and 100°C. Different concentrations 1.0, 2.0 and 3.0wt.% was used to explore the effect of concentration on rheological modification of mineral base oil.

Rheological measurements test was performed on a Brookfield programmable Rheometer HV DV-III UITRA used in conjunction with Brookfield software, RHEOCALC V.2, through RHEOCALC all Rheometer function (rotational speed, instrument % torque scale time interval, set temperature) are controlled by a computer. The corresponding shear stress, shear rate, dynamic viscosity, mathematical model and confidence of fit consistence index were also recorded by the software. Then, series of experimental was performed to determine the effect of prepared additives on the rheological properties of the mineral base oil at temperatures 40, 70 and 100 ºC.Finally, Prediction of viscosity values were obtained from applying of the trend lines or regression with different modeling till its choosing of the suitable model to excellent predict to viscosity at different temperature.

IV. RESULT AND DISCUSSION

The physicochemical characteristics and structural group analysis of the base mineral oil with and without poly-aromatic cationic surfactant were presented in **Table 1**. The base mineral oil without additive in this Table is characterized high pour point (+3) and high paraffinic carbon percentage (47% of CP**).** So that the base oil under investigation could be classified as paraffinic oil.

Data inthis **Table** show that the prepared modifier has significant effect on pour point and yield values of blended oil with modifier compared with the mineral oil without modifier; this indicate that the efficiency increases with increasing the concentration of prepared modifier. This may be due to the effect of the salvation power of the modifier on the paraffinic compounds, in particular wax content, of base mineral oil. Also, this modifier obstructs the lateral crystal growth at lower temperature. Accordingly, the poly-aromatic cationic surfactant can use as pour point depressant for base mineral.

In this respect, significant increases of the kinematic viscosity at 40 and 100°C of blend base oil with increasing of poly-aromatic cationic surfactant were observed. This may be because of the fact that, at a higher temperature, while the lube oil viscosity gets decreased, the polymer molecules change from tight coil to expanded ones as a result of increase in the interaction between the additive molecule and the solvent molecule. This increase in volume causes an increase in the viscosity of the blend and offsets the normal reduction in viscosity of the oil with increasing temperature. The increase of concentration of the additive, from 1.0 to 3.0 wt. %, may be leads to an increase in total volume of surfactant micelles in the oil solutions. Consequently, a high concentration of additive will impart a high viscosity index rather than a low concentration of the additive

Rheology is the study of those properties of materials that govern the relationship between shear rate and shear stress. In general, the rheological program calculated and output the yield value using power low mathematical model. **Table 1** show calculated yield values data of base mineral oil with and without modifier. From this table in general, the yield value of base oil alone is higher compared with base oil contains additive. In this respect, the yield value decreases with increasing the concentration of the poly-aromatic cationic surfactant. This indicates that the additive compound is efficient as flow improver and rheological improver by decreasing yield value or yield stress. This view is in agreement with the dynamic viscosity data for base oil with and without additive. It may be explained that the poly-aromatic cationic surfactant tends to solvation power and reduces the attractive forces between the base mineral oil molecules. Accordingly, base mineral oil with additive is close to Newtonian behavior compared with base oil alone and is weekly dependent on temperature.

Dynamic viscosity-shear rate profiles for base oil with and without additives at temperatures 40°C, 70°C and 100°C are presented in **Figures 1, 2 and 3**, respectively. These figures indicate that the flow behavior of base oil with and without additive obey Newtonian flow. Also, it is found that the dynamic viscosity of oil and oil blends with additive approaches low viscosity as the temperature increase. The increase of temperature, from 40°C to 100°C, tends to increase the molecular motion leads to reduce the attractive forces between molecules.

The correlation between yield stress in the **Table 1** and dynamic viscosity- shear rate profiles in **Figures 1, 2 and 3**, indicates highly Newtonian behavior with increasing weight percent of poly-aromatic cationic surfactant to base oil. Also, the viscosity variation with shear rate decreased with increasing temperature and the base oil with additive approach a more Newtonian behavior at high temperature 100°C and high concentration 3.0 wt. % of additive. The obtained results showed that the flow behavior of base oil with additive increased with increasing the additive concentration. This reveals the important role of the additive to enhance the flow properties of the base oil.

Table.1: Physicochemical properties of mineral base oil with and without additives.

Properties	**Base oil**	**Base oil + 1.0 wt. % additives***	**Base oil + 2.0 wt. % additives***	**Base oil + 3.0 wt. % additives***	**Test method**
Density @ 15°C	0.8911	0.8915	0.8917	0.8917	ASTM D-4052
Kinematic Viscosity					
@ 40°C	53.8	59.5	65.1	75.4	ASTM D-445
@100°C	9.10	10.6	12.0	13.9	ASTM D-445
Flash point,°C					
Close	193	193	193.5	193.5	ASTM D-93
Open	215	215	215	215	ASTM D-93
Pour point,°C	+3	-3	-10	- 16	ASDM d-97

Cont'sTable.1: *Physicochemical properties of mineral base oil with and without additives.*

Properties	Base oil	Base oil + 1.0 wt. % additives*	Base oil + 2.0 wt. % additives*	Base oil + 3.0 wt. % additives*	Test method
Carbon residue, wt%	0.4	0.4	0.4	0.4	ASTM D-189
Structural group analysis					
Paraffin **% C_p**	47	---	---	---	n-d-M method
Aromatic**%C_A**	22	---	---	---	
Naphthenic**%C_N**	31	---	---	---	
Dynamic viscosity measured, by Rheometer HV DV-III UITRA					
@40°C	418.84	440.69	459.45	461.74	with RHEOCALC V.2 program.
@70°C	104.2	108.93	112.58	113.45	
@100°C	39.08	40.12	42.83	44.12	
Yield value, D/cm^2					
@ 40°C	10.5	7.5	3.2	2.1	
@ 70°C	6.2	3.1	2.3	1.0	
@100°C	4.4	2.1	0.0	0.0	

* Additives are weight percent of poly-aromatic cationic surfactant to base oil.

V. PREDICTION MATHEMATICAL MODELLING

The studied main task for work experimental was to develop models for the prediction of theviscosity of mineral base oil at high temperature (HT) conditions; in particular the implementation of reliable and accurate models for predicting viscosities of HT fluids and select of the best modelling for obtained the correct viscosity results at any value from temperature. Additionally, experimental data needed to be acquired on a set of selected fluids being representative of mineral base oil. A final task for the work was the validation of the models developed in order to test the accuracy of the results in a wide range of industrial applications. The need for the work followed from the fact that in the oil as well as other industries, theviscosity is one of the weakest predicted parameters.

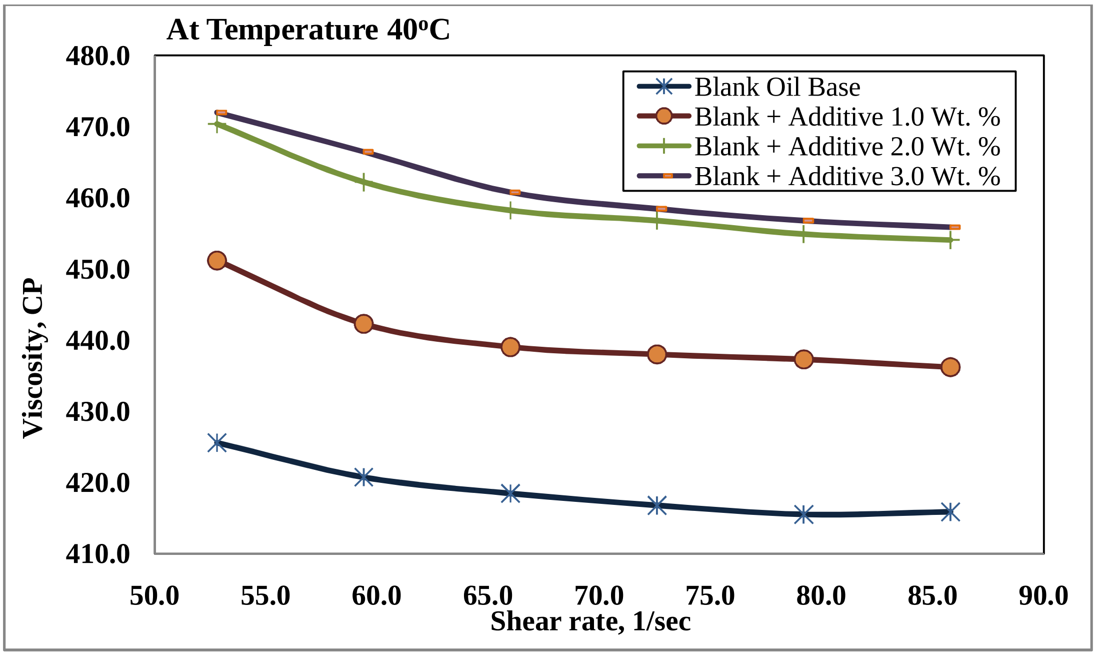

Fig. 1: Viscosity Measurement Versus Shear Rate at Temperature 40°Cfor Blank and Different Concentration of Additives for co-polymers on mineral base oil.

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Thus, this study has been carried out as one of the main contributions of the ***Trendline Options*** group or **Regression Types** (Best types such as Exponential, Polynomial and power modelling) to this study focusing on the friction result for viscositymodeling predict values. As it is widely illustrated in next section, the modeling results obtainedwith this novel approach have been validated far beyond the high temperature conditionsconsidered in this work.The effect of temperature on viscosity is different for liquids. Thus, an increase in temperature causes a decrease in viscosity for liquids. An equation for the variation of liquid viscosity with temperature is (2):

$$\mu = Ce^{b/T} \qquad \text{Equation 1}$$

For example for calculating viscosity of liquid as a function of temperature, we can select for two value of viscosity measurement at different temperature. The following value of viscosity at temperature 40 and 70^{o}C are shown below:

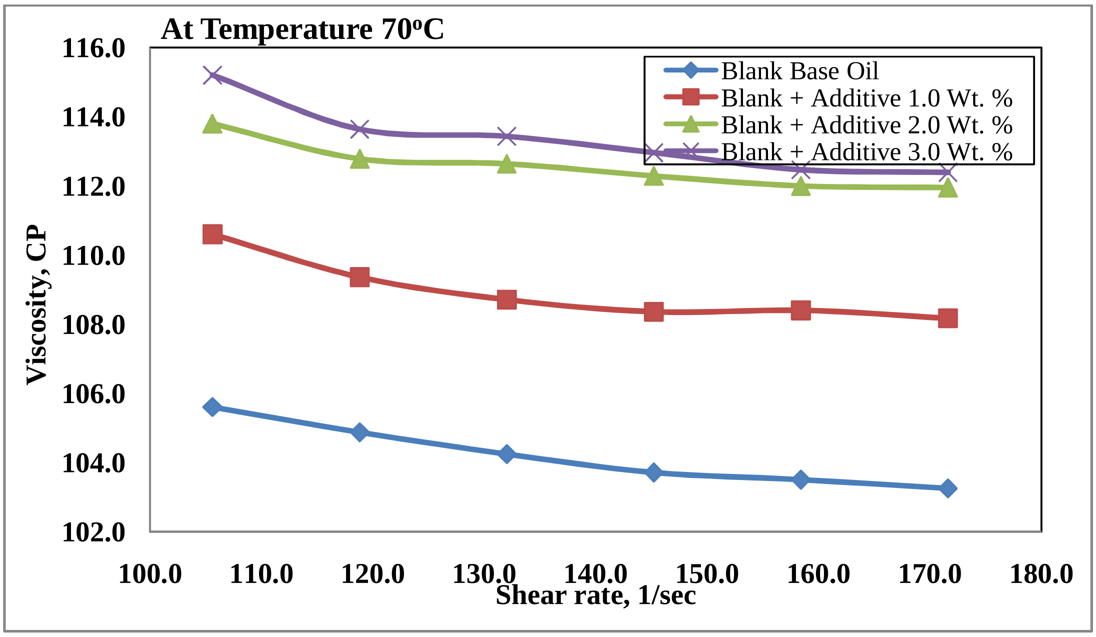

Fig.2: Viscosity Measurement Versus Shear Rate at Temperature 70^{o}Cfor Blank and Different Concentration of Additives for co-polymers mineral base oil.

For Example, mineral baseoil viscosity (Blank sample) at 40^{o}C is **418.84** CP and viscosity value at 70^{o}C is 104.20 CP. We could use the below equation for calculate the constant value with the following steps:

1. Logarithm of Equation above ,

   $\ln\mu = \ln C + b/T$ Equation 2

2. Interpolation for two Equations of two value viscosity at 40 and 70^{o}C,

   ln 424.18 = ln C + b/40

   6.050158 = ln C + 0.0250000 b

   ln 104.66 = ln C + b/70 4.640717 = ln C + 0.0142857 b

3. Solution for ln C and b

   ln C= ?????

   b= ?????

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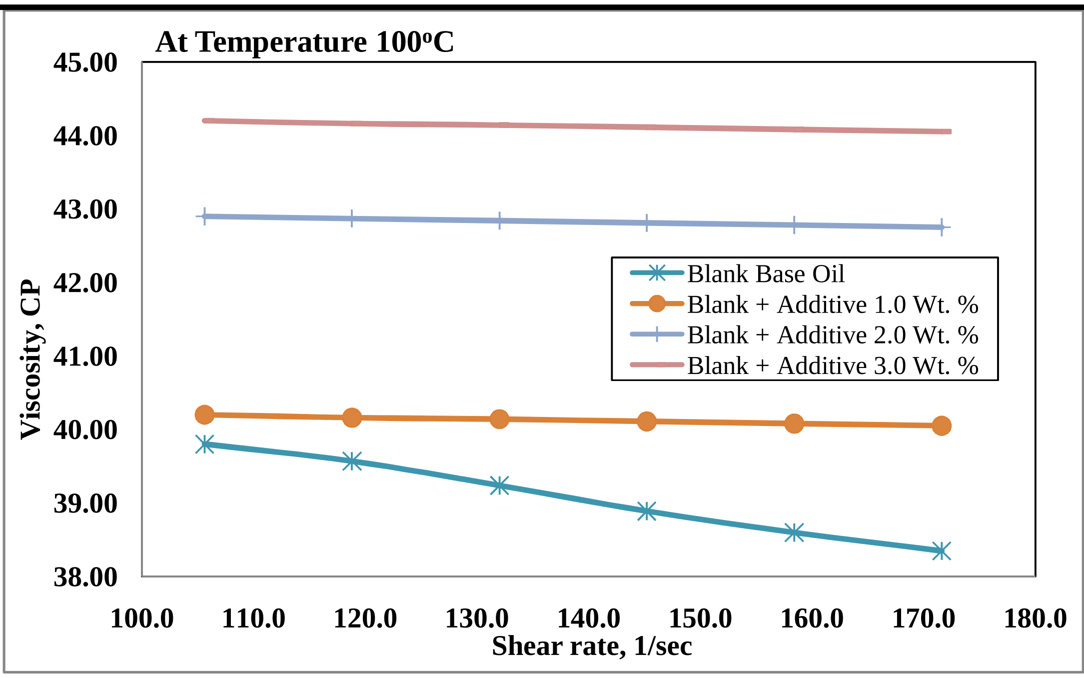

Fig.3: Viscosity Measurement Versus Shear Rate at Temperature 100°Cfor Blank and Different Concentration of Additives for co-polymers mineral base oil.

VI. ANALYSIS OF PREDICTION MATHEMATICS MODELLING

As a result, up to four different viscosity estimations, for each one of the reference sets of viscosities are derived for each measured temperature. The previous**Table 1 s**hows that the dynamic viscosity measurement of Mineral base oil blank and with different additives 1.0, 2.0, and 3.0% by weight concentration ofPoly-aromatic Cationic Surfactant at different temperature 40, 70 and 100°C. **Fig. 4** shows that measurement of dynamic viscosity for Mineral baseOil and different additives concentration on it versus different temperature. In addition to **Fig. 5** shows that measurement of dynamic viscosity for mineral baseOil versus different additives concentration of Poly-aromatic Cationic Surfactant at different temperature.

In order to predict the dynamic viscosities for Poly-Aromatic Cationic Surfactant mixtures, we havebeen used different mathematics models that only involve the viscosity data of the pure compounds of themixture. For pure poly-aromatic Cationic Surfactant mixtures, the experimental measurement for dynamic viscosity values between 40°C and 100°C has been taken from a Brookfield Viscometer. **Table 2** represents the Predict of viscosity value at different temperature from 40°C to 200°C formineral base Oil without additive (Blank sample),

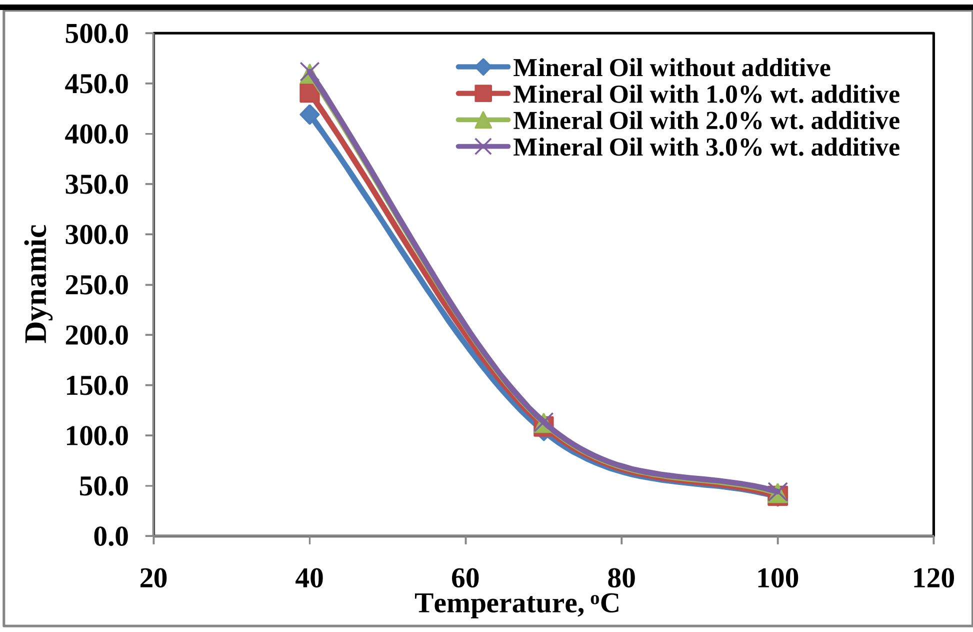

Fig.4: Measurement of dynamic viscosity for mineral base oil blank and different additives concentration of poly-aromatic cationic surfactant on it versus different temperatures.

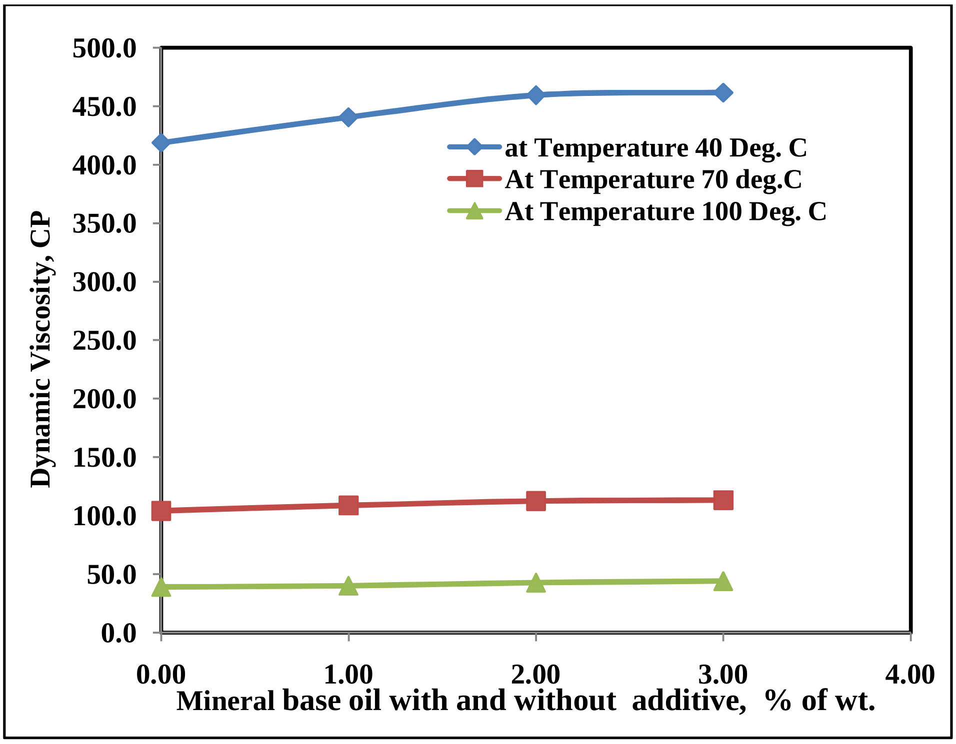

Fig. 5: Measurement of dynamic viscosity for Mineral Base Oil versus different additives concentration of poly-aromatic cationic surfactant at different temperature.

Table.2: Predict of viscosity value at different temperature from 40 to 170°C For Mineral base Oil without additive calculated with using Exponential Trendline option.

An Equation for the variation of liquid viscosity with temperature : $\mu = C\,e^{b/T}$						
Temperature T,	Average Viscosity measured μ,	Empirical Constant **b**	Empirical Constant **C**	**b/T**	**Predict Viscosity, μ,**	**% Error**
°C	**cp**	value	value	value	**cp**	
40	**418.84**	158.125211	8.0394943	3.953130	**418.840**	**0.00**
50	**???**			3.162504	**189.969**	
60	**???**			2.635420	**112.143**	
70	**104.20**			2.258932	**76.960**	**-0.27**
80	**???**			1.976565	**58.028**	
90	**???**			1.756947	**46.586**	
100	**39.08**			1.581252	**39.080**	**0.00**
110	**???**			1.437502	**33.847**	
120	**???**			1.317710	**30.026**	
130	**???**			1.216348	**27.132**	
140	**???**			1.129466	**24.874**	
150	**???**			1.054168	**23.070**	
160	**???**			0.988283	**21.599**	
170	**???**			0.930148	**20.379**	

In addition **Tables 3, 4 and 5** illustrated that Predict of viscosity value at different temperature from 40°C to 170°C for Mineral base Oil with D-1.0; D-2.0 and D-3.0% wt. additive of poly-aromatic Cationic Surfactant.

Table.3: Predict of viscosity value at different temperature from 40°C to 170°C For mineral base Oil with D-1.0% wt. additive of poly-aromatic Cationic Surfactantcalculated with using Exponential Trendline option.

An Equation for the variation of liquid viscosity with temperature : $\mu = C\,e^{b/T}$						
Temperature T,	Average Viscosity measured μ,	Empirical Constant	Empirical Constant	**b/T**	**Predict Viscosity, μ,**	**% Error**
°C	**cp**	value	value	value	**cp**	
40	**440.69**	**159.764448**	**8.1191907**	3.994111	**440.690**	0.00
50	**???**			3.195289	**198.248**	
60	**???**			2.662741	**116.393**	
70	**108.93**			2.282349	**79.565**	-0.29
80	**???**			1.997056	**59.817**	
90	**???**			1.775161	**47.913**	
100	**40.12**			1.597644	**40.120**	0.00
110	**???**			1.452404	**34.696**	
120	**???**			1.33137	**30.741**	
130	**???**			1.228957	**27.749**	
140	**???**			1.141175	**25.417**	
150	**???**			1.065096	**23.555**	
160	**???**			0.998528	**22.038**	
170	**???**			0.939791	**20.781**	

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Table.4: Predict of viscosity value at different temperature from 40°C to 170°C for mineral base Oil with D-2.0% wt. additive of poly-aromatic Cationic Surfactant calculated with using Exponential Trendline option.

An Equation for the variation of liquid viscosity with temperature : $\mu = C\ e^{b/T}$						
Temperature T,	Average Viscosity measured μ,	Empirical Constant	Empirical Constant	**b/T**	**Predict Viscosity, μ,**	**% Error**
°C	**cp**	value	value	value	**cp**	
40	**459.45**	**158.186059**	**8.80555121**	3.954652	**459.450**	0.00
50	**???**			3.163722	**208.325**	
60	**???**			2.636435	**122.954**	
70	**112.58**			2.259801	**84.367**	-0.28
80	**???**			1.977326	**63.606**	
90	**???**			1.757623	**51.060**	
100	**42.83**			1.581861	**42.830**	0.00
110	**???**			1.438055	**37.093**	
120	**???**			1.318217	**32.904**	
130	**???**			1.216816	**29.731**	
140	**???**			1.129901	**27.256**	
150	**???**			1.054574	**25.278**	
160	**???**			0.988663	**23.666**	
170	**???**			0.930506	**22.329**	

Table.5: Predict of viscosity value at different temperature from 40°C to 170°C For Gear Oil with D-3.0% by wt. additive of poly-aromatic Cationic Surfactant calculated with using exponential Trendline option.

An Equation for the variation of liquid viscosity with temperature : $\mu = C\ e^{b/T}$						
Temperature T,	Average Viscosity measured μ,	Empirical Constant	Empirical Constant	**b/T**	**Predict Viscosity, μ,**	**% Error**
°C	**cp**	value	value	value	**cp**	
40	**461.74**	**156.539251**	**9.2213429**	3.913481	**461.740**	0.00
50	**???**			3.130785	**211.095**	
60	**???**			2.608988	**125.275**	
70	**113.35**			2.236275	**86.297**	-0.24
80	**???**			1.956741	**65.252**	
90	**???**			1.739325	**52.502**	
100	**44.12**			1.565393	**44.120**	0.00
110	**???**			1.423084	**38.268**	
120	**???**			1.304494	**33.988**	
130	**???**			1.204148	**30.743**	
140	**???**			1.118138	**28.210**	
150	**???**			1.043595	**26.183**	
160	**???**			0.97837	**24.530**	
170	**???**			0.920819	**23.158**	

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Also, a comprehensive dynamic viscosity study has been carried out for three ternary mixtures composed of poly-aromatic cationic surfactant concentration at different temperatures range from 40^{o}C to 170^{o}C with applied of three types of regression exponential, polynomial and power Trendline options using excel program. From these results during applied of their types, it should be typical result representations by used the power regression.

Table 6 shows that Trendline options of Exponential, Polynomial and Power in case of mineral base oil (Blank Sample), and at different concentration additives of Poly-aromatic Cationic Surfactant.**Fig. 6** illustrated that Relation between dynamic viscosity values measured and Predicted at different temperature for gear oil (blank sample) and with additives of Poly-aromatic Cationic Surfactant concentration by using the power regression type (Typical Values).

The experimental viscosity data obtain in this study have been used in order to evaluate the performance of three types from Trendline option (regression types) such as exponential, polynomial and power regression types mathematic modelling from applied with used of Excel software, applicable to gear oil blank and different additives concentrations of poly-aromatic Cationic Surfactant. The evaluation of these mathematic models shows the typical or best results for this modelling are obtained the power regression type for totally typical predictive of dynamic viscosity at certain temperature as we need to know.

Table.6: Trendline options of Exponential, Polynomial and Power in case of mineral base Oil (Blank Sample), and at different concentration additives of Poly-aromatic Cationic Surfactant.

Mineral base oil (Blank Sample)			
Trendline Options	**Exponential**	**Polynomial**	**Power**
Fitting Equation	**$Y=1901.4\ e^{-0.040X}$**	**$Y= 0.1386\ X^2 – 25.736\ X + 1226.5$**	**$Y=6\ E+06\ X^{-2.579}$**
Error	**$R^2= 0.9901$**	**$R^2 =1.0000$**	**$R^2=0.9992$**
D-1.0% by wt. of Poly-aromatic Cationic Surfactant			
Trendline Options	**Exponential**	**Polynomial**	**Power**
Fitting Equation	**$Y=2037.6\ e^{-0.040\ X}$**	**$Y=0.1461\ X^2 – 27.128\ X + 1292.1$**	**$Y=7\ E+06\ X^{-2.605}$**
Error	**$R^2= 0.9909$**	**$R^2= 1.0000$**	**$R^2=0.9990$**
D-2.0% by wt. of Poly-aromatic Cationic Surfactant			
Trendline Options	**Exponential**	**Polynomial**	**Power**
Fitting Equation	**$Y=2076.8\ e^{-0.040\ X}$**	**$Y=0.1540\ X^2 – 28.497\ X + 1353$**	**$Y=6\ E+06\ X^{-2.583}$**
Error	**$R^2=0.9887$**	**$R^2= 1.0000$**	**$R^2=0.9996$**
D-3.0% by wt. of Poly-aromatic Cationic Surfactant			
Trendline Options	**Exponential**	**Polynomial**	**Power**
Fitting Equation	**$Y=2045.9\ e^{-0.039X}$**	**$Y=0.1551\ X^2 – 28.673\ X + 1360.5$**	**$Y=6\ E+06\ X^{-2.558}$**
Error	**$R^2= 0.9873$**	**$R^2= 1.0000$**	**$R^2=0.9998$**

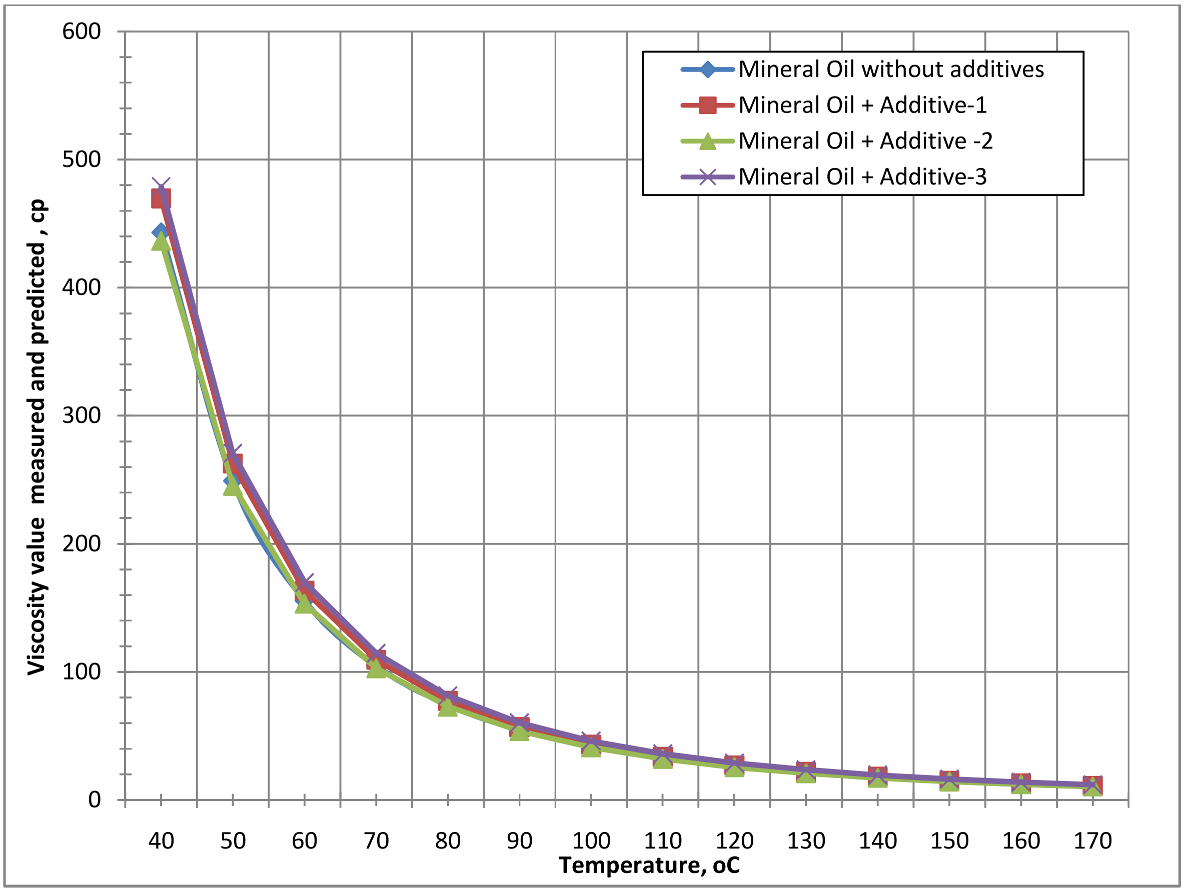

Fig. 6: Relation between dynamic viscosity value measured and Predicted at diferent temperatures for mineral base oil (blank sample) and with additives of Poly-aromatic Cationic Surfactant concentation by using the power regression type (Typical Values).

VII. CONCLUSION

The evaluation of this optimization shows that the best results for different this ternary system are obtained with the Trendline Options group. In spite of their mathematical simplicity, these viscosity approaches have a physical and theoretical background and related to characteristic parameters and properties of pure compounds, making these Prediction formals totally typical predictive for different mixtures.

In spite the studied Trendline Options(regression types) is only simple representationof some petroleum distillation cuts, the obtained results further show the capabilities ofthese viscosity approaches to real petroleum fluids and close to the experimental uncertainty (±2%) for the studied Trendline Options system.

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Appendix A:

We have some tables for prediction of viscosity value at different temperatures for mineral base oil (Blank Sample), and variation of concentrations of poly-aromatic cationic surfactant of 1.0%, 2.0% and 3.0% by wt. with used three methods from trend-line options for regression typeseither polynomial, power or exponential modelling calculations for the viscosity predict at any certain temperature but the typical predicted dynamic viscosity has been obtained from applied of power regression type in case of this study. Table A-1 shows that Predicted viscosity for Gear Oil (Blank sample) and with additives 1.0, 2.0 and 3.0% by wt. of Poly-aromatic Cationic Surfactant by using the typical results from applied Trendline option of **Power** Regression and general R- squared values.

Table.A-1: Predicted viscosity for mineral baseoil (Blank sample) and with additives 1.0, 2.0 and 3.0% by wt. of Poly-aromatic Cationic Surfactant by using the best result from applied Trendline option of Power Regression and general R- squared values.

Set -3a	**Mineral baseoil (Blank Sample) at 40 to 150°C.**											
Trend-line Power	**$Y= 6E+06\ X^{-2.579}$**				**for Predict of viscosity**							
$\mu_p = C\ T^b$		**C =**	**6E+06**			**b=**	**-2.579**		**General R^2=**		**0.9992**	
Temperature, °C	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**
Average Viscosity, μ, cp	**418.84**	**???**	**???**	**104.20**	**???**	**???**	**39.08**	**???**	**???**	**???**	**???**	**???**
Predicted Viscosity, μ_p, cp	**443.04**	**249.18**	**155.70**	**104.63**	74.15	54.72	41.70	32.61	26.06	21.20	17.51	14.66
Error, %	0.06			0.00			0.07					

Set -3b	**Mineral base oil with D-1.0% by wt. additive of Poly-aromatic Cationic Surfactant at 40 to 150°C.**											
Trend-line Power	**Y= 7E+06 X$^{-2.605}$**				**for Predict of viscosity**							
μ_p=C T^b		**C =**	**7E+06**			**b=**	**-2.605**			**General R^2=**	**0.9990**	
Temperature, °C	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**
Average Viscosity, μ, cp	**440.69**	**???**	**???**	**108.93**	**???**	**???**	**40.12**	**???**	**???**	**???**	**???**	**???**
Predicted Viscosity,μ_p, cp	**469.60**	**262.59**	**163.31**	**109.30**	**77.19**	**56.79**	**43.16**	**33.67**	**26.84**	**21.79**	**17.97**	**15.01**
Error, %	-0.01			0.05			-0.01					

Set -3c	**Mineral base oil with D-2.0% by wt. additive of Poly-aromatic Cationic Surfactant at 40 to 150°C.**											
Trend-line Power	**Y= 6E+06 X$^{-2.583}$**				**for Predict of viscosity**							
μ_p=C T^b		**C =**	**6E+06**			**b=**	**-2.583**			**General R^2=**	**0.9996**	
Temperature, °C	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**
Average Viscosity, μ, cp	**459.45**	**???**	**???**	**112.58**	**???**	**???**	**42.83**	**???**	**???**	**???**	**???**	**???**
Predicted Viscosity,μ_p, cp	**436.55**	**245.31**	**153.17**	**102.86**	**72.86**	**53.75**	**40.94**	**32.01**	**25.56**	**20.79**	**17.17**	**14.37**
Error, %	0.05			0.09			0.04					

Set -3d	**Mineral base oil with D-3.0% by wt. additive of Poly-aromatic Cationic Surfactant at 40 to 150°C**											
Trend-line Power	**Y= 6E+06 X$^{-2.583}$**				**for Predict of viscosity**							
μ_p=C T^b		**C =**	**6E+06**			**b=**	**-2.558**			**General R^2=**	**0.9998**	
Temperature, °C	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**
Average Viscosity, μ, cp	**461.74**	**???**	**???**	**113.35**	**???**	**???**	**44.12**	**???**	**???**	**???**	**???**	**???**
Predicted Viscosity,μ_p, cp	**478.72**	**270.51**	**169.68**	**114.39**	**81.29**	**60.14**	**45.94**	**36.00**	**28.81**	**23.48**	**19.42**	**16.28**
Error, %	0.04			0.01			0.04					