A Comparative Study on Oil Performance Prediction Methods: The Case of Shuanghe Oilfield, China

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Abstract: While being the dominant source of energy, oil has also brought affluence and power to different societies. Energy produced from oil is fundamental to all parts of society. In the foreseeable future, the majority of energy will still come from oil production. Consequently, reliable methods for forecasting that production are crucial. Petroleum engineers have searched for simple but reliable way to predict oil production for a long time. Many methods have been developed in the latest decades and one common practice is decline curve analysis. Prediction of future production of petroleum wells is important for cost-effective operations of the petroleum industry. This work presents a comparative analysis of methods used to predict the performance of Shuanghe oilfield, China. Using decline curve analysis including three different methods: Arps empirical methods, LL-model and simplified model and the new simplified model, LL-Model, to crosscheck Arps exponential decline model prediction results. The results showed by the comparative analysis of predictions calculated proved LL-model to be the best predictor for Shuanghe oilfield since it takes into account more parameters than the old models used in this work. However, the subsurface information or parameters of the reservoir used in LL-model may not be available every time, therefore Arps models may apply as defined. In Shuanghe oilfield calculated average geological reserves N was estimated at 9449.41 $\times 10^4$ tons, the average recoverable reserves N_R were estimated to 4274.61×10^4 tons while the water cut was 97% and the water cut predicted by LL-model was 96.7%; not far from water flooding curves value. The exponential decline model showed recoverable reserves $\mathbf{N_R}$ estimated around 4685.88×10^4 tons of oil while the decline phase of total development was estimated around 34 years which means that if the actual production conditions remain unchanged, Shuanghe oilfield would continue producing for another 25 years from 2008.

Key words: Shuanghe oilfield, Oil production prediction, decline curve

1 Introduction

Decline curve analysis is a graphical procedure used to analyse declining production rates and forecast future performance of oil and gas wells (Fetkovich, 1980; Da Prat et al, 1981). A curve fit of past production performance is done using certain standard curves. This curve fit is then extrapolated to predict potential future performance. Decline curve analysis is a basic tool for estimating recoverable reserves. However, conventional or basic decline curve analysis can be used only when the production history is long enough that a trend can be identified (Agarwal, et al., 1999; Agbi and Ng, 1987; Arps, 1945)

However, decline curve analysis is fundamentally an empirical process based on historical observations of well performance. Because of its empirical nature, decline curve analysis is applied, as deemed appropriate for any particular situation, on single or multi-fluid streams. It is implicitly assumed that, when using decline curve analysis, the factors causing the historical decline continue unchanged during the forecast period. These factors include both reservoir conditions and operating conditions. Some of the reservoir factors that affect the decline rate include: pressure depletion, number of producing wells, drive mechanism, reservoir characteristics, saturation changes and relative permeability (Chenet al., 2009; Hu et al., 2007; Fetkovich et al., 1987;). Operating conditions that influence the decline rate are: separator pressure, tubing size, choke setting, workovers, compression, operating hours, and artificial lift. As long as these conditions do not change, the trend in decline can be analysed and extrapolated to forecast future well performance. If these conditions are altered, for example through a well workover, then the decline rate determined pre-workover will not be applicable to the post-workover period (Agarwal, et al., 1999; Agbi and Ng, 1987, Feteke, 2010). Good engineering practice demands that, whenever possible, decline curve analysis should be reconciled with other indicators of reserves, such as volumetric calculations, material balance, and recovery factors. Most of the existing decline curve analysis techniques are based on the Arps empirical equations: exponential, hyperbolic, and harmonic. However, the main concern rise on one hand in the judgment of which equation among the three the reservoir will follow. On the other hand, these types of declines have their limitations. In some cases, production decline data does not follow any models and just crosses over these decline curves. So, estimating the natural decline rate has been a challenge for many years (Höök et al., 2009 Chen, 2003). Many experts have attempted to interpret the empirical Arps equations or to provide some theoretical based on specific cases. It seems that few of new models have consolidated theory behind. As Raghavan (1993) pointed out, "Until the 1970s, decline curve analysis was considered to be a convenient empirical procedure for analyzing performance; no particular significance was to be attributed to the values of D_i and b. To an extent, this is still true even today." This may be the case still, even though another 10 years have passed. Xie *et al* (2010) focused on advanced decline analysis using integration and analysis of sub-surface information and well performance data, and combined static (geological) and dynamic flow models to predict reservoir performance. There is more here than just replacing the modeling process with a function. In this work we cross-checked the results produced using LL-model of Xie *et al*, (2010) and the simplified model of Khaled (2006), for which the decline rate D and the exponent b (noted as n by some authors), are generated from production history data by double regression method in Shuanghe oilfield. Actually, we predicted the production performance using D_i and b calculated using LL-model in the Arps equations because those parameters (D_i and b) were already calculated considering sub-surface information. After this prediction we proceeded to the other prediction technique which, as proposed by Khaled (2006), combines both exponential and hyperbolic in one equation to predict production performance.

2 Methodology

It is always very difficult to decide which decline curve model (among the three; exponential, hyperbolic, harmonic) to be used to predict reservoir performance. This brings errors related either to the use of incompatible model or the natural weakness of the used model. Furthermore, previously used decline curve analysis techniques did not take into account the sub-surface information. To compensate

http://www.eajscience. com ISSN 2227-1902 (Online version) eajscience@gmail.com

for this problem, a solution has been implemented that limits the minimum decline rate value. On one hand, Khaled (2006) and Chen et al. (1996) developed a simple technique for evaluating production data by decline curve and combined both exponential and hyperbolic to generate a new model which use exponential decline to extrapolate hyperbolic decline. On the other hand, Xie (2010) developed a new model *"LL-model"* which involves sub-surface information to calculate the decline rate. The results of prediction calculated using both methods will be compared to decide which predicts more accurately the performance of Shuanghe oil reservoir.

i. Description of the simplified model

The model introduced a simple method to obtain the point where the decline is expected to hold and follow an exponential decline. One can easily calculate reserves for the separate hyperbolic and exponential decline segments, and add them together to estimate the total remaining reserves. The proposed model was simple compared to the models available in the literature, and provided almost similar results while saving significant time and efforts. In other words, this model is very handy and easy to use, especially for routine industry tasks. All decline curve theory starts from the definition of the instantaneous or current decline rate (*D*). Taking the derivative of exponential equation with respect to time, results in equations below.

$$\frac{dq}{dt}=\frac{d\left[q_i(1+bD_it)^{\frac{-1}{b}}\right]}{dt}=q\left[\frac{-D_i}{(1+bD_it)}\right]$$
(1)

$$\frac{-qdq}{dt}=\frac{1}{D_i+bt} \quad \textbf{(1)}$$

From the definition of the hyperbolic decline curve, the value of decline rate *D* at time *t* can be determined from the following equations [17, 19-20, and 16] : Rowland and Chung,1985; Shirman, 1999 ; Nind, 1981; Thompson, et al., 1987; Ibrahim et al., 2002)

$$D=\frac{1}{-q}\frac{dt}{dq}=\frac{1}{\left(\frac{1}{D_i+bt}\right)} \quad \textbf{(3)}$$

$$\frac{1}{D}=\frac{1}{D_i+bt}=\frac{1+btD_i}{D_i} \quad \textbf{(4)}$$

$$D=\frac{D_i}{(1+bD_it)} \quad \textbf{(5)}$$

By differentiating the equation 5 to determine the time t_o, at which one must change the forecast from hyperbolic to exponential decline we have:

$$\frac{dD}{dt}=\frac{d\left(\frac{D_i}{1+bD_it}\right)}{dt} \quad \textbf{(6)}$$

$$\frac{dD}{dt}=\frac{-bD_i^{\,2}}{(1+bD_it)^2} \quad \textbf{(7)}$$

With $\frac{dD}{dt}$, the rate of change of decline rate with time; which is constant and noted as *C*. That constant C should be close to zero where the decline rate of exponential decline is constant for all time, to match the transition point to transfer from hyperbolic to exponential decline. If the transition point occurs at t_o then from equation 7 t_o can be expressed as:

$$t_o=\frac{\left(\frac{-bD_i^2}{C}\right)^{0.5}-1}{bD_i} \quad (8)$$

From this time value t_o, we can determine the corresponding exponential decline rate D, which will be constant over the next time period to the economic limit by substituting t_o in equation 5: Therefore, the initial exponential production rate may be obtained by substituting t_o in equation 9. A production rate in the exponential decline segment can be expressed by expanding equation 8 as shows equation 10. Thus, the combined hyperbolic and exponential production decline equation can be expressed as follows:

Hyperbolic decline segment

$$q=q_i(1+bD_it_i)^{\left(\frac{-1}{b}\right)} \quad (9)$$

For $0 \le t \le t_0$

Exponential decline segment

$$q = q_i(1 + bD_it_i)^{\left(\frac{-1}{b}\right)} exp\left(\frac{-D_i(t-t_i)}{1+bD_it_i}\right)$$
(10)

For $t \geq t_0$

Description of LL-Model

The Arps decline curve analysis approach was proposed nearly 60 years ago. However, a great number of studies on production decline analysis are still based on this empirical method. Many published papers have tried to interpret the Arps decline equation theoretically (Hu et al., 2007; xie et al., 2010). The empirical Arps decline equation is used to represent the relationship between production rate and time for oil/gas wells during the pseudo-steady state period and is shown in hyperbolic equation:

Where *q* is the oil production rate at time *t* and q_i is the initial oil production rate; *b* and D_i are two constants. Hyperbolic equation can become two special cases when *b* equals to 0 or 1: b=0 represents an exponential decline in oil/gas production; b=1 suggests a harmonic decline in oil/gas production. Any other value of *b* between 0 and 1 indicates a hyperbolic decline in oil/gas production. The type curves based on the Arps equations are used for production decline analysis good for the pseudo-steady state phase. The curves (D_i vs water cut) are shaped like a set of saddles in different liquid production rates. The saddle shape enables D_i to decline quickly during high water cut periods. On the contrary, the decline rate is relatively slow in the field after water cut higher than 90 percent.

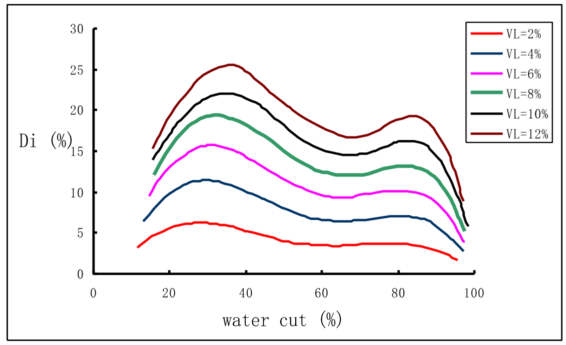


Figure 8. Typical decline rate curves (decline rate vs water cut) in different VL in Shuanghe oilfield (Xie , 2010)

Xie (2010) developed an analytical model called LL-model to predict decline rate with time for high water cut periods. This model is expressed as follows:

$$D_i = D_o + at^b e^{-ct} \quad (11)$$

Where D_i is the decline rate at time *t* and D_0 is the initial decline rate by the year when the production starts to decline. The values of the three constants *a*, *b* and *c* are associated with the formation factors: Kh (product of formation permeability and net pay), porosity (φ) and remaining oil saturation (Soi), respectively (Table 1). Equation 11 was solved in terms of decline rate and time. Using the reservoir properties in Shuanghe oilfield, equation 11 could become the following equation:

$$D_i = 4.5 - 4.375t^{0.1837}e^{-0.1163t}$$
(12)

Table 2 The relationship between three constants (a,b and c) and formation factors (Kh, Φand Soi)

Type	Kh(mD.m)	A	B	Φ (%)	C	Soi (%)
I	>10	-4.529～-4.22	0.1376～0.2298	>21	0.1089 ～ 0.1237	>35
II	6-10	-4.245～-3.81	0.1777～0.3238	19-21	0.1277 ～ 0.1518	30-35
III	1-6	-3.893～-3.17	0.2505～0.5387	10-19	0.1623 ～ 0.2123	28-30

The program written and ran in Matlab-m language can calculate the natural decline rate in any time. We use ND_i instead of Di to fit the curve in order to display when water cut is close to the limited water cut. ND_i is the sum of every D_i when the program was run. This program may predict future decline rates. More, the analytical model was benchmarked with some conventional models. Equation 12, demonstrates the non-linear relationships between the natural decline rates and the production time. If time *t* is replaced by water cut in equation 12, the curves could become the forms shown in Fig.3, which shows that the LL-model predicts decline rate during high water cut periods in the oilfield. The curve in Fig.3 indicates that the decline rate would become moderate when water cut is higher than 96.2 percent until the economic limit in the Shuanghe oilfield. A series of similar curves can be derived from different *a*, *b* and *c* within the range like shown in table 1. Fig.3 shows three types of decline curves which are practically used in Shuanghe oilfield. The best one is type I with high Kh (Kh>10), high porosity (φ>21%) and high remaining oil saturation (Soi >35%); the worst one is type III with low Kh (1<Kh<6), low porosity (φ<19%) and low remaining oil saturation (Soi<30%); Type II is the middle case between type I and type III. The exact relationships between *a* and *Kh*, *b* and *φ*, *c* and Soi need to be investigated further. But one thing can be proved that the better the oil reservoir quality is the slower oil production rate declines [18, 7, 15].

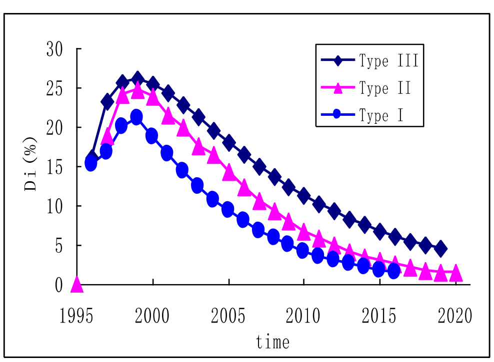


Figure 9 Different decline rate curves with three sets of oil reservoir properties

To validate the LL-model, we computed the predicted decline rates in 2007 and 2008 using equation 12 and compared with the field observed decline rates.

3 Results and discussions

Predicting decline rate D_i using LL-model

This part presents a new model called LL-model prepared by Xie (2010) to predict decline rate using integration and analyses of sub-surface information and dynamic data. As described, this new model puts into consideration some sub-surface information for the forecast of decline rate. Furthermore, this model will be used not only to predict decline rate and water cut but also oil production in Shuanghe oilfield. In this model the focus was put on advanced decline analysis using integration and analyses of sub-surface information and well performance data, and combined static (geological) and dynamic flow models to predict reservoir performance. The type curves based on the Arps equations are used for production decline analysis good for the pseudo steady-state phase. LL-model is an analytical model to predict decline rate with time for high water cut periods. It is expressed as shown in equation 11, where D_i is the decline rate at time *t* and D_o is the initial decline rate by the year when the production starts to decline.

Table 3.Shuanghe oilfield predicted decline rate D_i by LL-model

Time	Actual decline rate (D_i, %)	Predicted decline rate (D_i, %)
2000	7.29	5.2
2001	9.3	7.4
2002	14.34	12.6
2003	14.45	12.9

2004	17.8	16.4
2005	17.31	16.1
2006	16.42	15.3
2007	17.3	16.9
2008	13.86	13.6
2009	13.52	12.4
2010	12.45	11.3
2011		10.2
2012		9.2
2013		8.3
2014		7.5
2015		6.5
2016		6.2
2017		6.1
2018		5.9

Table 5 shows the results of a 10 year predicted decline rate D_i calculated using LL-model. The period from 2000-2008 is the comparison between actual rates and predicted rates and the period from 2009-2018 is only prediction. As it can be seen, taking into account reservoir subsurface information, the decline rate D varies more or less at constant rate. The predicted water cut using the same LL-model shows the highest value of 96.7% (Table 6), while the water displacement curve shows the value of 97% which is slightly high the offset is 0.3% only.

Table 4 Shuanghe oilfield predicted decline rate *Di* and water cut f_w

Time	Predicted decline rate (Di, %)	Water cut (f_w, %)
2009	12.4	95.8
2010	11.3	95.9
2011	10.2	96.0
2012	9.2	96.1
2013	8.3	96.2
2014	7.5	96.3
2015	6.5	96.4
2016	6.2	96.5
2017	6.1	96.6
2018	5.9	96.7

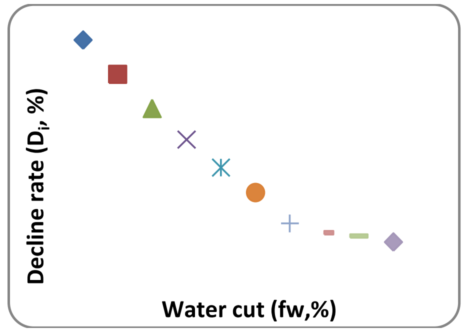


Figure 10. Shuanghe Oilfield predicted decline rate D_i versus water cut calculated using LL-model

As shows the Fig.5, decline rate D_i varies very fast but becomes moderate when the water cut f_w grows high above 96.4 % in Shuanghe oilfield. After the prediction of Decline rate D_i and f_w using LL-model, oil production need to be forecasted as well.

ii. Predicting oil production using LL-model

In previous parts of this section "*LL-model*" has been used to predict some useful parameters like f_w and *Di* for oil production prediction. Starting from the already calculated parameter we can calculate the remaining ones like exponent *b* and the initial flow rate q_i. Using multiple regression analysis for Shuanghe oilfield production data we calculated *b* which equals to 0.22 and the initial flow rate q_i =86.78. As mentioned the decline *Di* varies with time and its actual and predicted values were reported in table 5. The following prediction of oil production will follow the hyperbolic equation and results are shown in table below.

2.

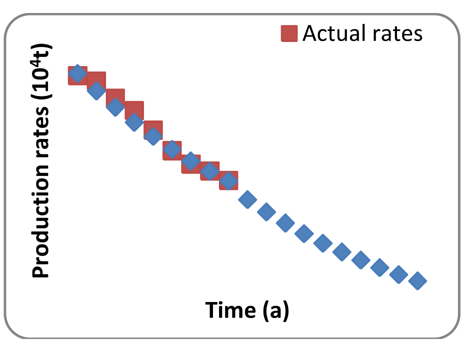
3.

4. Table 5 Shuanghe oilfield oil production predicted using LL-Model

Year	Time interval	Actual rates (10^4 tons/a)	Predicted Rates (10^4 tons/a)

2000	0	86.11	86.78
2001	1	84.46	81.36
2002	2	79.19	76.34
2003	3	75.32	71.70
2004	4	69.32	67.39
2005	5	62.96	63.40
2006	6	58.82	59.69
2007	7	56.71	56.62
2008	8	53.78	53.58
2009	9	51.86	47.83
2010	10	49.71	44.05
2011	11		40.57
2012	12		37.37
2013	13		34.42
2014	14		31.71
2015	15		29.20
2016	16		26.89
2017	17		24.76
2018	18		22.79

Table 7 reports the 10 year prediction of Shuanghe oilfield production rates. The first 9 years (2000-2008) showed the comparison between actual rates and predicted rates, which showed that both values were almost similar even though prediction is never the reality. The relative errors are very small, and we can conclude that our predictions are accurate. Based on this comparative period we can assume that if conditions remain unchanged in Shuanghe oilfield for the next 10 years (2009-2018) the production will continue to decline up to the rate of 22.79 (10^4 tons/a) by the year 2018.



5. Figure 11 Shuanghe oilfield predicted oil production rates calculated using LL-model.

The Figure 6 shows the prediction of oil production in Shuanghe oilfield for 19 years from 2000-2018 as far as LL-model is concerned. The blue dots represent the actual rates while red ones stand for predicted rates. During that first period of actual rates production was declining and LL-model predicted new values for the flowing 10 years as if reservoir conditions continued to behave and evolve in the same way. The innovation brought by this new model is the consideration of sub-surface information like formation factors: Kh (product of formation permeability and net pay), Φ (porosity) and so on. That sub-surface information was used to calculate the prediction of decline rate *Di* which later has been integrated in the equation to calculate the oil production prediction.

i. *Predicting oil production using simplified model*

The hyperbolic curve frequently yields an unrealistically high reserve estimate and lifetime because the curve continually flattens with time. To compensate for this problem, a solution has been implemented that limits the minimum decline rate value. Khaled (2006) developed a simple technique for evaluating production data by decline curves. Hyperbolic decline curve occurs when the decline rate is no longer constant. From the definition of the hyperbolic decline curve by different works, the value of decline rate D, at time t, can be determined from the equations 2, 3, 4 and 5:

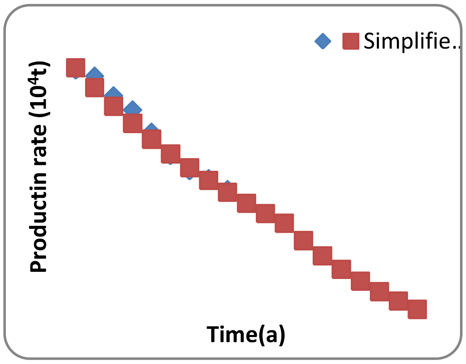
By differentiating equation 5 we can determine the time t_0, at which one must change the forecast from hyperbolic to exponential decline, this results in equation

6.

7. 6 and 7 where $\frac{dD}{dt}$ is the rate of change of decline rate with time; which is constant noted as C. The time where the model shifts from hyperbolic to exponential decline is noted as t_0. The constant *C* should be close to zero where the decline rate of exponential decline is constant for all the time, to match the transition point to transfer from hyperbolic to exponential decline. If the transition point occurs at t_0, then from equation 8, t_0 can be expressed as shows equation 9. From this time value t_o, we can determine the corresponding exponential decline rate *D*, which will be constant over the next time period to the economic limit by substituting t_0 in equation 9. The initial exponential production rate may be obtained by substituting t_0 into the hyperbolic equation 9.Calculations gave the time t_o=3.6 years and the initial exponential rate q_i=44.67 as reported in table 8.

Table 6 Shuanghe oilfield oil production predicted using simplified model

Year	Time interval	Actual rates (10^4 t)	Predicted rates (10^4 t)
2000	0	86.11	86.78
2001	1	84.46	81.36
2002	2	79.19	76.34
2003	3	75.32	71.70
2004	4	69.32	67.39
2005	5	62.96	63.40
2006	6	58.82	59.69
2007	7	56.71	56.25
2008	8	53.78	53.04
2009	9	51.86	50.05
2010	10	49.71	47.27
2011	11		44.67
2012	12		39.97
2013	13		35.83
2014	14		32.18
2015	15		28.96
2016	16		26.11
2017	17		23.58
2018	18		21.34



8. Figure 12 Shuanghe oilfield oil production rates forecasted using the simplified model

Figure 7 shows the prediction of oil production in Shuanghe oilfield for 19 years from 2000-2018 as far as Simplified model is concerned. As clearly described above the prediction using the simplified model is used once the choice of one among three Arps decline methods is difficult to make. This model combines exponential and hyperbolic decline equations. It has an advantage when the production history curve did not fit any type of the three models (exponential, hyperbolic and harmonic). Nevertheless, this model was proved to predict fewer values comparatively to other methods. Relative errors calculation shows that this model can be effective.

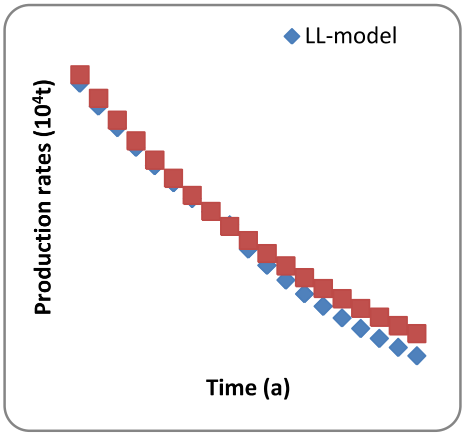
Comparative analysis and cross-checking of results from used models

This work presents three variable models of decline curve analysis; Exponential decline model, LL-model and simplified model. All these three models were used to predict mainly the oil performance of Shuanghe oilfield. In this section a comparison of produced results is reported in tables and figures and at the end analysis of variance and relative errors calculation are also made.

i. *Comparative analysis between results from exponential decline and LL-model*

As shown on the Fig.8, prediction made by LL-model and exponential decline model were almost the same for

the whole predicted period. However, the exponential decline model predicted slightly higher values comparatively to LL-model. The average offset between the two models was estimated at 2.69×10^4tons/a. Even though the offset looked to be minor; it is clear that these methods are different and LL-model was the most convincing because it included more reliable data and has lower relative errors.



9. Figure 13 Comparison of results for oil production forecast between LL-model and exponential decline model.

i. Comparative analysis of results produced by LL-Model and simplified model

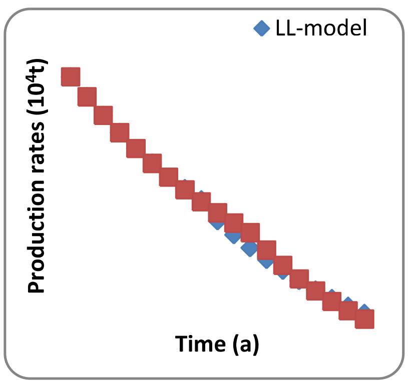
Table 9 shows that LL-model slightly predicts lower values than the new simplified model. However towards the end of prediction period, we observe quite the reverse; simplified model predicts slightly fewer values. Nevertheless, the difference is not so high for both models and we can say that each of the two is usable to forecast the performance of a given oilfield because each has its own advantages. For instance, the LL-model is the best forecast used when the water cut is higher and has the privilege of taking into account some geological parameters like permeability, porosity, Soi and so on. However, in some cases the geological information are not available to the engineer who must do the prediction therefore the simplified model or Arps decline can be used. The simplified model comes into account once the production history analysis is not clear about the equation to be used among three Arps decline equations. Further comparative analysis will show the relationship between all these methods.

Table 7. Comparison of the prediction results between LL-Model and simplified new model

Time	Actual rates (10^4 t)	Forecast by LL-model (10^4 t)	Forecast by Simplified model (10^4t)
2000	86.11	86.78	86.78
2001	84.46	81.36	81.36
2002	79.19	76.34	76.34
2003	75.32	71.70	71.70
2004	69.32	67.39	67.39
2005	62.96	63.40	63.40
2006	58.82	59.69	59.69
2007	56.71	56.62	56.25
2008	53.78	53.58	53.04

2009	51.86	47.83	50.05
2010	49.71	44.05	47.27
2011		40.57	44.67
2012		37.37	39.97
2013		34.42	35.83
2014		31.71	32.18
2015		29.20	28.96
2016		26.89	26.11
2017		24.76	23.58
2018		22.79	21.34

As shown by the Fig.9, the first part of the predicted rate curve had the same appearance as for the one of actual rates which may lead us to conclude that once the reservoir conditions remain unchanged the 10 year prediction curve also is very close to the reality or it is a very good prediction and further statistical analysis are conforming. We must note that more accuracy was observed on the LL-model results.



10. Figure 14 Comparison of results for oil production forecast between LL-model and new simplified model

i. *Comparative analysis of results produced by exponential decline model and simplified model*

The Figure 10 shows a comparative analysis between exponential decline model and simplified model prediction results. In the beginning (actual rate period) both trends were almost the same even though values were not very similar, however towards the end of the 10 years prediction period the simplified model predicts very lower values than exponential decline model. The average offset between two methods was about 2.19×10^4t/a. Further statistical analysis lead to the conclusion that the simplified model is relatively poor predictor in the reservoir where water cut is high like Shuanghe oilfield. The simplified model presented higher relative errors and standard deviations during this work.

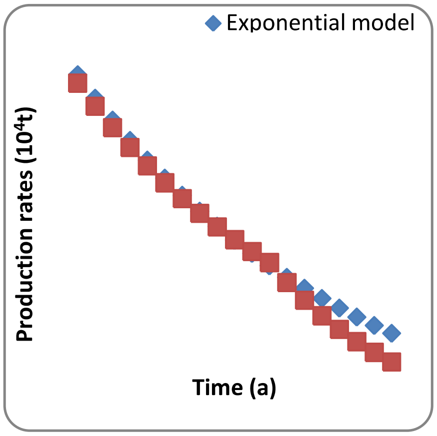
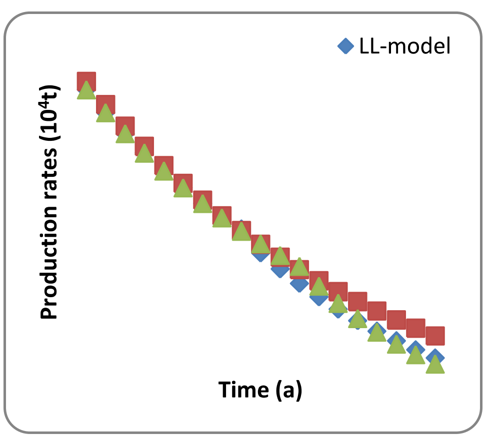


Figure 15 Comparison of results for oil production forecast between exponential decline and simplified model

Comparative analysis of results

11. *produced by all three models*

The Figure 11 shows the comparison of results from all three oil prediction methods. Generally, all three prediction methods were almost the same even though the exponential predicts slightly higher values than others. Furthermore the LL-model predicts slightly lower values but was almost similar to simplified model prediction. However, all these prediction models have one common condition which is actually their weakness: the reservoir must continue to produce in constant conditions for the prediction to be validated. So if the reservoir conditions would change due to any circumstance those predictions would not be verified as real. And it is not easy to have an environment very constant for so long in these days where environmental conditions change day and night because of climate change. Here we can cite some examples of earthquakes or flooding. Unfortunately, some of those climate change effects are unpredictable and that is why we have to rely on our prediction model because they are the only available at present. Comparative analysis showed the difference and the relationship between all those three production predictions. Table 10 reports all predicted values.



12. Figure 16 Comparison of production forecast results from all three prediction models

13. Table 8 Comparison of predicted results using all 3 models (Exponential, LL-model and Simplified)

Time	Predicted rates (10^4 t)		
	LL-model	Exponential model	Simplified model
2000	86.78	88.78	86.78
2001	81.36	83.27	81.36
2002	76.34	78.11	76.34
2003	71.70	73.27	71.70
2004	67.39	68.73	67.39
2005	63.40	64.47	63.40
2006	59.69	60.47	59.69
2007	56.62	56.72	56.25
2008	53.58	53.20	53.04
2009	47.83	49.91	50.05
2010	44.05	46.81	47.27
2011	40.57	43.91	44.67
2012	37.37	41.19	39.97
2013	34.42	38.63	35.83
2014	31.71	36.24	32.18
2015	29.20	33.99	28.96
2016	26.89	31.88	26.11
2017	24.76	29.91	23.58
2018	22.79	28.05	21.34

4 Conclusions

This work presents the results of a comparative study with regard to production analysis and forecast for Shuanghe oilfield. From this work, the following conclusions have been reached: On comparing the new simplified model and LL-model curves, it was observed that LL-model gives slightly lower predictions than the simplified model in terms of quantity.

Considering the slight difference between two methods there is an average offset of about (0.50×10^4 tons/a) in favor of the simplified model. The LL-model was the most reliable method because it involves subsurface information and the new simplified model which predicted almost same values is useful not only when geological data are not available but also when the decision to choose among Arps equation becomes difficult to make.The LL-model is the best method to forecast Shuanghe oilfield production, but one must be cautious to use it everywhere because the water cut has to be higher for this method to give worthy results. Exponential decline model predicts slightly higher values of oil production in Shuanghe oilfield comparatively to other methods used while the simplified model predicts medium values of oil production in Shuanghe oilfield. The LL-model looks to be the best forecast for decline rate because it takes into accounts more parameters than the remaining models used in this work. However, the subsurface information and parameters of the reservoir used in LL-model may not be available every time, for this reason exponential decline may apply the best to predict performance in Shuanghe oilfield.

Acknowledgements

This study was financially supported by the government of Rwanda through Student financing agency for Rwanda (SFAR) and the People's Republic of China through China Scholarship Council (CSC). The authors would like to sincerely thank Dr Habiyaremye Gabriel for his helpful comments and excellent contribution to the improvement of this manuscript.

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