



Modeling of Oil Viscosity for Southern Iraqi Reservoirs using Neural Network Method

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Abstract:

The calculation of the oil density is more complex due to a wide range of pressures and temperatures, which are always determined by specific conditions, pressure and temperature. Therefore, the calculations that depend on oil components are more accurate and easier in finding such kind of requirements. The analyses of twenty live oil samples are utilized. The three parameters Peng Robinson equation of state is tuned to get match between measured and calculated oil viscosity. The Lohrenz-Bray-Clark (LBC) viscosity calculation technique is adopted to calculate the viscosity of oil from the given composition, pressure and temperature for 20 samples. The tuned equation of state is used to generate oil viscosity values for a range of temperature and pressure extends from the reservoir to surface conditions.

The generated viscosity data is utilized in the neural network tool (NN) to get fitting model correlates the viscosity of oil with composition, pressure and temperature. The resulted error and the correlation coefficient of the model constructed are close to 0 and 1 respectively. The NN model is also tested with data that are not used in set up the model. The results proved the validity of the model. Moreover, the model's outcomes demonstrate its superiority to selected empirical correlations.

عمل نموذج بالشبكة العصبية للزوج النفط لمكان جنوب العراق

الخلاصة:

هنالك صعوبة كبيرة في حساب كثافة النفط على نطاق واسع من الضغوط ودرجات الحرارة، والحسابات التي تجرى لهذا الغرض دائما ما تكون محددة بشروط وضغط وحرارة معينين، لذلك فإن الحسابات التي تعتمد على مكونات النفط تكون أكثر دقة وسهولة في إيجاد هكذا نوع من المطالب.

في هذا البحث تم استخدام تحاليل مختبرية لعشرين نموذج جمعت من مختلف حقول جنوب العراق، استخدمت في هذا البحث معادلة (3 Parameters Peng-Robinson) لعمل التوافق بين لزوجة النفط المخرجة من التحاليل المختبرية وبين المحسوبة بواسطة البرنامج المستخدم. (LBC Correlation) هي الطريقة المتبعة لحساب لزوجة النفط لجميع الآبار المستخدمة تحت ضغوط ودرجات حرارة مختلفة اعتمادا على مركبات نفوط هذه الآبار. معادلة الحالة استخدمت لإيجاد تطابق جيد بين قيم اللزوجة المقاسة والمحسوبة وكذلك إيجاد قيم جديدة للزوج لنطاق واسع من درجات الحرارة والضغط.

ادخلت اللزوجة المحسوبة في برنامج الذكاء الصناعي (Neural Network) لإيجاد نموذج الكتروني لحساب لزوجة النفط باستخدام التركيب والضغط والحرارة، بعد إيجاد النموذج وجد ان نسبة الخطأ كانت ضئيلة جدا مما يبرهن نجاح عملية النمذجة، كذلك تم فحص النموذج للتأكد من صحة عمله وذلك بأدخال بيانات بئر جديد لم تدخل بياناته في عملية النمذجة وكانت النتائج مطابقة للقيم المقاسة.

Introduction:

Viscosity is a very important parameter that governs the flow of fluids either in a porous media or through transporting pipes. Sometimes, the measurement of oil viscosity is costly especially when the oil has dissolved gas. Therefore, a number of correlations [2-9] have been developed to provide alternative tool for getting the viscosity of specific hydrocarbon at the certain conditions. The most common correlation is the Lohrenz-Bray-Clark [1] (LBC). LBC is an efficient tool for viscosity estimation for the operating time management. Therefore, it is usually used in reservoir simulation where the execution time is a principal factor.

In this work, 20 live sample analyses are implemented. The data has been provided as PVT reports. The reports include the measurement of oil viscosity at certain temperatures with pressure values ranging from atmospheric pressure up to the initial reservoir pressure. The PVT reports also include the composition of oil with one

pseudo component. The saturation pressure is also recorded for each sample at a given temperature.

The above-mentioned data is used to tune an equation of state using the principle of the corresponding state for computing the oil viscosity. The viscosity is calculated by LBC correlation, which is then used to create viscosity data used in developing the model. The oil viscosity model is the ultimate target of the current project. A nonparametric regression method is elected to correlate the data. The neural network [10] technique is selected for creating the model.

Viscosity matching:

In this work, the composition of 20 Iraqi oil samples is considered. The samples were taken from several southern Iraqi oil fields, reservoirs, and wells. Before estimating the oil viscosity from its composition, temperature, and pressure, the experimental data should be fitted with the results of the equation of state. In the tuning of the equation of state, its variables are adjusted well to make its results close enough to the experimental test. The used oil properties in tuning phase are the saturation pressure and oil properties at pressure range from the atmospheric pressure to the initial reservoir pressure. The good match between real PVT data and calculated data is necessary to generate a large set of viscosity values in different temperatures. This set of values is used in neural network fitting tool to get a good viscosity correlation.

Matching is done with PVTi software by doing regression for the equation of states parameters such as critical pressure, critical temperature, and the acentric factor for all components. Matching between calculated and real data is tested by the root mean square (RMS) of these values. The smallest RMS is found for the best match. Table (1) and Figure (1) show the matching of one of the wells that are adopted in this work (Amara-4).

Table (1) Matching Between Calculated and Observed Viscosity

Well no.		Am-4	
Field		Amara	
Formation		Mishrif	
Bottom Hole Temperature		210.2 °F	
Observed Saturation Pressure		2588.04 psi	
Calculated Saturation Pressure		2596.988 psi	
RMS%		0.026483	
Liquid Viscosity, cp			
Pressure	Observed	Calculated	(RMS) %
5688	1.808	1.8065	0.08109
4977	1.696	1.6922	0.22370
4266	1.584	1.5765	0.47276
3555	1.472	1.4596	0.84412
2844	1.36	1.3415	1.35690
2596.988	-	1.3003	-
2588.04	1.3	1.3042	0.32371
2133	1.5	1.5227	1.516
1422	1.976	1.9646	0.57571
14.695		4.8224	

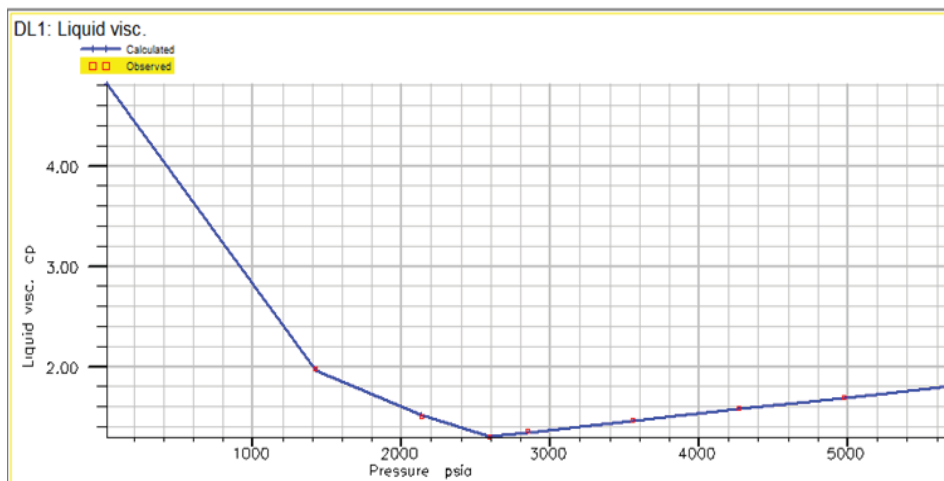


Fig. (1) Matching Between Calculated and Observed Viscosity

Generating Viscosity Data

To create a viscosity model, a large set of data is needed. Different temperatures values were used to produce viscosity. The temperature values were (100, 120, 140, 160, 180, 200, 220, 240, 260, 280 and 300)° F. These values were from the range of reservoir temperature values of 20 wells that are used in this work. The range of pressure used is from the initial pressure to the surface pressure of each well. The calculation was applied to all oil wells and 4609 viscosity values were calculated. These values are used in neural network function to get the viscosity model.

Viscosity Model

The nonparametric regression tool, neural network, is proved to produce good fitting models even if the network is a simple one. Consequently, this technique is adopted in the current work. Neural network function needs 3 sets of data; training data, validation data, and test data. Training data are the set of data that would be used to train the proposed network. The network is adjusted according to the training data as giving the minimum error. Validation data are used to measure the network improvement and would stop the training process when the improvement ceased. The test data are measuring the performance of the model independently. These three sets of data are provided from the calculated viscosity data.

The inserted data were the mole fraction of each component, pressure, and temperature, which were inserted as an input data (3 independent variables). Viscosity data were inserted as a target data. The results found from inserted the data of 20 wells is represented in the following points. The correlation coefficient, R, is an indication of the relation between the target and the output. The value of R ranges from 0 to 1. Zero value of R means there is no relation between the input and the target. On the other hand, the values are the average of the squared divergence between the target and the output. The perfect value of this variable is zero when all inputs coincide with all of the outputs.

Three different models are found. First model has been made with Levenberg-Marquardt [11] back propagation, which is usually the fastest. The second model has

been made with Bayesian Regularization [12, 13] back propagation, which takes longer time but may be better for challenging problems, like existence of many independent variables and their large amount and differences of them .While the third model has been made with scaled conjugate gradient [14] back propagation, which uses less memory and so it is suitable in low memory situations.

The difference between the three neural network models is presented in Figures (2 to 10).

Figures (2) to 4 show the regression plots of the models. Regression plots explain the difference between the calculated output and the input target. The equation that shown in the y-axes in regression plot represent the best straight line that means the target factor much closer to 1 gives better result, and the constant must be closest to zero. It was found from the results that the second model was the best one.

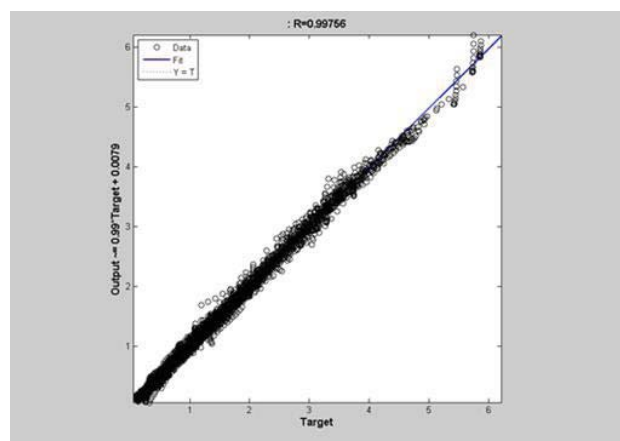


Fig. (2) Regression plot of model 1

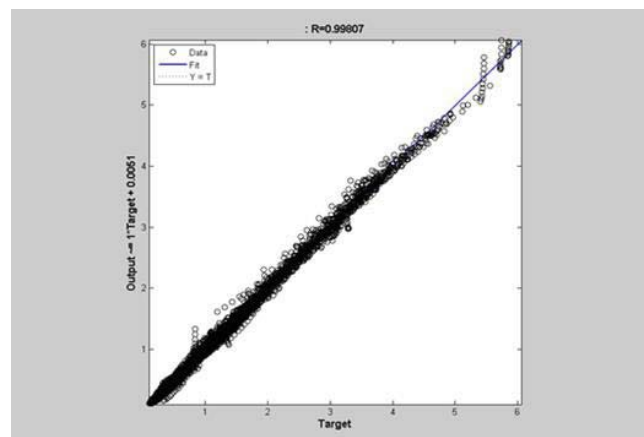


Fig. (3) Regression plot of model 2

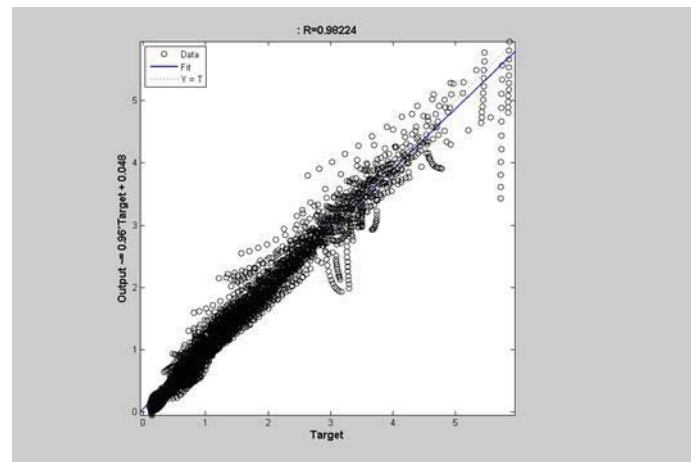


Fig. (4) Regression plot of model 3

Figures (5 to 7) show the error histogram of each model. This plot shows the instance of the error of the model. The x-axes represent the instance of viscosity values, while the y-axes represent the frequency of the points having the mentioned error in viscosity values. The negative errors values mean the results are lower than the inputs and the positive values mean the results are higher than the inputs. Figure (5) shows the median of the instance (1400 values of viscosity) is at error value of (0.002179), while Figure 6 shows the median (1600 values) error is (-0.0582) and Figure (7) shows that (2000 values) is at error of (-0.04326). In Figures (5 and 6) showed the scale of the error axes is between (-0.4 to 0.35) while it is between (-1 to 2.21) in Figure (7). This means the third model have the highest error values. It is noticed from the comparison between histograms of the first and second models, Figures (5) and 6 that the instance of values for the first one is approximately 2000 values at errors between (-0.04 to 0.04) while for the second one is about 1400 values at error of 0.02, which means the second model is the best one.

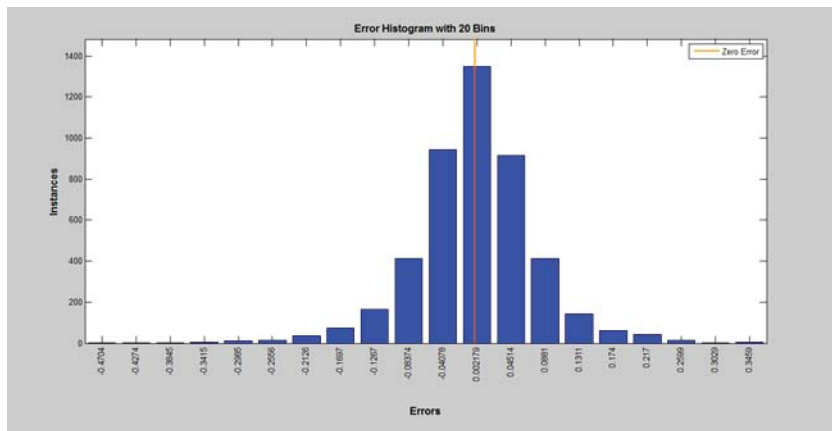


Fig. (5) Error histogram of model 1

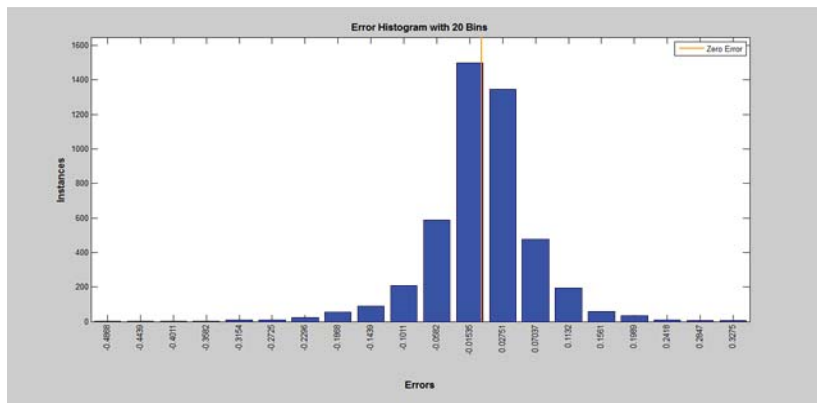


Fig. (6) Error histogram of model 2

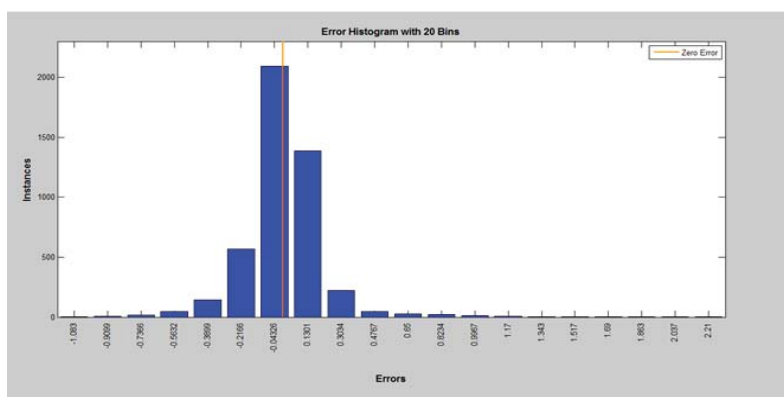


Fig. (7) Error histogram of model 3

The last three Figures (8 to 10) show the performances of the data of each model. Performance plot shows the Mean Square Error (MSE) with the number of epochs.

The training stops when the validation data reach the best performance. Figure (9) shows that in model 2, no validation data has been inserted; that means, the training has stopped when the maximum epochs have reached the maximum default number of epochs (1000) and the improvement still continuous. However, it is concluded that few epochs are required to reach the state of no improvement since the MSE approaches to a very small value.

Viscosity Comparison:

Viscosity of three wells could be represented in this work. One of these three wells wasn't inserted in the neural network while developing the model (the one unnamed well). The viscosity has been calculated with the three models and shown in tables (2 to 4) with the root mean square error (RMS).

Data of the same mentioned three wells has been inserted in PVTp software to calculate their viscosity with three other empirical correlations which are Beal et al. [2], Beggs [3], Petrosky [9]. The results of these three correlations have been compared with the result of the three models and shown in Tables (2 to 4).

In Tables 2 to 4 the measured and calculated viscosities at different pressure for wells Hf-1, Am-4, and well (1) are presented. The values of RMS1, RMS2 and RMS3 in these Tables represent the errors between the measured values and calculated by model1, model2 and model3 respectively. While the errors RMS4, RMS5, and RMS6 are between measured viscosity and these obtained from Beal et al., Beggs, and Petrosky correlations respectively. Figures (11–13) also show the comparison between measured and calculated viscosity values for each well.

Comparison of RMS1, RMS2 and RMS3 with RMS4, RMS5 and RMS6 shows that the three developed models have generally better performance than the three correlations results. The second model can be considered as the best one according to its lower error.

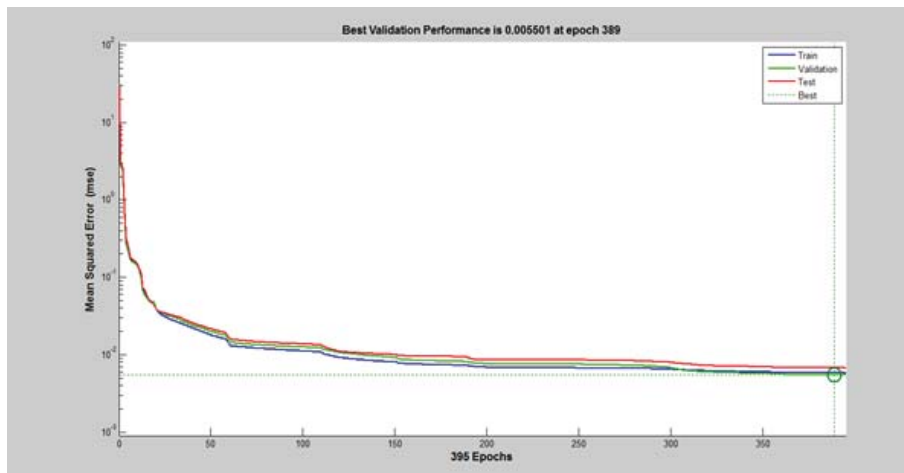


Fig. (8) Performance plot of model 1

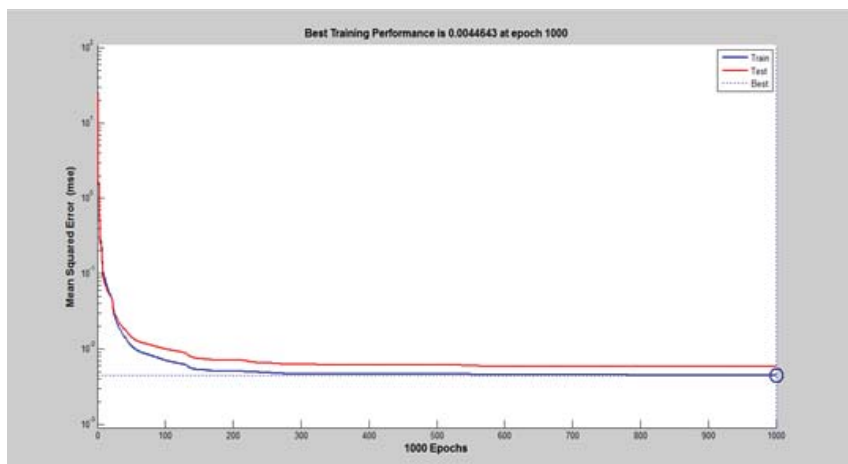


Fig. (9) Performance plot of model 2

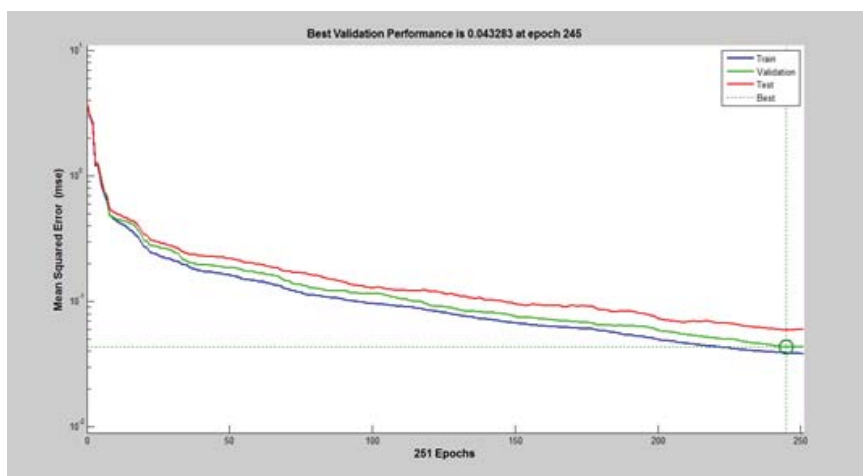


Fig. (10) Performance plot of model 3

Table (2) Comparison between calculated and actual viscosity for Hf-1

Pressure, psi	Measured vis., cp	Calculated LBC vis., cp	Modell vis., cp	Model 2 vis., cp	Model 3 vis., cp	Beal et al. vis., cp	Beggs vis., cp	Petrosky vis., cp	RMS1	RMS2	RMS3	RMS4	RMS5	RMS6
5498.874	0.676	0.6571	0.664	0.667	0.6599	1.89002	19.4765	3.06346	0.012	0.009	0.0161	1.21402	18.8005	2.38746
4998.33	0.648	0.6347	0.63	0.635	0.6175	1.84617	16.0339	2.94143	0.018	0.013	0.0305	1.19817	15.3859	2.29343
4499.208	0.62	0.612	0.603	0.611	0.58	1.80245	13.0504	2.81975	0.017	0.009	0.04	1.18245	12.4304	2.19975
3998.664	0.603	0.5889	0.585	0.592	0.5483	1.7586	10.4969	2.69773	0.018	0.011	0.0547	1.1556	9.8939	2.09473
3499.542	0.579	0.5655	0.577	0.58	0.5241	1.71488	8.36317	2.57605	0.002	0.001	0.0549	1.13588	7.78417	1.99705
2998.998	0.555	0.5416	0.582	0.578	0.5111	1.67103	6.60255	2.45402	0.027	0.023	0.0439	1.11603	6.04755	1.89902
2499.876	0.58	0.5753	0.605	0.593	0.5158	1.62731	5.18463	2.33235	0.025	0.013	0.0642	1.04731	4.60463	1.75235
1999.332	0.64	0.6647	0.652	0.635	0.55	1.58346	4.05837	2.21032	0.012	0.005	0.09	0.94346	3.41837	1.57032
1497.366	0.714	0.7761	0.731	0.719	0.637	1.53949	3.18411	2.08795	0.017	0.005	0.077	0.82549	2.47011	1.37395
999.666	0.845	0.9138	0.856	0.872	0.811	1.4959	2.5329	1.96662	0.011	0.027	0.034	0.6509	1.6879	1.12162
500.544	1.055	1.0813	1.045	1.094	1.1317	1.45217	2.07069	1.84494	0.01	0.039	0.0767	0.39717	1.01569	0.78994
250.272	1.265	1.1755	1.18	1.163	1.3727	1.43025	1.91227	1.78392	0.085	0.102	0.1077	0.16525	0.64727	0.51892
99.54	1.494	1.2438	1.426	1.437	1.55	1.41705	1.84762	1.74718	0.068	0.057	0.056	0.07695	0.35362	0.25318

Table (3) Comparison between calculated and actual viscosity for Am-4

Pressure, psi	Measured vis., cp	Calculated, LBC vis., cp	Model 1 vis., cp	Model 2 vis., cp	Model 3 vis., cp	Beal et al. vis., cp	Beggs vis., cp	Petrosky vis., cp	RMS1	RMS2	RMS3	RMS4	RMS5	RMS6
5688	1.808	1.8065	1.853	1.722	1.697	1.56587	1.01154	1.85101	0.047	0.086	0.111	0.24213	0.79646	0.04301
4977	1.696	1.6922	1.743	1.693	1.581	1.50173	0.948219	1.69334	0.029	0.003	0.115	0.19427	0.747781	0.00266
4266	1.584	1.5765	1.613	1.602	1.488	1.50531	0.926424	1.61878	0.003	0.018	0.096	0.07869	0.657576	0.03478
3555	1.472	1.4596	1.469	1.463	1.435	1.87731	1.09395	1.98933	0.006	0.009	0.037	0.40531	0.37805	0.51733
2844	1.36	1.3415	1.354	1.368	1.452	2.35264	1.31778	2.4802	0.05	0.008	0.092	0.99264	0.04222	1.1202
2588.04	1.3	1.3003	1.35	1.375	1.485	2.55421	1.4178	2.69405	0.022	0.075	0.185	1.25421	0.1178	1.39405
2133	1.5	1.5227	1.478	1.473	1.591	2.95986	1.63103	3.13318	0.044	0.027	0.091	1.45986	0.13103	1.63318
1422	1.976	1.9646	2.02	1.875	1.933	3.74204	2.09932	4.00316	0	0.101	0.043	1.76604	0.12332	2.02716

Table (4) Comparison between calculated and actual viscosity for a well (1)

Pressure, psi	Measured vis., cp	Calculated, LBC vis., cp	Model 1 vis., cp	Model 2 vis., cp	Model 3 vis., cp	Beal et al. vis., cp	Beggs vis., cp	Petrosky vis., cp	RMS1	RMS2	RMS3	RMS4	RMS5	RMS6
4266	3.4	3.3172	3.2932	3.3943	3.1687	4.53142	2.27802	3.65147	0.1068	0.0057	0.2313	1.13142	1.12198	0.25147
3555	3.199	3.1802	3.1179	3.1108	3.1472	4.31273	2.10283	3.41898	0.0811	0.0882	0.0518	1.11373	1.09617	0.21998
3199.5	3.094	3.1102	3.0639	3.0427	3.1524	4.18152	2.011	3.27949	0.0301	0.0513	0.0584	1.08752	1.083	0.18549
2844	2.986	3.0392	3.0539	3.0277	3.1731	4.09405	1.95607	3.18649	0.0679	0.0417	0.1871	1.10805	1.02993	0.20049
2282.31	2.82	2.9249	2.1458	3.1182	3.2529	4.78491	2.21943	3.67305	0.6742	0.2982	0.4329	1.96491	0.60057	0.85305
1848.6	3.069	3.2122	3.3116	3.2886	3.3745	5.75997	2.62235	4.39726	0.2426	0.2196	0.3055	2.69097	0.44665	1.32826
1422	3.444	3.5555	3.5537	3.5462	3.5696	6.92321	3.13759	5.27509	0.1097	0.1022	0.1256	3.47921	0.30641	1.83109
995.4	4.034	3.9589	3.8709	3.8969	3.8638	8.31567	3.81471	6.33395	0.1631	0.1371	0.1702	4.28167	0.21929	2.29995
568.8	5.135	4.3965	4.2601	4.2867	4.2725	9.94915	4.71065	7.57157	0.8749	0.8483	0.8625	4.81415	0.42435	2.43657
14.22	6.82	5.6285	5.8034	5.8767	4.9523	12.383	6.30348	9.37909	1.0166	0.9433	1.8677	5.563	0.51652	2.55909

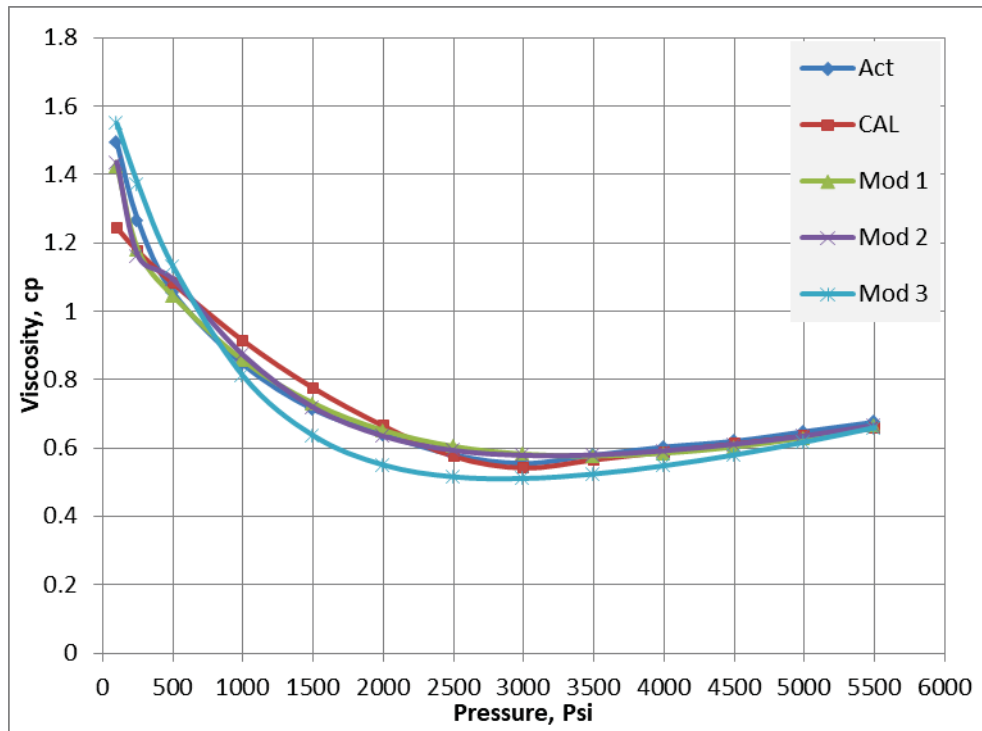


Fig. (11) Viscosity matching of the three models, Hf-1

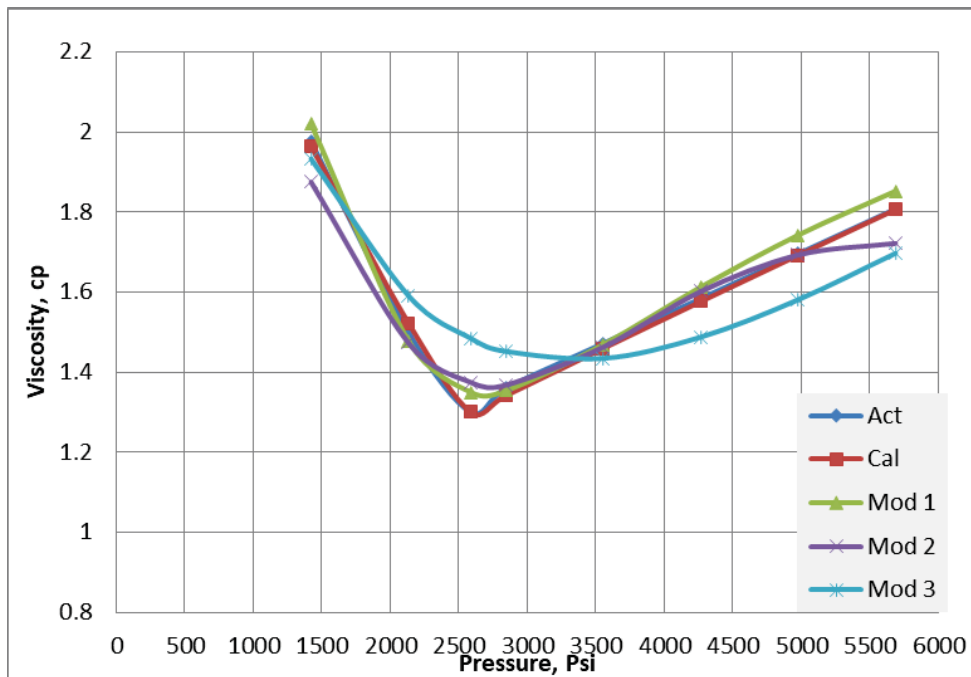


Fig. (12) Viscosity matching of the three models, Am-4

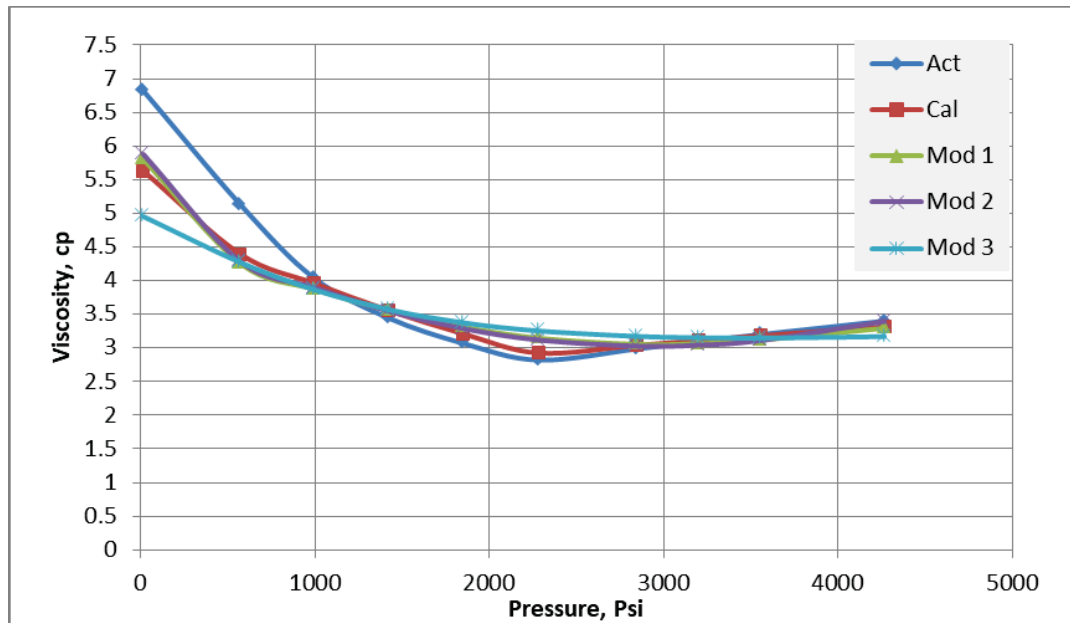


Fig. (13) Viscosity matching of the three models, well (1)

Conclusions:

1. A viscosity model was developed to calculate the viscosity of oil in the fields of southern part of Iraq using the mole fractions of the component, pressure, and temperature.
2. The calculated viscosity was found very close to the measured viscosity due to the perfect match exhibited by the new model.

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