PREDICTIVE CORRELATION FOR THE VISCOSITY - TEMPERATURE RELATION OF SOME IRAQI CRUDE OILS

Lec. Husham.M.Majeed Ass. Lec. Ahmed A.Ubeed, Ass. Lec. kassim K.Hameed

hmmt_2005@yahoo.com alshibly83@yahoo.com K_alshemary@yahoo.com

Chem. Eng. Dept., College of Engineering, Al-Qadisiyah University.

Received 2 Jun 2015 Accepted 27 August 2015

ABSTRACT:

The viscosity at different temperature are measured for some Iraqi wells, A mathematical model was proposed to describe the viscosity as a function of temperature depending on the experimental results , All the samples were collected from storage tanks of the following sites: South of Al Rumeela, North of Al Rumeela, Al Halfaya and Bozorgan. The results give good agreement with the experimental result that was measured for Iraqi wells, where the maximum average percentage of error was 7.4 % , the maximum AAD% was 4.4% and the maximum SD was 0.49013%.

Key Words: Viscosity, Temperature, Predictive Correlation, Iraqi crude oil, polyfit.

تنبأ علاقة تربط بين اللزوجة ودرجة الحرارة لبعض النفط الخام العراقي

م. هشام محمد مجيد م.م. أحمد عباس عبيد م.م.قاسم كاظم حميد

جامعة القادسية / كلية الهندسة / قسم الهندسة الكيمياوية

الخلاصة:

تم قياس مقدار اللزوجة في درجة حرارية مختلفة لنفط بعض الآبار العراقية، حيث تم اقتراح نموذج رياضي لوصف اللزوجة كدالة لدرجة الحرارة بالاعتماد على النتائج التجريبية اذ تم جمع النماذج من خزانات النفط الخام العراقي ومن المواقع التالية: جنوب الرميلة، شمال الرميلة، الحلفاية و بزركان. اظهرت النتائج المحسوبة توافق جيد مع النتائج التجريبية التي تم قياسها للآبار العراقية وكان الحد الأقصى لمعدل الخطأ النسبي هو 7.4% واعظم مقدارللانحراف المطلق فكان 4.4% اما الخطأ المعياري فكان مقدارة 0. 49013%

INTRODUCTION:

The viscosity is one of the important crude oil properties, therefore it is important to understand the viscosity behavior of crude petroleum and used it in the different engineering applications such as the calculation of total power requirement for pumping the crude oil, studying the energy loses during production, transportation through pipelines, and reservoir simulations as well as in determining the structure of liquids[1].

The viscosity is a function to some parameters such as the temperature, pressure, composition of the crude oil….etc. But the viscosity of one type of a crude oil is a strong function of temperature only, which is the most important variable during the pumping requirements, especially; the temperature could be varied during the processing of the oil.

Generally the relation generally between temperature and viscosity of the crude oil is an inverse relationship, and the prediction of this relation in form of formula to relate these two variables has received great attention from engineers in the field of the oil refineries especially for design of equipments, and pipelines.

The old procedure to calculate the viscosity of the oil is accomplished by using the generalized reduced viscosities chart [17], where this is not direct method because the critical viscosity μ_c must be determined before using this chart. There is another method is used to calculate the viscosity at different temperature depending on the ASTM chart method but it also has a basic disadvantage where the extrapolation is required. Therefore many viscosity- temperature equations have been proposed to predict the relation between the temperature and the viscosity to solve this problem and predict a suitable equation between the viscosity and the temperature.

The first study were began in 1946 by Beal[4], after some years in 1972 Velzen et al. proposed a simple method to estimate the viscosity value [1], after that some researchers tried to find an accurate relation such as (Amin and Maddox[3]; Ely and Hanley [7]; Beg et al[14]; and Al-Besharah[2]) But the main shortcoming in all these predictive correlations is the error which is present as a result to the deviation between the theoretical and experimental data. Also all these correlations have some coefficients that must be determined from the available crude oil data.

In 1993 Puttagunta et al.[12] have been successful proposed a good model to describe the relation between the viscosity of the American crude oil with temperature which gave a small deviation. This model was tested for different crude sources such as Nigerian crude oil[1] and also gave good and suitable results for predicting effect of temperature on kinematic viscosity.

The Viscosity of Middle-East crude oil was modeled by Singh et al [15]. They modified their model where it gave overall average absolute deviation less than 5 %.

Other predicted studies were developed to correlate the viscosity with temperature such as Ghetto et al.[6]; Petrosky and Farshad [11]; Wakabayashi [18]; Bennison [5]; Miadonye and Puttagunta [9]) and also these correlation has a significant errors.

Jabir Shanshool was developed a new correlation between the kinematic viscosity and temperature in 2001[8]. He based on experimental kinematic viscosity data for twenty TBP fractions of Arab heavy, Arab medium and Arab light and Arab extra-light crude oils. His correlation gave average absolute deviation of 7.2%

The viscosity of Iranian crude oil in 2013 was predicted by using artificial neural network using Matlab program environment depending on 75 samples [10].

The viscosity of Iraq crude oil was predicted by Rwaida Kaiser Abdulmajeed [13] in 2014 according to an experimental data collected from different samples of Iraqi oil reservoirs ,She develop a new correlation to calculate the oil viscosity at various temperature, her study gave (1.72 %) standard deviation error compared with the other correlations.

In this work, a simple correlation has been developed to calculate the viscosity of crude oil with temperature using 40 samples collected from different Iraqi wells. The samples were collected from

storage tanks of the following sites: South of Al Rumeela, North of Al Rumeela, Al Halfaya and Bozorgan.

EXPERIMENTAL WORK

The samples of crude oil from different wells were collected, from storage tanks of the following sites: South of Al Rumeela, North of Al Rumeela, Al Halfaya and Bozorgan. These samples were used for measuring the viscosity experimentally with different temperatures.

A 100 ml of each crude oil sample was added into a beaker. The beaker was putted inside the digital heating mantle; the mantle must be maintained to the desired temperature before heating the sample by setting the temperature to a desired point. The temperature was recorded depending on the thermometer reading. The viscosity was measured by viscometer apparatus during heating (as shown in **Figure 1**), where the wheel of the apparatus was immersed in the beaker at each measuring point. This process is repeated for the various crude oils and at different temperature. The temperatures range was 20 to 60 ^{o}C.

SIMULATION OF VISCOSITY

A new model was predicted by using Matlab simulation program depended on the data which measured for these sites.

We develop the following function of the viscosity-temperature correlation as follow:

$$\vartheta = b\, e^{mT} \qquad (1)$$

Where;

ϑ is the kinematic viscosity in centistoke (cSt.)

b, m: are constants

T is the temperature in ^{o}C.

RESULTS AND DISCUSSION:

The comparative viscosity-temperature variation of the experimental and the Predictive results (from Matlab simulation) for some Iraqi crudes oil are presented in **Tables (1)** and (**2)**. The relation gave a good agreement between the predictive and measured viscosity with error (average percentage of error (equation **2**)) of 7.4 %

The predictive model parameters (b& m) are calculated using Polynomial curve fitting (polyfit) function and shown in **Table (3)**.

In order to verify the correctness of our predictive correlation the average percentage of error was calculated for each of the viscosity and compared with experimental values according to the equation (**2**)

$$\%Error = \frac{|\vartheta_{experimental} - \vartheta_{Predictive}|}{\vartheta_{experimental}} * 100\% \quad (2)$$

The average absolute deviation (AAD) was calculated as follow:

$$AAD = \left({}^{1}/_{N}\right) \sum(\left|\left(\vartheta_{exp} - \vartheta_{pre}\right)\right| / \vartheta_{exp}) * 100\% \quad (3)$$

Where the overall average absolute deviation for the entire data AAD % are shown in **Table (4).**

The maximum AAD% was 4.4% for Bozorgan crude oil. The smallest average absolute deviation was found to be 2.37% for South of Al Rumeela crude oil samples.

It was illustrated as shown in **Table (1)** and (**2)** that the error values does not depend on the increasing or decreasing of the temperature nor on the type of crudes, where the relationship was tended to increases and decreases for each of the crude oil samples.

It is evident generally that as temperature increases the experimental and predictive viscosities are decreases of each oil, also it can be explained that the relationship as shown in the equation (**1**) does not represent reality the relationship between viscosity and temperature, but rather represent the closest relationship to reality which gives the lowest value of the error calculated by equation (**2)**.

The values of experimental and predicted viscosities Al Halfaya, North of Al Rumeela, South of Al Rumeela and Bozorgan crude oils as function of temperature are plotted in **Figure 2, 3, 5** and **5** respectively. Each figure illustrates a comparison between the predicted and experimental viscosities of the Iraqi crude oil for 10 data points of these wells.

The reliability of the proposed model with the parameters was evaluated by the average absolute deviation AAD% (see equation (**3**)). The maximum AAD% was 4.4% in the Bozorgan crude oil as shown in the **Table (4)**.

COMPARISON THE PROPOSED MODEL WITH DIFFERENT MODELS

It is worth mentioning that there are no previous studies to estimate the viscosity correlation for Iraqi crude oil except the predictive equation which was adopted by Rwaida Kaiser Abdulmajeed[13].

She wasn't depending on the average percentage of error as described in equation (**2**). She was examined their proposed equation by using the standard deviation error (SD), as shown in equation (**4**) below:

$$SD = \sqrt{\left(\frac{1}{N-1}\sum_{i=1}^{N}\left|\frac{\vartheta exp - \vartheta perd}{\vartheta exp}\right| - AAD)\right)^{2}} \quad (4)$$

Her model gave 1.72% SD, Therefore in order to compare our model with her equation we must calculate the standard deviation error for our model. The standard deviation error (SD) was calculated for our model shown below in **Table (5):**

We can say that our model gave more accurate result for comparison between the experimental and predictive data according to the result shown in **Table (5)**, where the maximum SD was 0.49013 for Bozorgan crude oil.

Conclusion

A simple and new kinematic viscosity-temperature correlation has been developed For South of Al Rumeela, North of Al Rumeela, Al Halfaya and Bozorgan crude oil.

The experimental results of viscosity with temperature represent nonlinear relation as shown in **Table (1)** and (**2).** The results showed that the proposed correlation gives a good agreement between the experimental and predictive viscosity, where this relation (which was represented by equation (**1**)) was found to be the most suitable for the prediction of viscosity, where it gives an (0.49013%) standard deviation error compared with the other correlations which give (1.72 %) standard deviation error.

Therefore it could be concluded that the present correlation can be considered an accurate correlation to predict viscosity with temperature of the Iraqi crude oils.

NOMENCLATURE

AAD Average Absolute Deviation

b, m constants

Cp Centipoise

polyfit Polynomial curve fitting function in MatLab program

SD Standard Deviation Error

T the temperature in ^{o}C.

ϑ the kinematic viscosity in centistoke (cSt.)

μ_{expr} experimental kinematic viscosity Centipoise

μ_{pred} predictive kinematic viscosity Centipoise

REFERENCES

[1] A.S. ABDULKAREEM and A. S. KOVO (Simulation of the Viscosity of Different Nigerian Crude Oil) , Leonardo Journal of Sciences . Issue 8, January-June 2006 , p. 7-12

[2] A1-Besharah, J. M., Akashah, S. A., Mumford, C. J.: (The effect of temperature and pressure on the viscosities of crude oils and their mixtures). Ind. Eng. Chem. Res. 28, 213-221 (1989).

[3] Amin, N.B. and R.N. Maddox. (Estimating Viscosity versus Temperature). Hydrocarbon Process. 59(12) (1980) 131.

[4] Andrade, E.N. da C., Philosophical Magazine., 17 (1934) 497; ibid, 17 (1934) 698.

[5] Bennison, T. 1998. (Prediction of Heavy Oil Viscosity. Presented at the IBC Heavy Oil Field) Development Conference, London, England, 2–4

[6] De Ghetto, G., Paone, F., and Villa, M. 1995. Pressure-Volume-Temperature Correlations for Heavy and Extra Heavy Oils. Presented at The SPE International Heavy Oil Symposium, Calgary, Alberta, 19–21 June. SPE-30316-MS. http://dx.doi.org/10.2118/30316-MS.December.

[7] Ely, J.F. and H.J.M. Hanley. (Prediction of transport properties. 1. Viscosity of fluids and mixtures), Ind. Eng. Chem. Fund., 20 (1981a) 323.
http://dx.doi.org/10.1016/S0016-2361(97)00090-2.
http://dx.doi.org/10.1080/10916469808949803.
http://www.pe.tamu.edu/barrufet/public_html/PETE310/ Papers/Visco%20models.pdf.

[8] Jabir Shanshool and Emad Talib Hashim (kinematic viscosity-temperature correlation for undefined petroleum fraction of a wide boiling. Petroleum Science and Technology. , 19(3&4), 257–268 (2001).

[9] Miadonye, A. and Puttagunta, V.R. 1998. Modeling the Viscosity-Temperature Relationship of Nigerian Niger-Delta Crude Petroleum. Petroleum Science and Technology 16 (5 & 6): 627–638.

[10] Mohmammed Soleimani Lashkenari,Majid Taghizadeh and Bahman Mehdizadeh. (Viscosity prediction in selected Iranian light oil reservoirs: Artifical Neural Network versus empirical correlations), Pet.Sci.(2013) 10 :126-133.

[11] Petrosky, G.E. and Farshad, F.F. 1995. Viscosity Correlations for Gulf of Mexico Crude Oils. Presented at the SPE Production Operations,

[12] Puttagunta, V.R., Miadonye, A., and Singh, B. 1992. (Viscosity Temperature Correlation for Prediction of Kinematic Viscosity of Conventional Crude). Trans. Inst. Chem. Eng. 70: 627–631.

[13] Rwaida Kaiser Abdulmajeed . (New Viscosity Correlation for Different Iraqi Oil Fields). Iraqi Journal of Chemical and Petroleum Engineering Vol.15 No.3 (September 2014) 71-76

[14] S.A. Beg, M.B. Amin and I. Hussain, "Generalized Kinematic Viscosity - Temperature Correlation for Undefined Petroleum Fractions", The Chemical Engineering Journal, 38, 123-136, 1987.

[15] Singh, Miadonye and Puttaguntat (Modeling the Viscosity of Middle-East Crude Oil Mixtures), Ind. Eng. Chem. Res. 1993,32, 2183-2186.
Symposium, Oklahoma City, Oklahoma, 2–4 April. SPE-29468-
MS.http://dx.doi.org/10.2118/29468-MS.

[16] Van Velzen, D., R.L. Cardozo and H. Langenkamp. (A Liquid Viscosity-Temperature-Chemical Constitution Relation for Organic Compounds). Ind. Eng. Chem. Fundam., 11 (1972) 20.

[17] W. L Nelson, (Petroleum refinery engineering), McGraw-Hill Book Company, Inc., New York, 4th edition 1958.

[18] Wakabayashi, T. 1997. Viscosity Correlation with Specific Gravity and Molecular Weight of Crude Oil Fractions. Fuel 76 (11): 1049–1056.

Table (1): Temperature versus Viscosity data for Al Halfaya, Bozorgan

T ^{o}C	**Al Halfaya**			**Bozorgan**		
	μexpr Centipoise(Cp)	μpred Cp	%Error Equation (**2**)	$\mu_{expr.}$ Cp	μ_{pred} Cp	%Error Equation (**2**)
15	180	165.8307	7.871833	59	57.1461	3.142203
20	136.65	134.4202	1.63176	48.15	47.8804	0.559917
25	109	108.9593	0.037339	44	40.117	8.825
30	85	88.321	3.90706	32	33.6124	5.03875
35	67.5	71.5919	6.06207	26.27	28.1625	7.20404
40	54.8	58.0314	5.89672	22.14	23.5962	6.57724
45	45	47.0395	4.53222	19.1	19.7703	3.50942
50	37.8	38.1296	-0.87196	16.5	16.5647	-0.39212
55	31.9	30.9074	3.111599	14.3	13.8789	2.944755
60	27.06	25.0531	7.416482	12.36	11.6285	5.918285

Table (2): Temperature versus Viscosity data for South of Al Rumeela, North of Al Rumeela.

T ^{o}C	**South of Al Rumeela**			**North of Al Rumeela**		
	μ_{expr} Centipoise(Cp)	μ_{pred} Cp	%Error Equation (**2**)	μ_{expr} Cp	μ_{pred} Cp	%Error Equation (**2**)
15	11.45	11.1755	2.39738	17	16.3122	4.045882
20	10.36	9.9706	3.758687	14.8	14.357	2.993243
25	8.78	8.8956	1.31663	12.62	12.6362	0.12837
30	7.81	7.9364	1.61844	10.7	11.1217	3.94112
35	6.8	7.0807	4.12794	9.45	9.7887	3.58413
40	6.225	6.3173	1.48273	8.35	8.6154	3.17844
45	5.52	5.6362	2.10507	7.33	7.5828	3.44884
50	4.96	5.0285	1.38105	6.7	6.6739	0.389552
55	4.55	4.4863	1.4	6	5.874	2.1
60	4.175	4.0026	4.129341	5.4	5.17	4.259259

Table (3): Parameters value of the predictive equation.

Well	parameters	
	b	m
Al Halfaya	311.3621	-0.0420
Bozorgan	97.1570	-0.0354
South of Al Rumeela	15.7366	-0.0228
North of Al Rumeela	23.9251	-0.0255

Table (4): Average absolute deviation values.

Well	AAD%
Al Halfaya	4.133904
Bozorgan	4.411173
South of Al Rumeela	2.371727
North of Al Rumeela	2.806884

Table (5): The standard deviation error values (SD).

Well	SD %
Al Halfaya	0.459323
Bozorgan	0.49013
South of Al Rumeela	0.263525
North of Al Rumeela	0.311876

Figure (1): Brookfield digital viscometer model DV-E in the Lab.

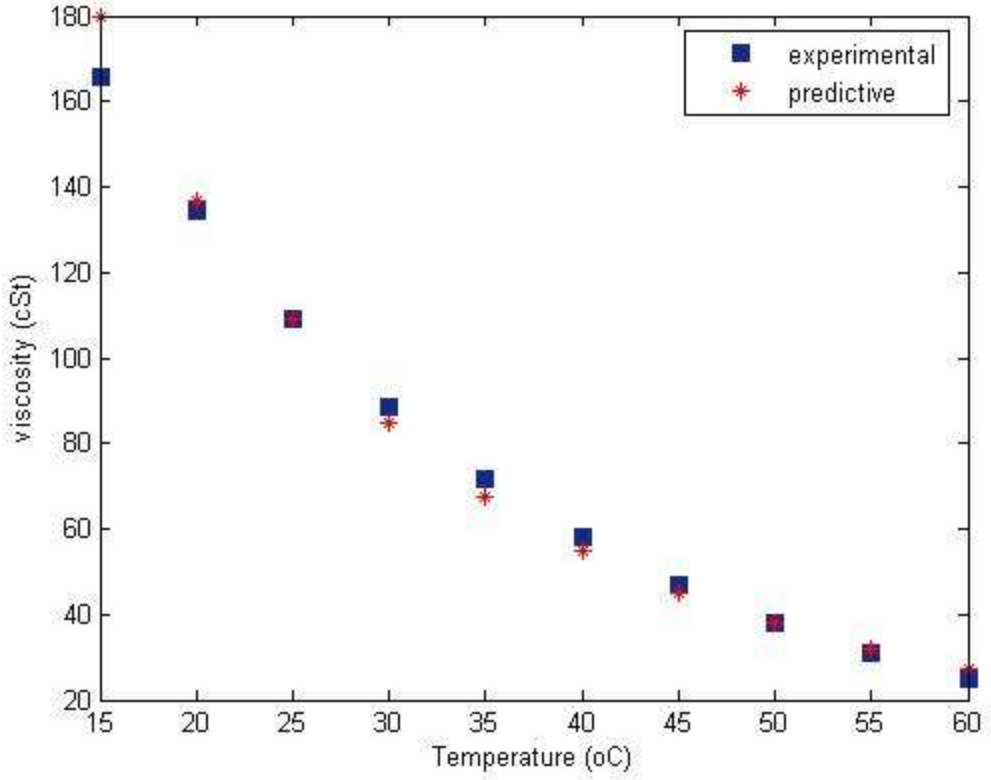

Figure (2): Al-Halfaya Temperature viscosity relation

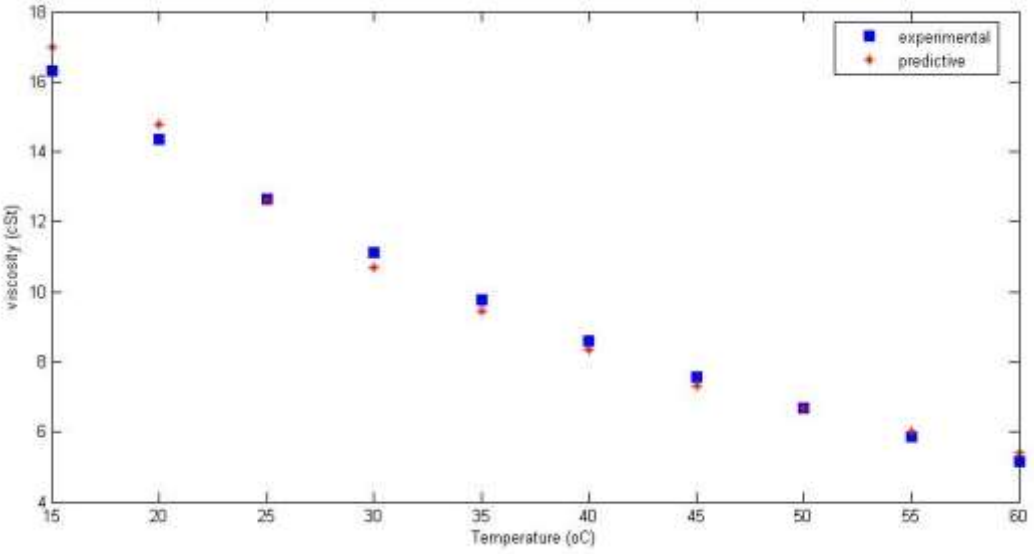

Figure (3): Al-North of Al-Rumeela Temperature Viscosity relation

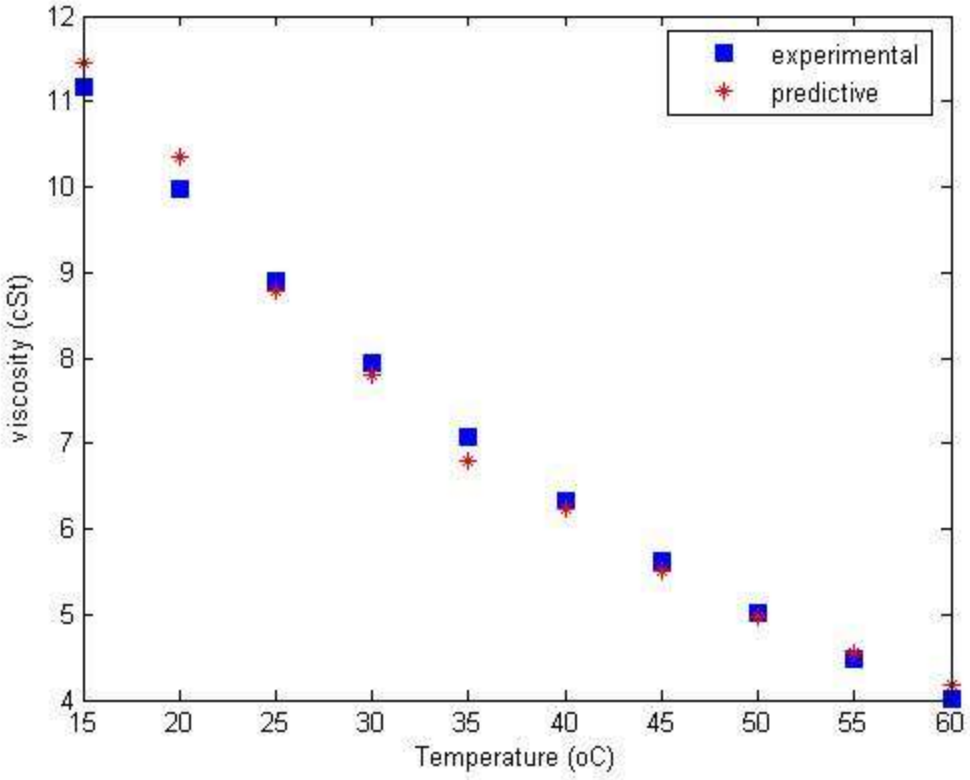

Figure (4): Al-South of Al-Rumeela Temperature Viscosity relation

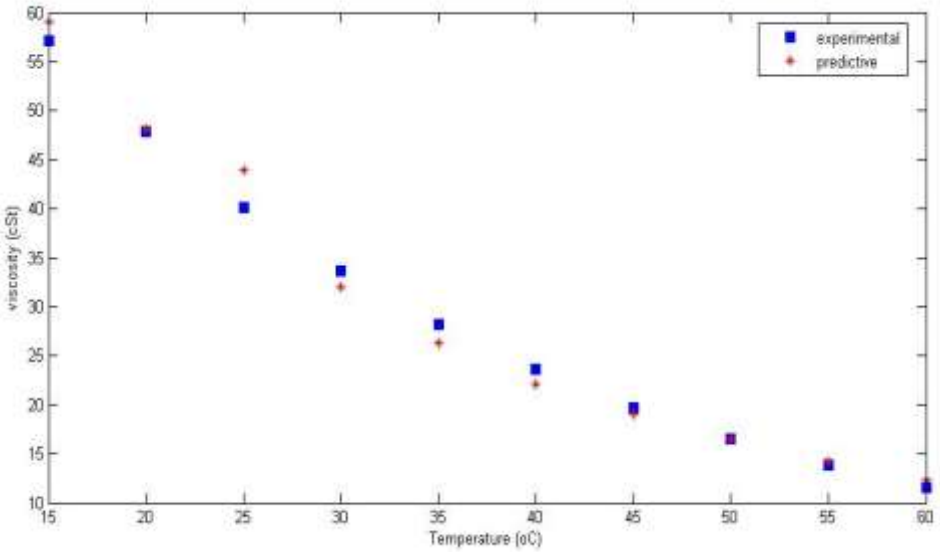

Figure (5): Bozorgan Temperature Viscosity relation