# التنبؤ بنموذج جديد للزوجة الحركية لخليط من النفط الخام بمجمع مليته الصناعي في ليبيا

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**ملخص البحث :**

تعتبر اللزوجة خاصية ذات أهمية كبيرة لتقييم الخصائص الانتقالية في عمليات معالجة النفط الخام . ومعرفة المعلومات حول اللزوجة يلعب دورا مهماً جداً في حل المشاكل الهندسية المتعلقة بتدفق السوائل وانتقال الزخم. وفي الدراسة الحالية، تم خلط خمس عينات مختلفة من (خام الوفاء عالي اللزوجة و خام الفيل منخفض اللزوجة ) وكانت على النحو التالي : - خليط 1 ( 15% H , 85% L) ; خليط 2 , 75% L) ( 25% H ; خليط 3 ( 40% H , 60% L ) ; خليط 4 ( 55% H , 45% L ) ; خليط 5 ( 75% H , 25% L ). عند درجات حرارة مختلفة ( 30، 35، 40 درجة مئوية ) للحصول على اللزوجة التجريبية؛ ومن ثم تطوير صيغة رياضية يمكن الاعتماد عليها للتنبؤ بالخصائص الفيزيائية وذلك باستخدام طرق الانحدار غير الخطية، وتحليل نتائج النموذج المتحصل عليها باستخدام الطرق الإحصائية القياسية. وقد تم التحقق من صحة قيم اللزوجة الكينيماتيكية بمقارنتها مع البيانات التجريبية التي تم قياسها في المختبر . وعند المقارنة لوحظ تقارب في النتائج بين القيم المتوقعة والتجريبية حيث كان متوسط الانحراف المطلق الكلي (٪ AAD) حوالي 2.50٪. ومن النتائج المتحصل عليها في هذه الدراسة، فإنه يمكن الاستنتاج أن أداء النموذج المطور كان ممتازاً من خلال هذه الدراسة .

# New Model for Predicting Kinematic Viscosity of Crude Oil Blends at Mellita Industrial Compound in Libya

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**Abstract** - viscosity is considerable importance trait for evaluating transport properties in crude oils processing. Information about viscosity plays a very important role to a solve engineering problems concern fluid flow phenomena and momentum transfer. In the current study , Five different crude oils blends from a heavy crude oil (**H**) at **Al-wafa** oil field and a light crude oil **(L**) at **Al-feal** oil field were prepared as follows : Blend1 ( 15% H , 85% L ) ; Blend2 ( 25% H , 75% L ) ; Blend3 ( 40% H , 60% L ); Blend4 ( 55% H , 45% L ) and Blend5 ( 75% H , 25% L ) at different temperatures ( 30, 35, and 40 °C ) to obtain the experimental viscosity; to develop the reliable mathematical expression for the most important physical properties using non-linear regression and to analyze the predictive model results using standard statistical techniques. The predicted kinematic viscosity results have been validated with the experimental viscosity data gathered in the laboratory. Good results between the predicted and experimental values have been noticed with overall average absolute deviation (% AAD) of 2.50%. From the predicted results in this study , it can be concluded that the performance of the developed model was excellent in this study.

## 1. INTRODUCTION

### Viscosity of Crude Oils

Viscosity is the property of a fluid that causes it to resist flow. The importance of viscosity as an input in the design of equipment processing and handling petroleum crude oils and their fractions and in solving the associated fluid flow and momentum transfer problems needs no fresh emphasis. Viscosity is the most significant property for establishing the thickness , pressure and temperature of an oil film in lubrication , Viscosity is also significant factor in predicting the performance and fatigue life of rolling element bearings and gears . Viscosity is important in equations for calculating many properties such as velocity of oil film , shear stress , fluid friction forces [1]

The kinematic viscosity is useful property in petroleum production, refining, and transportation. It is used in reservoir simulators to estimate the rate of oil or gas flow and their production. It is needed in calculation of power required in mixers or to transfer a fluid , the amount of pressure drop in a pipe or column , flow measurement devices, and design and operation of oil/water separators. [2]

**Viscosity Model for Liquid Mixtures**

For the development, design, planning and operation of processes in the petroleum industry, an engineer has to deal with the so-called undefined mixtures such as petroleum fractions. The kinematic viscosities of these fractions are required in calculations involving mass transfer and fluid flow. Currently, there are increasing demands on the accuracy of viscosity prediction techniques for implementation in property prediction computer routines. Considering the complex nature of petroleum fractions and the difficulty of even identifying the components present in such mixtures, developing a viscosity estimation correlation accounting for all the composition details is difficult. In process calculations, it is much easier to express the viscosity as a function of temperature with a simple analytical expression that is easy to use in computer applications.

Numerous estimation methods have been developed to represent the effect of the temperature on the viscosity of different crude oil fractions at atmospheric pressure. Most of these methods are empirical in nature since no fundamental theory exists for the transport properties of liquids. [3]

**Mellita compound**

The company of mellta for oil and is one of the largest oil companies in Libya . It is daily production nearly ( 600,000 ) barrels ( crude oil , natural gas , condensate gas for propane , Butane and naphtha ) .

The company runs a number offshore and onshore oil fields located in different regions of Libya . The most important onshore field operated by . the company is AL-Wafa field and AL-Feal field ,who are heading to array crude oil to Mellitah oil compound . the crude oil AL-Wafa is highly viscous while the crude oil AL-Feal is low viscous , therefore their crude oil is mixed in the compound to obtain medium viscosity.

**Objectives of the Study**

The present study is concerned with the measuring and predicting of the kinematic viscosities of crude oils, where published data are relatively scarce. The objectives can be highlighted as follows:

- To obtain the experimental viscosity data of crude oils and their blends at different temperatures.
- To develop the reliable mathematical expression for the most important physical properties using non-linear regression technique.
- To analyze the predictive model results using standard statistical techniques.

**Benefits**

- Experimental correlations to determine the physical properties of crude oil blends would be positive in both cost and time.

- To determine the viscosity of crude oils using very accurate models

## 2. EXPERIMENTAL PROCEDURES

### Materials and preparation predation data samples

Two types of crude oils provided by Libyan oil companies were used . denoted as a heavy crude oil (**H**) at **Al-Wafa** oil field and a light crude oil **(L**) at **Al-Feal** oil field. From the base crude oils , five binary mixtures were prepared with different sample compositions : These are named as follows **:**

**Blend 1 (15% H , 85% L)**

**Blend 2 (25% H , 75% L)**

**Blend 3 (40% H , 60% L)**

**Blend 4 (55% H , 45% L)**

**Blend 5 (75% H , 25% L)**

Some Important physical properties of the base crude oils and their blend were measured , such as kinematic viscosities and densities. .

The experiments were carried at atmospheric presume and temperatures ranges ( 30,35,40 $^{o}$C ), the results will be presented in the next section .

The apparatus used in the experiments was Stabinger Viscometer (SVM 3000) as shown in figure (1) . kinematic viscosities of the samples (blends) were determined according to ASTM D-445. It can be noticed that all apparatus used in this work existed in Libyan Petroleum Institute and the experimental work was carried out in their labs.[4]

Figure (1) Stabinger Viscometer (SVM) 3000/G2.

## 3. EXPERIMENTAL RESULTS AND DEVELOPED MODEL

**kinematic viscosity Experimental**

The kinematic viscosities of pure and crude oils blends were measured at various temperatures (30, 35 and 40 $^{o}$C) as shown in Table (1).

Table (1) Experimental Kinematic Viscosity (cSt) of pure crude oils and **investigated Blends at various temperatures ($^{o}$C)**

| Type of Blend | Percent of blends | | Kinematic Viscosity(cSt) | | |
|---|---|---|---|---|---|
| | (H)% | (L)% | 30 °C | 35°C | 40 °C |
| Pure (H) | 100 | 0 | 22.6934 | 18.4612 | 14.9455 |
| Pure (L) | 0 | 100 | 2.1704 | 1.9413 | 1.7604 |
| Blend 1 | 15 | 85 | 3.0462 | 2.8241 | 2.6313 |
| Blend 2 | 25 | 75 | 3.8473 | 3.4798 | 3.1567 |

| | | | | | |
|---|---|---|---|---|---|
| **Blend 3** | **40** | **60** | **5.3454** | **4.8235** | **4.3265** |
| **Blend 4** | **55** | **45** | **7.6345** | **6.6245** | **5.8619** |
| **Blend 5** | **75** | **25** | **12.0112** | **10.2896** | **8.7598** |

**Predicted of kinematic viscosity by new developed model**

The crude oil is highly refined oil that consists of paraffinic and naphthenic hydrocarbons. In the more conventional oil reservoirs, It have complex mixture whose physical and chemical properties vary considerably with their composition. The present model has been extended by comparing the predicted values of the kinematic viscosity for some crude oils considered with the experimental data obtained in the laboratory at different temperature.[5]

In this work, nonlinear regression technique is used to determine the developed model parameters (**a** and **b**) for some oil blends considered. The general form of the kinematic viscosity model in terms of composition (x) and temperature (T) can be expressed as:

$$\mathbf{v = a\, e^{bx}} \qquad (1)$$

Where (**v**) is the kinematic viscosity in (cSt) , the parameters **a** and **b** are the coefficients which will be determined by the regression technique. it may be noted that (**a**) is only a function of temperature (T) and can be expressed as :

$$\mathbf{a = a'' \, T^{b''}} \qquad (2)$$

where **a"** and **" b** are constant which will be determined

From Table (1) can be drawn in terms of a graph Figure. (1) showing relationship between kinematic viscosity at different temperatures and percentage of blends by using the Excel software and Nonlinear Regression Technique.

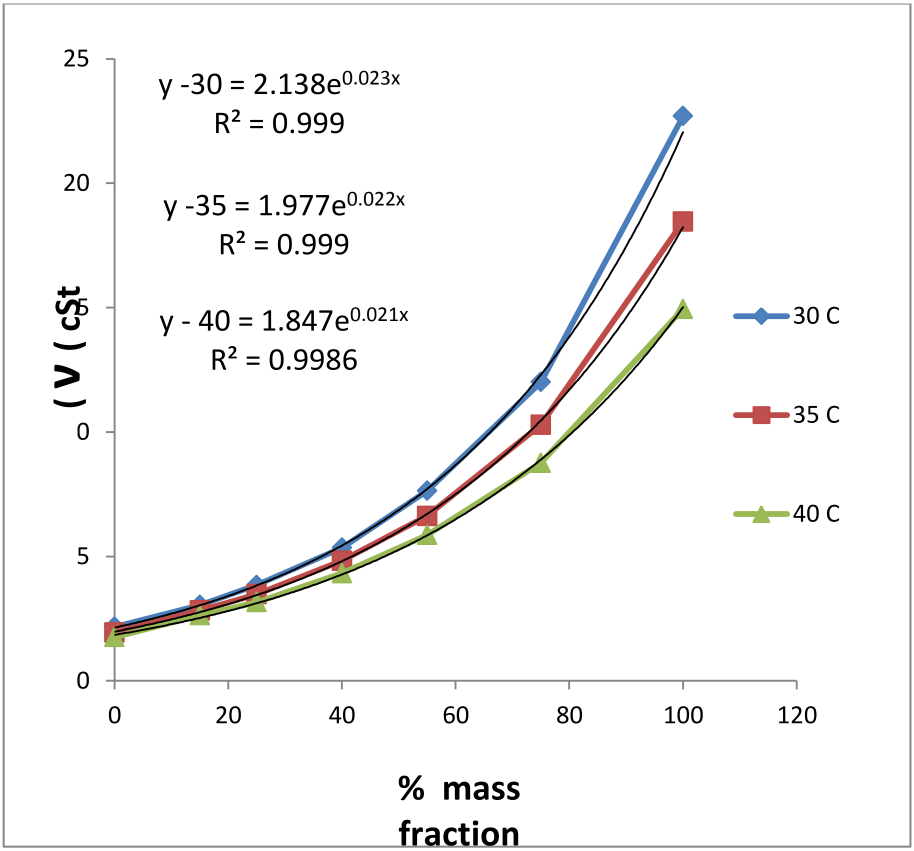


Figure (2) kinematic viscosity at different temperatures vs percentage of blends.

Figure (2) shows the best three curves (nonlinear) at different temperatures according to Equation (1). The parameters of (a and b) determined and presented in Table (2).

Table (2 ): ( a and b) parameters at different temperatures

| T | a | b |
|---|---|---|
| 30 | 2.138 | 0.023 |
| 35 | 1.977 | 0.022 |
| 40 | 1.847 | 0.021 |

From the Table (2 ) It can draw the relationship between the (a) parameter and (T) temperature as shown in Figure (3).

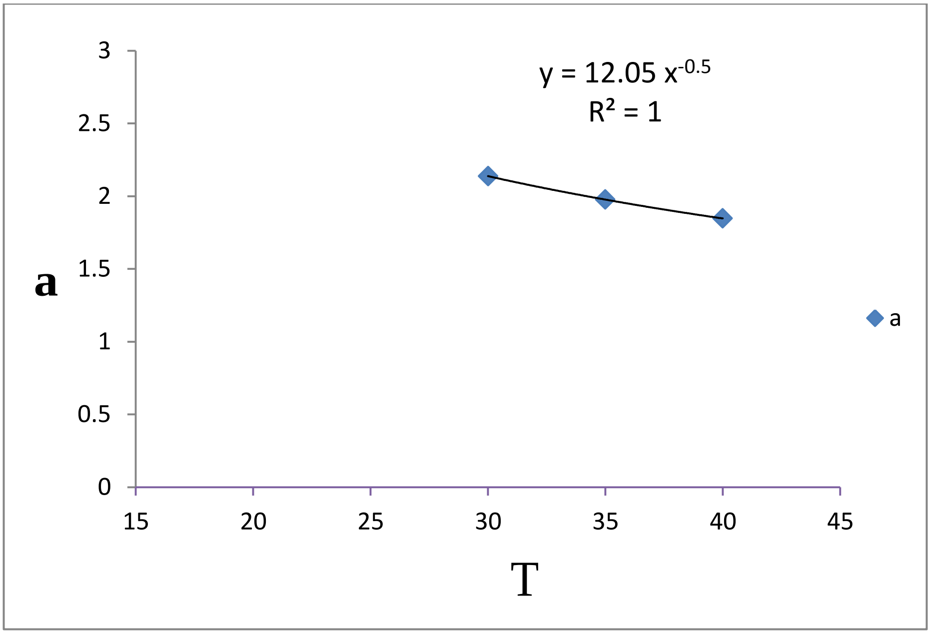


Figure (3) (a) parameter vs (T) temperature.

Figure(3) , shown the linear relationship between parameter (a) and temperature (T). From this relationship it can determine ( a" and b" ) parameters , these values are constant for all blends at different temperatures .

**(a" =12.05 )** , **(b"= -0.5)**

Equation (2) can be rewritten as:

$$\mathbf{a= 12.05\ T^{(-0.5)}} \qquad (3)$$

By substituting the value of **( a )** in the Equation(1) when can be expressed in terms of composition as general rule for any blend:

$$\mathbf{\nu = 12.05\ T^{(-0.5)}\ \ e^{bx}} \tag{4}$$

from this equation the kinematic viscosity can be calculated for different blends at different temperatures. It can be noticed that the constant (b) is ranged as : **0.023**, **0.022** and **0.021** for temperatures ( 30,35 and 40 ) receptivity

Table (3) calculated kinematic viscosity (cSt) of blends at various temperatures.

| Type of Blend | Kinematic Viscosity(cSt) | | |
|---|---|---|---|
| | **30 °C** | **35°C** | **40 °C** |
| Blend 1 | 3.1064 | 2.8760 | 2.6902 |
| Blend 2 | 3.9097 | 3.5303 | 3.2208 |
| Blend 3 | 5.5205 | 4.9106 | 4.4133 |
| Blend 4 | 7.7949 | 6.8305 | 6.0474 |
| Blend 5 | 12.3477 | 10.6057 | 9.2039 |

## 4-DISCUSSION OF RESULTS

### Statistical Error Analysis

The accuracy of correlations relative to the observed values (experimental values) is determined by using various statistical means. The following criteria are used in this study:

**% Average Deviations (% AD)**

It is defined as describe by (Riazi, 2005; Nhaesi and Asfour, , 2000):

$$\%\ \mathrm{AD} = \frac{|\nu^{\exp} - \nu^{\mathrm{cal}}|}{\nu^{\exp}} \times 100 \tag{5}$$

Where : $\nu^{exp}$ and $\nu^{cal}$ represented the experimental and calculated kinematic viscosity values respectively. The % AD indicates how close the calculated values are to experimental values.

**% Absolute Average Deviations (% AAD)**

The experimental data obtained in this study Table (1) have been used to subject various models for predicting the kinematic viscosity of crude oil blends. The percentage absolute an average deviation (% AAD) described by (Riazi, 2005; Nhaesi and Asfour, 2000) is applied and can be defined as:

$$\% AAD = \frac{1}{n} \sum_{i=1}^{n} \frac{\left| \nu^{\exp} - \nu^{cal} \right|}{\nu^{\exp}} \times 100 \qquad (6)$$

Where: n is the total number of data points and $\nu^{exp}$ and $\nu^{cal}$ representing the experimental and calculated kinematic viscosity values, respectively.

**Graphical Error Analysis**

Graphical means help in visualizing the accuracy of a correlation between the experimental and calculated kinematic viscosity values. This relationship are drawn by a cross plot type.

**Cross plot type**

In this technique, all estimated values are plotted against the observed values and thus a cross plot is formed. A 45° straight line $\nu^{exp} = \nu^{cal}$ , is drawn on the cross plot which indicate the perfect data points to this line, good results gat when both of the viscosity are very close. (Riazi, 2005; Nhaesi and Asfour, , 2000) [2,6]

## Application of the developed model for Prediction Kinematic Viscosity of crude oil Blends

The experimental and the predicted kinematic viscosity data of the investigated crude oils are listed in Tables (1) and (3), respectively. Then, It can make a comparison between both results can be observed .

**Table (4) AAD% of developed model:**

| Blend NO. | T (C) | ν (Calc) | ν (Exp) | AD % | AAD % |
|---|---|---|---|---|---|
| Blend 1 | 30 | 3.1064 | 3.0462 | 1.9764 | 2.02 |
| | 35 | 2.8760 | 2.8241 | 1.8368 | |
| | 40 | 2.6902 | 2.6313 | 2.2394 | |
| Blend 2 | 30 | 3.9097 | 3.8473 | 1.6225 | 1.70 |
| | 35 | 3.5303 | 3.4798 | 1.4520 | |
| | 40 | 3.2208 | 3.1567 | 2.0301 | |
| Blend 3 | 30 | 5.5205 | 5.3454 | 3.2755 | 2.36 |
| | 35 | 4.9106 | 4.8235 | 1.8052 | |
| | 40 | 4.4133 | 4.3265 | 2.0065 | |
| Blend 4 | 30 | 7.7949 | 7.6345 | 2.1006 | 2.79 |
| | 35 | 6.8305 | 6.6245 | 3.1089 | |
| | 40 | 6.0474 | 5.8619 | 3.1641 | |
| Blend 5 | 30 | 12.3477 | 12.0112 | 2.8012 | 3.65 |
| | 35 | 10.6057 | 10.2896 | 3.0719 | |
| | 40 | 9.2039 | 8.7598 | 5.0695 | |

**Over all AAD % = 2.50**

**The developed model was given an overall average** absolute deviation of 2.50% between experimental and predicted data. From the previous results ,it can be concluded that the model equation can predict accuracy values as good as those from experimental measurements

**Comparison of experimental and calculated from developed model .**

The accuracy and ability of present model for predicting kinematic viscosity of crude oil was checked with experimental data. Figure (4) depicts the comparison of experimental values of viscosity for different blends at temperature (30 , 35 and 40$^{o}$C ). It was noticed from Figure (4) that the model provides a good result with experimental data , using this method the overall average absolute deviation (%AAD) between experimental and predicted data was 2.50 % .

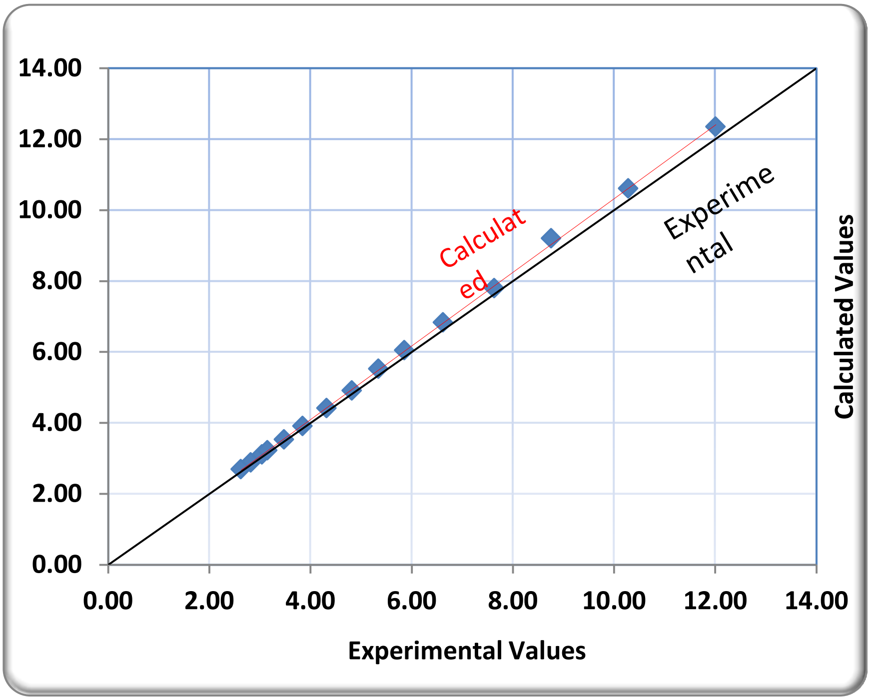


Fig. (4) Compared of experimental values with calculated values from developed model .

**Results of AD percentages for each ail blend at different temperatures**

Absolute Deviation percentage (%AD) was calculated for each blend at different temperature. As observed from the results in Table (5)

Table (5) % AD for each blend at different temperature.

| Temp.(°C) | % AD | | | | |
|---|---|---|---|---|---|
| | Blend 1 | Blend 2 | Blend 3 | Blend 4 | Blend 5 |
| 30 | 1.9764 | 1.6225 | 3.2755 | 2.1006 | 2.8012 |
| 35 | 1.8368 | 1.4520 | 1.8052 | 3.1089 | 3.0719 |
| 40 | 2.2394 | 2.0301 | 2.0065 | 3.1641 | 5.0695 |

The values for %AD were given as a logical results ( statistical histogram ) . This deference in the result can be clearly seen in Figure (5).

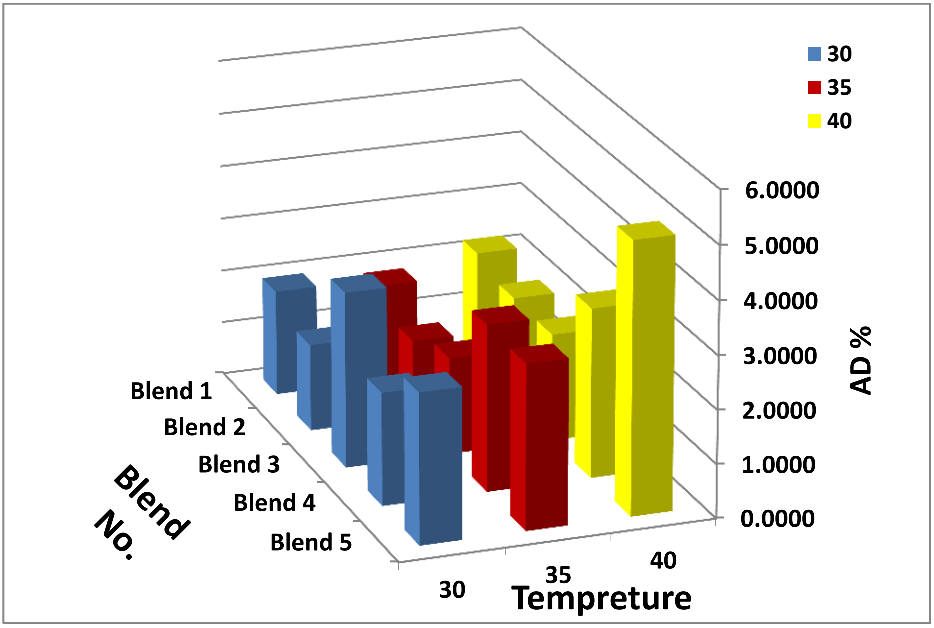


Figure. (5 ) Results of AD% for each blend at different temperatures.

**Results of AD and AAD percentages for each ail blend at variable temperatures.**

The results of % AD and % AAD for each blend of mineral oils at different temperatures are shown in Table (6).

Table (6) %AD and %AAD for each blend at different temperatures

| Temp.($^{o}$C) | % AD | | | | |
|---|---|---|---|---|---|
| | Blend 1 | Blend 2 | Blend 3 | Blend 4 | Blend 5 |
| 30 | 1.9764 | 1.6225 | 3.2755 | 2.1006 | 2.8012 |
| 35 | 1.8368 | 1.4520 | 1.8052 | 3.1089 | 3.0719 |
| 40 | 2.2394 | 2.0301 | 2.0065 | 3.1641 | 5.0695 |
| %AAD | 2.02 | 1.70 | 2.36 | 2.79 | 3.65 |

The lowest (the best) %AAD value (1.70 %) of the predicted kinematic viscosity was obtained ( **blend 2**) (25% L , 75% H) was used. On the other hand , the highest %AAD value ( 3.65%) of the prediction was obtained (**blend 5**). The other %AAD blends came in between , and this deference in the result can be clearly seen in Figure (6).

According to the obtained results , it is highly recommended to use the ( blend 2) mixture for crude oils , because it give us the lowest error in comparison between the experimental and calculated data.

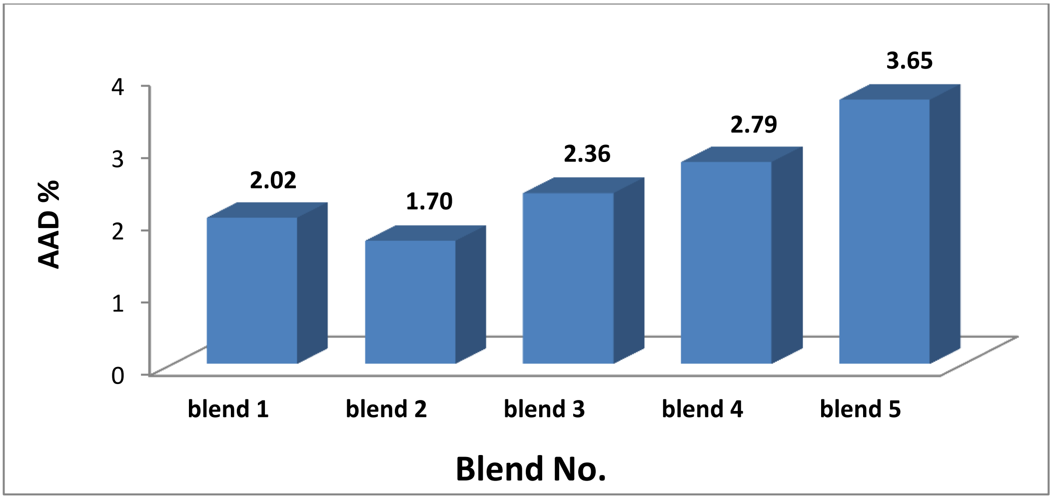


Figure (6) Results of AAD% for each blend at different temperatures

**Results of AD and AAD percentages at constant temperatures for each oil blend.**

The results of % AD and % AAD at different temperature for each blend are shown in Table (7).

Table (7) % AD and % AAD the results of various temperatures for each blend.

| Type of Blend NO | AD % | | |
|---|---|---|---|
| | 30 °C | 35 °C | 40 °C |
| Blend 1 | 1.9764 | 1.8368 | 2.2394 |
| Blend 2 | 1.6225 | 1.4520 | 2.0301 |
| Blend 3 | 3.2755 | 1.8052 | 2.0065 |
| Blend 4 | 2.1006 | 3.1089 | 3.1641 |
| Blend 5 | 2.8012 | 3.0719 | 5.0695 |
| AAD % | 2.36 | 2.25 | 2.90 |

The lowest %AAD value of (2.25 %) of the predicted kinematic viscosity was considered the best result obtained at temperature **35 °C** , followed by the value of (2.36 %) at 30 °C and the last one was (2.90 %) at 40 °C. The deference in the result can be clearly shown in Figure (7).

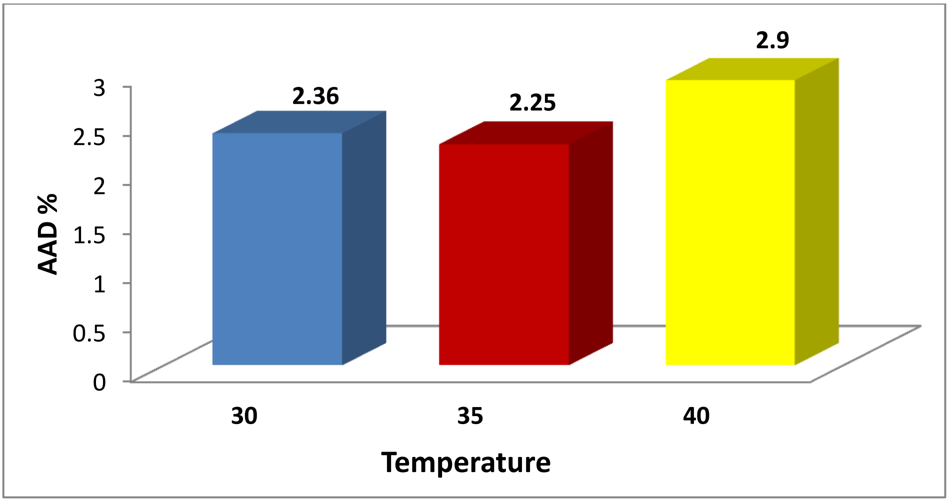


Figure (7 ): Results of AAD% at different temperature for each blend.

According to the obtained results it is highly recommended to prepare and use blends of crude oils at temperature **35 °C** .

Because, it gives a best result in comparison between the experimental values and calculated data as shown in Figure (8).

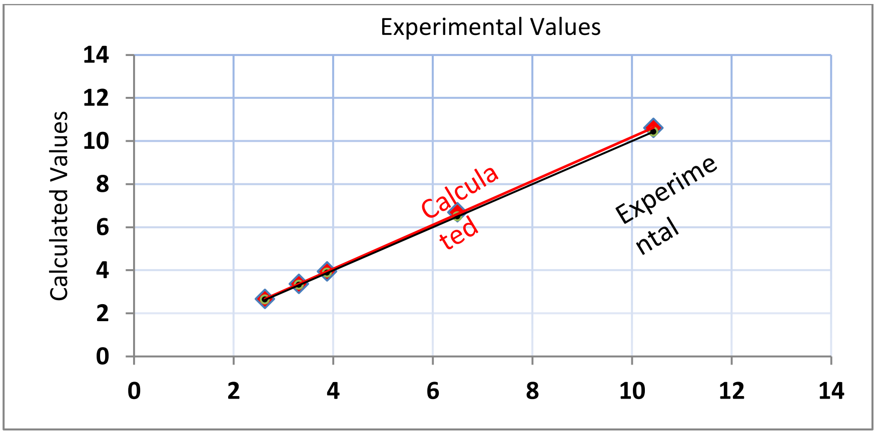


Figure. (8) Compared of experimental values vs calculated values at 35 °C.

## CONCLUSION

In present study, experimental data-base consists of five different crude oils blends from a heavy crude oil (**H**) at **Al-wafa** oil field and a light crude oil **(L**) at **Al-feal** oil field at different temperatures (30, 35, and 40°C) to obtain the experimental viscosity and analyze the predictive model results using standard statistical techniques. The predicting results have been validated with the experimental viscosity data gathered in the laboratory. Good results between the predicted and experimental values have been observed with the overall percentage average absolute deviation (AAD%) of **2.50 %**

According to the obtained results, it is highly recommended for engineers to use the **blend 2** mixture for crude oils, because it give us the lowest error in comparison between the experimental and calculated data. As well as from the obtained results it is highly recommended for engineers to prepare and use blends of crude oils at temperature **35$^{o}$C**, because it give us best result when a comparison made between the experimental and calculated data.

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