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Development of Predicting Model of API gravity for Crude Oil Blends at (Al-Wafa & Al-Feal) Field – Libya

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الملخص:

API gravity هو مقياس كيفية مقارنة النفط الخام الثقيل أو الخفيف بالماء. وهو رقم موجب يرتبط عكسياً بالكثافة النوعية للنفط الخام (كلما كان الزيت الخام أخف وزناً , زادت API gravity). وتعد مهمة لتداول النفط الخام وتحديد سعره. و في الدراسة الحالية , تم تحضير خمسة عينات مختلفة الزيت الخام الممزوجة من زيت خام الوفاء الخفيف جداً (W) و زيت خام الفيل الخفيف (F) وكانت على النحو التالي :- خليط 1 ; (W% 20 ,F% 80)خليط2 (W% 35 ,F % 65) ;خليط 3 (W% 55 , 45 F%) ; خليط 4 (W%70 ,F%30)؛ خليط 5 (W% 85 ,F% 15) عند درجة حرارة 15.6°C. للحصول على API gravity التجريبية ؛ ولتطوير صيغة رياضية يمكن الاعتماد عليها للتنبؤ API gravity باستخدام طرق الانحدار غير الخطية ، وتحليل نتائج النموذج المتحصل عليها باستخدام الطرق الإحصائية القياسية. تم التحقق من صحة النتائج المتوقعة لقيم API gravity بمقارنتها مع البيانات التجريبية التي تم قياسها في المختبر . ولوحظت نتائج عالية الدقة بين القيم المتوقعة والتجريبية بمتوسط الانحراف المطلق الكلي (AAD %) حوالي (0.68%). ومن النتائج المتوقعة في هذه الدراسة, يمكن الاستنتاج أن أداء النموذج المطور كان ممتازًا.

الكلمات الدليلية: جاذبية API ، مزيج الزيت الخام الخفيف / الخفيف جدًا ، (a, b) معاملات النموذج المطور ، (x) النسبة المئوية للخلطات ، متوسط الانحرافات ، متوسط الانحرافات المطلقة.

Abstract:
API gravity is a measure of how heavy or light crude-oil is compared with water. The measurement is a positive number that is inversely correlated to crude-oil specific gravity (the lighter the crude-oil, the higher the API gravity). that is important for crude oil trading and pricing. In the current study, Five were prepared with different sample crude oils blends from a very light crude oil Al-Wafa (W) and a light crude oil Al-Feal (F) as follows: Blend1 (20%W , 80% F); Blend2 (35% W , 65% F) ; Blend3 (55% W , 45% F); Blend4 (70% W , 30% F) and Blend5 (85% W , 15% F) at a temperature15.6 °C. to obtain the experimental API gravity; to develop the reliable mathematical expression for the most important API gravity using non-linear regression and to analyze the predictive model results using standard statistical techniques. The predicted API gravity results have been validated in comparison with the experimental data gathered in the laboratory. High precision results between the predicted and experimental values have been noticed with overall average absolute deviation (AAD%) of (0.68%). From the predicted results in this study, it can be concluded that the performance of the developed model are excellent.
Key-words: API gravity **,** very light / light crude oil blend **, (a, b)** coefficients the developed model **, (x)** percentage of blends **,** Average Deviations **,** Absolute Average Deviations.

1. INTRODUCTION

1.1. API gravity of Crude Oils

Like any other material, Crude Oil has a set of properties that defines its chemical and physical characteristics. These properties form the basis of comparison between several crude oil blends. Depending on the purpose of comparison, some properties prevail more than others. For instance, viscosity, wax content, sulfur, and acidity are important to crude oil transportation and refining, while API gravity is important for crude oil trading and pricing **[1].**

The American Petroleum Institute gravity, (API gravity), is a measure of how heavy or light a petroleum liquid is compared to

water. API gravity is thus an inverse measure of a petroleum liquid's density relative to that of water: (density of crude oil / density of water).I fits API gravity is greater than 10, it is lighter and floats on water; if less than 10, it is heavier and sinks. It is used to compare densities of petroleum liquids. For example, if one petroleum liquid is less density than another, it has a greater API gravity. Although API gravity is mathematically a dimensionless quantity, it is preferred to be in 'degrees'. API gravity is graduated in degrees on a hydrometer instrument. API gravity values of most petroleum liquids fall between 10 and 70 degrees**[2].**

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

- To obtain the experimental API gravity data of crude oils and their blends at temperature (15.6 ^{O}C).
- To develop the reliable mathematical expression for the most important API gravity using non-linear regression technique.
- To analyze the predictive model results using standard statistical techniques.

1.2. Mellita compound

The company of Mellita for oil is one of the largest oil companies in Libya . It is daily production nearly (600,000) barrels (crude oil , natural gas , condensate gas , 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, which are main source of crude oil to Mellita oil compound. The very light crude oil AL-Wafa is API gravity (58) while the light crude oil AL-Fealis API gravity (38.5). Therefore their crude oil is mixed in the compound to obtain medium API gravity.

1.3. Model of API gravity Preparation

- API gravity formulas:

The formula to calculate API gravity from specific gravity (SG) is :

$$\text{API gravity} = \frac{141.5}{\text{S.G}} - 131.5$$

Conversely, the specific gravity of petroleum liquids can be derived from their API gravity value as :

$$\text{SG at } 60°\text{F} = \frac{141.5}{API gravity + 131.5}$$

Thus, a heavy oil with a specific gravity of 1.0 (i.e., with the same density as pure water at 60 °F) has an API gravity of:

$$\frac{141.5}{1.0} - 131.5 = 10.0°\text{API}$$

- Using API gravity to calculate barrels of crude oil per metric ton:

In the oil industry, quantities of crude oil are often measured in metric tons. One can calculate the approximate number of barrels per metric ton for a given crude oil based on its API gravity:

- Barrels of crude oil per metric ton $= \frac{\text{API gravity} + 131.5}{141.5 \times 0.159}$

For example, a metric ton of West Texas Intermediate (39.6° API) has a volume of about 7.6 barrels.

- Measurement of API gravity from its specific gravity:

To derive the API gravity, the specific gravity (i.e., density relative to water) is first measured using either the hydrometer, detailed in ASTM-D1298 or with the oscillating U-tube method detailed in ASTM-D4052 **[3].**

Density adjustments at different temperatures, corrections for soda-lime , glass expansion , contraction and meniscus corrections for opaque oils are detailed in the Petroleum Measurement Tables, these details usage specified in ASTM-D1250. The specific gravity is defined by the formula below.

$$\text{SG oil} = \frac{\rho \text{ Crude Oil}}{\rho H_2O}$$

With the formula presented in the previous section, the API gravity can be readily calculated. When converting oil density to specific gravity using the above definition, it is important to use the correct

density of water, according to the standard conditions used when the measurement was made. The official density of water at 60 °F according to the 2008 edition of ASTM-D1250 is 999.016 kg/m^3**.** The 1980 value is 999.012 kg/m^3.In some cases the standard conditions may be 15 °C (59 °F) and not 60 °F (15.56 °C), in which case a different value for the water density would be appropriate (see standard conditions for temperature and pressure)**.**

- Direct measurement of API gravity (hydrometer method)

There are advantages to field testing and on-board conversion of measured volumes to volume correction. This method is detailed in ASTM-D287 **[4].**

1.4. Classifications or grades

Crude oil is classified as light, medium, or heavy according to its measured API gravity as shown in Table (1) **[5].**

TEBLE 1. Type of Crude Oil

Type of crude oil	API gravity	Densité (kg/m^3)
Light crude oil	**> 31.1°**	**< 870**
Medium oil	**22.3 – 31.1°**	**870 – 920**
Heavy crude oil	**< 22.3°**	**920 – 1000**
Extra heavy oil	**< 10.0°**	**> 1000**

2.EXPERIMENTAL PROCEDURES

Materials and preparation predation data samples

Two types of crude oils provided by Libyan oil companies were used. denoted as very light crude oil (**W**)at **Al-Wafa** oil field and light crude oil **(F**) at **Al-Feal** oil field. From the base crude oils, Five binary mixtures were prepared with different sample compositions.

The API gravity of crude oils pure and crude oils blends were measured. The experiments were carried at atmospheric presume and temperature (15.6 ºC), the results will be presented in the next section.

The apparatus used in the experiments was hydrometer as shown in Figure 1. API gravity of the samples (Blends) were determined according to ASTM-D-1250.It can be noticed that all apparatus used in this work existed in Mellita Industrial Compound and the experimental work was carried out in their labs[6].

Figure 1. Hydrometer.

3. EXPERIMENTAL RESULTS AND DEVELOPED MODEL

API gravity Experimental

The API gravity of crude oils pure and crude oils blends were measured at temperature (15.6 ^{o}C) as shown in Table (1).

Predicted of API gravity 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 API gravity for some crude oils considered with the experimental data obtained in the laboratory at temperature (15.6 ^{o}C) **[7].**

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 API gravity model in terms of composition (x) can be expressed as:

API = a e^{bx}……(1)

Where :

API **:** American Petroleum Institute.

a ,b **:** coefficients which will be determined by the regression technique.

x **:** one of the blend component fraction and value as **(**w) fraction, **x = f (w)**

From Table (2) it can be drawn in terms of a graph Figure (2) showing relationship between API gravity at temperature (15.6 ^{o}C) and percentage of blends by using both Excel software and Nonlinear Regression Technique.

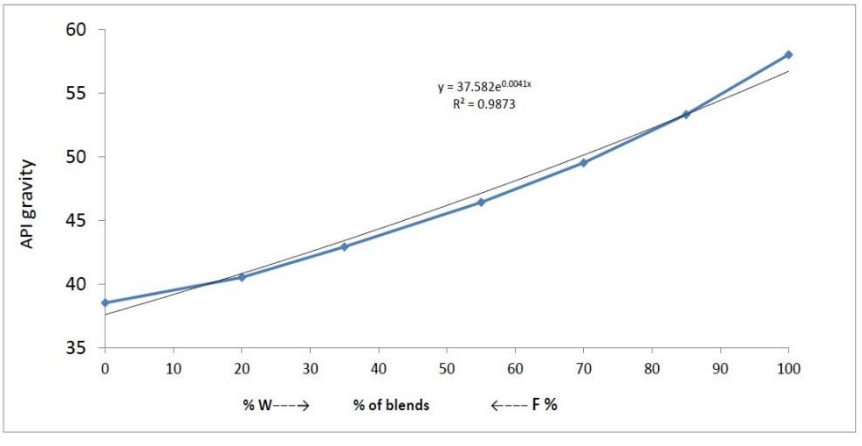

Figure 2. API gravity at vs percentage of lends.

Figure 2. shows the best curve (nonlinear) at temperature(15.6 ^{o}C) according to Equation (1). The parameters of (**a** and **b**) determined as:

a = 37.58 , b = 0.004

By substituting the value of **a** and **b** in the Equation(1) which can be expressed in terms of composition as general rule for any blends Mellita compound :

API = 37.58 $e^{0.004x}$……(2)

a ,b, x has been previously defined the Equation(1)
From this Equation (2) the API gravity can be calculated for different blends

TEBLE 2. Experimental and Calculated API gravity of Blends.

Type of Blend	% of blends		API (Exp)	API (Cal)
	(W)%	(F)%		
Pure (F)	0	100	38.5	-
Blend 1	20	80	40.5	40.7
Blend 2	35	65	42.9	43.2
Blend 3	55	45	46.4	46.8
Blend 4	70	30	49.5	49.7
Blend 5	85	15	53.3	52.8
Pure (W)	100	0	58.0	-

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):

$$\% \text{ AD} = \frac{\left|API^{\exp} - API^{\text{cal}}\right|}{API^{\exp}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:
API^{exp} & API^{cal} Represented the experimental and calculated API gravity values respectively.
% AD Indicates how close the calculated values are to experimental values.

Absolute Average Deviations (% AAD)

The experimental and calculated data obtained in this study Table (2) have been used to subject various models for predicting the API

gravity 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:

$$\%\,AAD = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|\,API^{\exp} - API^{cal}\,\right|}{API^{\exp}} \times 100 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where:

n Total number of data points.

API^{exp} & API^{cal} Representing the experimental and calculated API gravity values, respectively**[8]**.

Graphical Error Analysis

Graphical means help in visualizing the accuracy of a correlation between the experimental and calculated API gravity values. This relationship are drawn by a cross plot type, as how in Figure (3).

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 $\mathbf{API^{exp} = API^{cal}}$ is drawn on the Figure (3) cross plot which indicate the perfect data points to this line, good results get when both of the API gravity are very close **[9]**.

Application of the developed model for Prediction API gravity of crude oil Blends

The experimental and the predicted API gravity data of the investigated crude oils are listed in Tables (2), respectively. Then, It can make a comparison between both results can be observed .

TEBLE 3. AD% and AAD% of Developed Model.

Type of Blend	API (Exp)	API (Cal)	AD %
Blend 1	40.5	40.7	0.49
Blend 2	42.9	43.2	0.70
Blend 3	46.4	46.8	0.86
Blend 4	49.5	49.7	0.40
Blend 5	53.3	52.8	0.94
		AAD %	0.68%

Over all AAD %

The developed model was given an overall average absolute deviation of (**0.68%)** 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 API gravity of crude oil was checked with experimental data. Figure (3) depicts the comparison of experimental values of API gravity for different blends at temperature (15.6 ^{o}C) with calculated values at developed model**.**

It was noticed from Figure (3) 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 (**0.68 %)**.

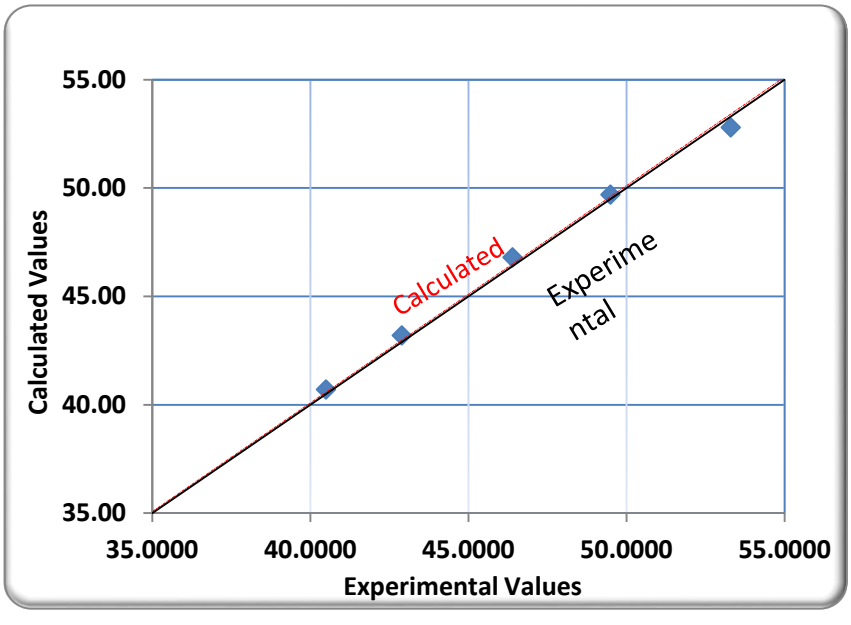

Figure 3. Experimental and calculated values Comparisons from Developed Model.

Results of AD% for each oil blend .

Absolute Deviation percentage (%AD) was calculated for each blend at temperature (15.6 ^{o}C). As observed from the results in Table (3).

The lowest (the best) % AD value (0.40%) of the predicted API gravity was obtained blend 4 (70% W , 30% F) was used. On the other hand, the highest %AD value (0.94 %) of the prediction was obtained blend 5 (85% W , 15% F). The other %AD blends came in between , and this deference in the result can be clearly seen in Figure (4).According to the obtained results ,it is highly recommended to use the blend 4 mixture for crude oils, because it give us the lowest error in comparison between the experimental and calculated data with AD % equal to (0.40).

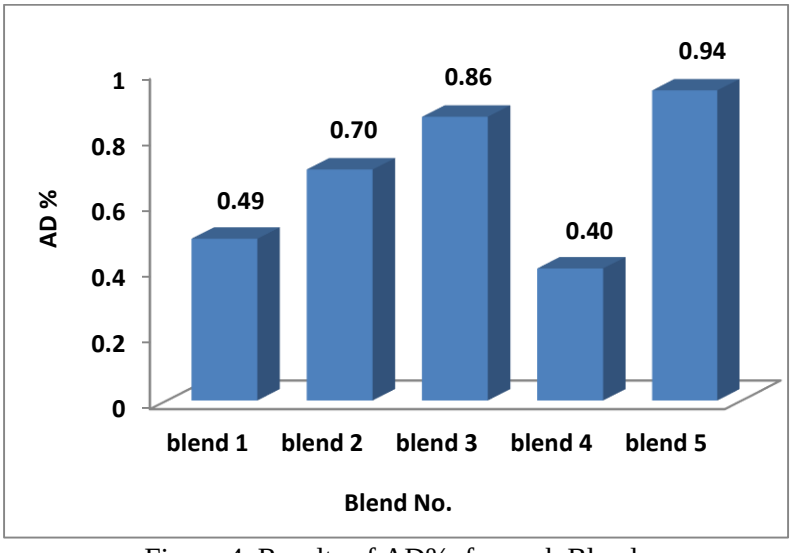

Figure 4. Results of AD% for each Blend .

Conclusion

In the present study, where the experimental data-base consists of five different crude oil blends from very light crude oil (W) at Al-Wafa oil field and a light crude oil (F) at Al-Feal oil field at temperature (15.6°C) to obtain the experimental API gravity, as

discussed before analysis of the predictive model results using standard statistical techniques shows that:

- The predicting results which is validated with the experimental Mellita compound data gathered in the laboratory, a lower discrepancy between experimental and calculated values.
- High precision results have been observed with the overall percentage average absolute deviation (AAD %) of (0.68%).
- Blend 4 of mixture crude oil are the best one amongst all the crude oil blends used, as it is lowest (AD%) between experimental and calculated values.
- The predict developed model have high sobriety to be used with any blend of two oil fields mentioned (W&F) at the Mellita Compound.
- It is highly recommended for oil Engineers at Mellita Compound to use blend 4, for the reasons mention eel in a step before.
- From the economic point of view the predicted formula offer more time and lower cost analysis

Recommendation

The study has suggested to do more investigation on API gravity as a function of blend (x) which is to be (x= f (W,F)), to get more precise results and general for both blend.

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