ANALYSIS OF DECLINE CURVE MODELS FOR UNCONVENTIONAL WELLS: CASE STUDY

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ABSTRACT

The energy industry has long known about huge gas resources trapped in organic matter, it is over the past decade that energy companies have combined technologies such as hydraulic fracturing and horizontal drilling to successfully unlock unconventional resources. While applying the traditional decline curve analysis models to gas produced from unconventional reservoirs, engineers commonly encounter difficulties such as matching the high initial production rate, the extremely sharp decline rate in the transient flow period, and the shallow decline resulting from boundary-dominated flow in late life. In this study, the current decline curve models are evaluated using the goodness of fit as a measure of accuracy with field data by using the concept of linear regression. The present study carried out the advantages and limitations of each model, and procedure to evaluate the estimated ultimate recovery of unconventional wells using the various correlations and plots. Finally, compare the various decline curve models with case studies and discuss the contrasts between the models in MATLAB.

Keywords:
unconventional reservoirs, decline curve models, decline curve analysis, estimated ultimate recovery.

INTRODUCTION

Unconventional reservoirs are essentially any reservoir that requires special recovery operations outside the conventional operating practices. They require assistance to be produced at provident flow rates and so produce economic volumes of oil/gas, these assists may be stimulation or steam injection [1,18]. The success of developing an unconventional reservoir depends on drilling a horizontal well with many transverse fractures to create a simulated reservoir volume. Unconventional wells mean crude oil or gas wells in producing fields that employ hydraulic fracturing to enhance crude oil or gas production volume. Several types of unconventional gas resources that are currently produced and these are shown in table1.1 [1,2].

Table-1.1: Types of unconventional reservoirs [1,2]

Reservoir	Definition	Properties	Occurrence and Resource Estimation

Oil Shale	These are fine-grained sedimentary rocks, which are rich in immature organic material called kerogen.	1. Oil shale is a mother rock 2. Not buried at a depth great enough for thermal maturity, 3. It contains more inert mineral matter (Carbonates, silicates, or even sulfides) than coal.	1. U.S.A., Germany, China, Brazil, Morocco, and Jordan. 2. Shale oil is estimated to be about 2.6×10^{12} bbl in world oil volume
Coal-Bed Methane Gas	Coal bed methane (CBM) is natural gas that is stored (or absorbed) in deeply buried coal seams.	**1.** Buried organic matter in an environment free from oxygen. 2. Biogenic methane is produced Carbon-carbon bonds break up generating gas as well as liquid hydrocarbon in deeper burial bituminous coals crack generating thermogenesis methane	1. North America (33%), former Soviet Union (44%), Central Asia including China (13%) and other countries (10%) 2. The world's total CBM resources at 9090 TCF.
Tight gas sands	The sand is called tight since it has low permeability due to cementation, compaction, poor sorting, and/or fine rock grains.	1. Continuous deposition, Low permeability, and Both traditional and basin canter settings. **2.** The buoyancy forces do not succeed because of the low permeability.	1. North America (19%), Latin America (17%) Africa (11%), Pacific OECD (10%). 2. Total volume of 7405 TCF gas.
Shale Gas	Shale gas is the gas produced from shale.	1. Shale permeability varies between micro and Nano Darcy. 2. High pressure (overpressure) 3. Thick net pay (60-500 ft) 4. Porosity (2-8%) 5. Higher thermal maturity	North America gas shale contributes over 9 Mscf/day.
Natural Gas Hydrate	Gas hydrate is a cage-like lattice of ice or compact snow.	1. Solutions of gases in crystalline solids rather than chemical compounds. 2. Hydrocarbon molecules occupy the void spaces within the attics of water molecules.	Kawata Y. and Fujita K. estimated methane hydrate gas resources to be about 731,000 TCFT

DECLINE CURVE MODELS FOR UNCONVENTIONAL WELLS

1. Arps Decline Model

Arps (1945) proposed the simplest empirical DCA model, which has been extensively used for conventional and unconventional resources [3,4]. This model is grounded on the observation that the first differences in the loss rates are roughly constant. In this Arps model, bottom-hole pressure is fixed, the skin factor is constant, and the inflow governance is boundary-dominated inflow. It's only applicable in pseudo-steady flows when the in-flow governance transfers from direct overflows to boundary dominated overflows [4,5]. This indicates the Arps equations don't apply to the production forecasting of the entire decline process of horizontal wells in low permeability reservoirs [4-6]. The decline curve analysis of Arps models can be epitomized into three types [7,8]:

Exponential Equation: $$q = q_i exp(-Dt) \qquad (1)$$

Hyperbolic Equation: $$q = \frac{q_i}{(1+bD_it)^{\frac{1}{b}}} \qquad (2)$$

Harmonic Equation: $$q = \frac{q_i}{(1+D_it)} \qquad (3)$$

Decline curve exponent $$-b = \frac{q}{\frac{dq}{dt}} \qquad (4)$$

Where q is the flow rate in STB/day or Mscf/day, q_i is the initial flow rate in STB/day or Mscf/day, D is the decline constant while D_i is the initial decline constant, which is measured in days, and b is the decline exponent. The most commonly employed hyperbolic form of the Arps decline Equation is used for shale reservoirs. The hyperbolic decline equation is suitable to use due to the best fit that it provides for the long transient linear-flow regime observed in shale gas wells with b values greater than unity.

2. Stretched Exponential Production Decline Model

Valka and Lee proposed the Stretched Exponential Production Decline Model (SEPDM), in which they assume that the product rate satisfies the stretched exponential decay [3,9]:

$$\frac{dq}{dt} = -n[\frac{t}{\tau}]^n \frac{q}{t} \qquad (5)$$

Integrating the above equation yields:

$$q=q_i exp(-\frac{t}{\tau})^n \qquad (6)$$

Where τ is the characteristic time constant and n is the exponent. Valka and Lee mentioned that a natural interpretation of this model is that the actual production decline is determined by a great number of contributing volumes [9]. All these volumes have exponential decay rates, but with a specific distribution of characteristic time constant. This method defines a characteristic number of periods τ, and a dimensionless exponent n of the ratio of time t [5]. The SEDM is advantageous for combining the concave and convex portions of decline curves without increasing the number of model-parameters, and could provide a finite (bounded) value of EUR without cut-offs in time or rate. It also provides a bounded EUR rather than an infinite value; moreover, the authors pointed out that the SEDM models transient flow rather than boundary-dominated flow, and requires a sufficiently long production time (usually >36 months) to accurately estimate the parameters t and n [8-10].

3. Logistic Growth Model

The LGM was developed in 1838 by the Belgian mathematician Pierre Verhulst who proposed that the increase in population rate may be limited and must be bounded by the availability of resources to sustain its growth (e.g., food, space). Hubbert (1956) was the first to employ the concept of LGM in the oil industry to prognosticate the cumulative production from gas and oil fields or regions. Clark et al. (2011) proposed a three-parameter growth model to forecast the production growth from a production well; that is, cumulative oil "N_P" or gas "GP." Clark and co-authors proposed the ensuring expression [11]:

$$N_p = \frac{(K)t^n}{a+t^n} \qquad (7)$$

The two parameters "a" and "n" can be viewed as regression variables that impact the shape and upward and downward of the decline curve [11]. The "K" is called the carrying capacity and perhaps better defined as the EUR and acts as a bounded or maximum growth. The production rate time of this model can be obtained by differentiating the above equation, which is shown below:

$$q_o = \frac{dN_p}{dt} = \frac{(k)nat^{n-1}}{(a+t^n)^2} \qquad (8)$$

The major advantage of the LGM is that the reserve estimate is constrained by the parameters K as well as the production rate, which terminates at infinite time. However, an upward inflection in the curve would occur if n>1. The main assumption in this model is that the entire reservoir can be drained by a single well over a sufficiently long period [9-13]. It is very flexible and confident in modeling long transient boundary-dominated performances of unconventional reservoirs and also, it is also capable of trending existing production data and providing reasonable forecasts of future production.

4. Duong Decline Model

Duong (2011), presented a model for predicting the performance of unconventional reservoirs flowing under long transient flow, shows that plotting q/Gp vs. time on a log-log graph paper yields a straight line [5,12]. This model suits the fracture-dominated flow and considers matrix contribution to be negligible, it adapts to the expanding stimulated reservoir volume condition which means that the connected fracture density in the fractured area must increase with time due to local in-situ stresses changes while fracture depletion [14,15]. The q/Gp used in the log-log plot can be described by the following power law equation [3]:

$$\frac{q}{G_p} = at^{-m} \qquad (9)$$

G_p is the cumulative gas production, q is the gas production rate in the first day, and a & m are constants that can be determined from the relationship between q/G_p and t in a double logarithmic coordinate system. Based on the above equation, Duong derived the formula for well production rate and cumulative production expressions as follows [5]:

$$q=q_i t^{-m} \exp\left(\frac{a}{1-m}(t^{1-m}-1)\right) \qquad (10)$$

$$G_p = \frac{q_i}{a} \exp\left(\frac{a}{1-m}(t^{1-m}-1)\right) \qquad (11)$$

The typical ranges for the DCA parameters in the Duong model are 1≤ m ≥2 and 0≤ a ≥2. If the m value increases the q valves reach to maximum value.

5. Power Law Exponential Decline Model

Ilk et al. (2008) developed the Power Law Exponential Decline (PLED) Model based on the Arps' decline curves and used the power law decline to approximate the production rate decline [5, 16]. This model is developed specifically for shale gas wells, but is also applied to unconventional oil wells. The production rate is shown below [5, 17]:

$$D = D_\infty + D_i t^{-(1-n)} \qquad (12)$$

D_∞ is the decline rate over a long-term period and is the time exponent. By substituting the above equation in the loss ratio equation, the production rate is obtained:

$$q = q_i \exp(-D_\infty T - D_i t^n) \qquad (13)$$

Where q_i is the rate "intercept", is the initial decline constant, and n is the time exponent. In addition, the parameters D and D_i are defined as follows:

$$D_i = D/n \qquad (14)$$

The power law exponential decline model becomes a traditional exponential model when D_∞= 0 and n=1. When n tends to zero, the Production declines sharply in the initial stage and the decline rate gradually decreases with production time, which is consistent with the production decline in a low-permeability gas reservoir. D_∞ is introduced to set a limit to avoid overestimation with production time. Multiple D_∞ values can gain favorable production data fittings in the initial prediction, and the predicted EUR is more sensitive to this parameter. D_∞ is equal to the parameter D_{lim} in a modified hyperbolic decline model and is usually an empirical or estimated value [16-18]. The power law exponential decline model applies to wells with a long production history. The prediction shows a relatively great uncertainty for wells with short production histories.

This paper presents a comparative study to show which one of the DCA models can fit the production data with the highest accuracy and also predict future production performance.

I. Case Study I

A single-layer unconventional reservoir with a gas well produced from a hydraulically fractured reservoir produced production in the last 30 years. The well has been producing under transient linear flow conditions. The 30 years of simulated production data, as presented in table 1.0

and the abandonment ratio is 10 Mscf/d and decline curve exponent b = 0.4333 [11]. Use Arps unconventional DCA approach to predict the future gas flow and compare with simulated production data in MBAL software.

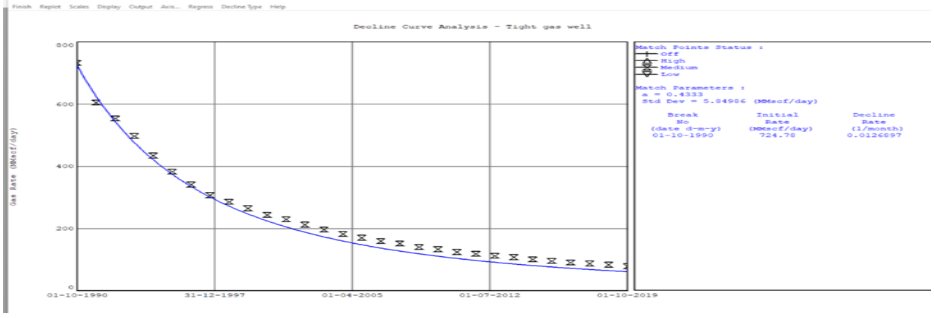
Table 1.0 Production History for Fractured Gas Well [11]

Data-Month-Year	Gas production rate (MMscf/d)	Data-Month-Year	Gas production rate (MMscf/d)
10-10-1990	733	10-10-2005	171
10-10-1991	605	10-10-2006	160
10-10-1992	554	10-10-2007	152
10-10-1993	498	10-10-2008	141
10-10-1994	435	10-10-2009	134
10-10-1995	383	10-10-2010	125
10-10-1996	342	10-10-2011	119
10-10-1997	307	10-10-2012	113
10-10-1998	286	10-10-2013	108
10-10-1999	265	10-10-2014	101
10-10-2000	244	10-10-2015	96
10-10-2001	230	10-10-2016	91
10-10-2002	213	10-10-2017	88
10-10-2003	197	10-10-2018	84
10-10-2004	183	10-10-2019	79

Simulation procedure by using MBAL software

The step-wise simulation procedure for decline curve analysis of fractured Unconventional gas well in MBAL software:

- Click on file select new Click on the tool option and select Decline curve analysis model.
- Click on option and then select reservoir fluid as gas.
- Select the decline type as hyperbolic and Decline curve exponent as b=0.433, production start date is 01-10-1990, and abandonment rate is 10 Mscf/d. and enter the production history data.
- Click on the match which shows a plot of the Time vs Gas rate and click on regress it shows a trend line fit to the curve and also gives a decline rate is 0.0126897 for a month as shown in fig. 1.0. Click on finish and click on done.
- Click on production prediction select prediction setup and give the production start (01-10-1990) and end (01-10-2099) dates, the abandonment rate is 10 Mscf/d.
- Click on reporting schedule click on user defined for 1 month and then click on done.
- Click on run prediction and click on calc it gives predicted production data and then select plot shows the decline curve for our prediction data select variable cumulative gas production and gas rate versus time as given in fig. 2.0.



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Match Parameters :
 a = 0.4333
 Std Dev = 5.84986 (MMscf/day)

    Break          Initial        Decline
     No             Rate           Rate
 (date d-m-y)   (MMscf/day)     (1/month)
  01-10-1990       724.78       0.0126897
```

Fig. 1.0. Plot Time vs Gas rate (MMscf/day)

Production history data in table 1.0 is entered in MBAL and production history data is matched using different decline models. It was found that the hyperbolic model is the best match for the production history data table 5.29 which is shown in Fig. 1.0. which gives less regress and a small decline rate is a good fit decline model. We found that the unconventional fractured well was able to produce gas economically up to 10-10-2099. This method does not apply to transient flow. It is used boundary dominant flow unconventional reservoir. In BDF Arp's hyperbolic models give good future production. The future production prediction data was calculated which was plotted in fig. 2.0. for future 70 years of production data.

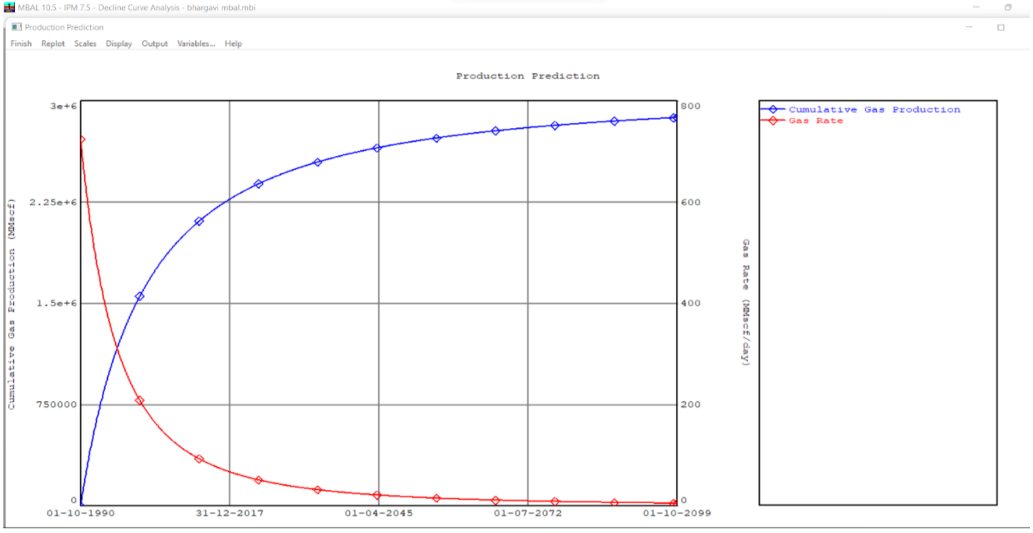

Fig. 2.0. Decline curve plot

2. Case Study II

The production history of a well flowing from an unconventional dry gas reservoir for 480 days is shown in table 2.0. The well has been producing under transient flow conditions. Different decline curve models for unconventional wells are calculated using the MATLAB software. Calculate future prediction production data for 1000 days and compare all future prediction data for all methods [11].

Table 2.0 Production History for Dry Gas Well [11]

Time, days	Dry Gas Rate Qg (MMscf/d)	Cumulative Dry Gas Rate Gp (MMscf/d)	Time, (days)	Dry Gas Rate Qg (MMscf/d)	Cumulative Dry Gas Rate Gp (MMscf/d)
1	2.34	2.3	250	0.88	530.5
10	4.35	36.1	260	0.81	540.5
20	5.51	92.5	270	0.71	548.1
30	4.64	141.7	280	0.69	556.4
40	3.38	175.7	290	0.72	563.1
50	3.01	209.2	300	0.63	570.1
60	2.84	238.0	310	0.67	577.0
70	2.98	266.7	320	0.57	583.6
80	2.64	293.9	330	0.75	590.3
90	2.33	318.0	340	0.38	596.7
100	2.15	340.1	350	1.29	602.8
110	1.96	360.4	360	1.35	611.0
120	1.75	378.4	370	0.07	624.3
130	1.63	394.5	380	0.39	635.1
140	1.59	410.6	390	0.19	641.4
150	1.48	425.4	400	0.15	645.4

160	1.34	439.3	410	0.02	647.4
170	1.20	452.2	420	0.03	648.9
180	1.08	463.5	430	0.28	651.4
200	0.96	484.0	450	0.68	667.2
210	0.90	493.5	460	0.50	673.4
220	0.84	502.2	470	0.37	679.1
230	0.93	511.3	480	0.43	683.7
240	1.32	520.3	--	--	--

MATLAB Simulation for Different Decline Curve Models Approaches:

2.1 Modified Arp's Model Approach

The production data were used for matching (480 days) and the production match results in modified Arp's model before and after regression using MATLAB. Results of regression values of D_i and q_i are given in table 3.0 by using of boundary dominant b valve.

Table 3.0 Assumed and Regression parameters of Modified Arp's Model

Parameters	Assumed Values	After Regression
D_i (day^{-1})	0.03	0.0134448
q_i (MMscf/day)	6	5.541
b	0.604	0.604

The initial (qi) and optimum (Di) values are assumed and the graph between gas rate and cumulative gas production versus time using the Arps model in MATLAB. which gives the regression value and also fine the decline rate and initial production values different from assumed and field history data variation as shown in fig.3.0.

Initial (qi) and optimum (Di) values are adjusted up to the gas rate and the cumulative production curve coincides with the production history cure of dry gas unconventional well in the field case. To consider the adjusted value for Di and qi and calculate future production prediction for 1000 days in MATLAB and plot the graph between gas rate and cumulative gas production versus time for production data in the filed case and future prediction for 1000 days as depicted in fig.4.0 in modified Arps model.

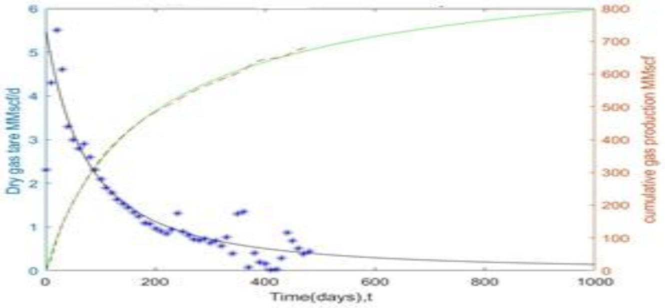

Fig. 3.0. Matching of production history data for Modified Arp's model before Regression

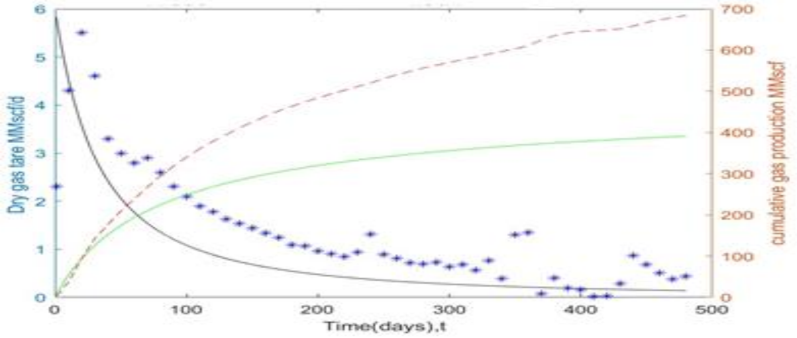

Fig. 4.0 Prediction of production performance using Modified Arp's model

The future production values are decreased and cumulative gas production increase values are to concerning time. The gas rate and cumulative production rate for 1000 days is 796.28 MMscf/day. EUR for a dry gas well producing from unconventional in Arps model is 2.10 MMscf/day. This method is good for linear flow regimes and for small production history data. The estimate of recovery and future prediction value in modified Arp's model is one of the best models for liner flow type dry gas unconventional wells.

2.2 Stretched Exponential Production Decline Curve Model (SEPD) Approach

The production data were used for matching (480 days) and the production match results in the SEPD model before and after regression using MATLAB. The highest observed gas flow rate of 6.034 /day was held constant MMscf and regression was performed using parameters "n" and "τ" to match the observed well cumulative production as illustrated in table 4.0.

Table 4.0 Assumed and Regression parameters of the SEPD Model

Parameters	Assumed Values	After Regression
q_i	6.039	6.039
τ	60	91.9764
n	0.5	0.6667

The parameters "n" and "τ" values are assumed and plot the graph between gas rate and cumulative gas production versus time using the SEPD model in MATLAB. which gives the regression value and also fine the decline rate and initial production values different from assumed and field history data variation as shown in fig. 5.0 for 480 days in the SEPD model.

Parameters "n" and "τ" values are adjusted up to the gas rate and the cumulative production curve coincides with the production history cure of dry gas unconventional well in the field case. To consider the adjusted value for "n" and "τ" and calculate future production prediction for 1000 days in MATLAB and plot the graph between gas rate and cumulative gas production versus time for production data in filed case and future prediction for 1000 days as on view in fig. 6.0 for the SEPD model.

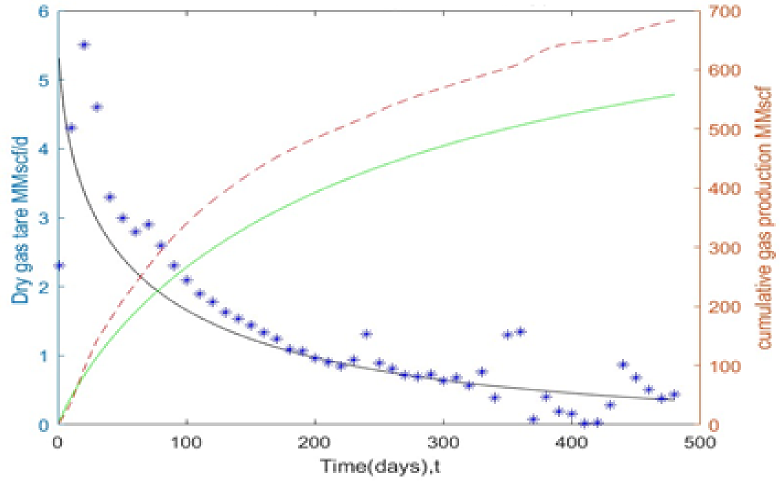

Fig. 5.0. Matching of production history data for SPED model before regression

The future production values are decreased and cumulative gas production values are increased to with respect time as depicted in fig.6.0. The gas rate and cumulative production rate for 1000 days is 720.4 MMscf/day. EUR for a dry gas well produced from unconventional in the SEPD model is 1.87 MMscf/day. This method is good for linear and bilinear flow regimes and for long production history data. The estimate of ultimate recovery and future prediction values in SPED models is good for liner flow type dry gas unconventional wells.

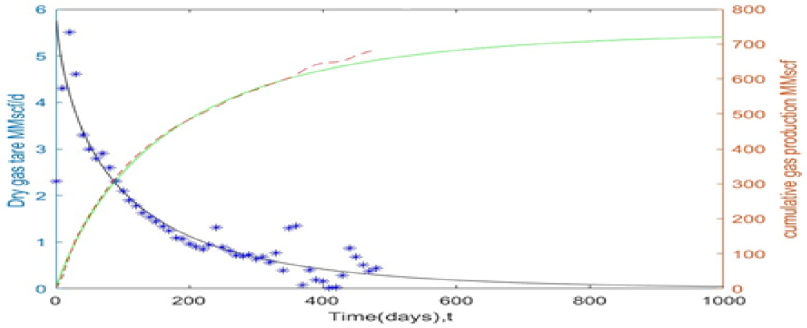

Fig. 6.0. Prediction of production performance using Modified SEPD model

2.3 Logistic Growth Decline Curve Model (LGM) Approach

The production data were used for matching (480 days) and the production match results in the logistic growth model before and after regression using MATLAB. The results of parameter value a, n, and k the estimated EUR value are presented in table 5.0.

Table 5.0. Assumed and Regression parameters of the LGM Model

Parameter	Assumed Values	After Regression
k	800	815
n	1.2	1.098
a	220	221.25

The parameters a, n, and k values are assumed, and the graph between gas rate and cumulative gas production versus time using the LGM model in MATLAB. which gives the regression value and also fine the decline rate and initial production values different from assumed and field history data variation as shown in fig.7.0. for 480 days in the LGM model.

Parameters a, n, and k values are adjusted up to the gas rate and the cumulative production curve coincides with the production history cure of dry gas unconventional well in field case. To consider the adjusted values for a, n, and k and calculate future production prediction for 1000 days in MATLAB and plot the graph between gas rate and cumulative gas production versus time for production data in the filed case and future prediction for 1000 days as delineated in fig.8.0. for the LGM model.

The future production values are deceased and cumulative gas production values are increased to with respect time as depicted in fig.8.0. The gas rate and cumulative production rate for 1000 days is 732.6 MMscf/day. EUR for a dry gas well produced from unconventional in LGM model is 2.03 MMscf/day. This method is good for linear, bilinear, and boundary dominate flow (BDF) regimes and production rates for a long flow period. The estimate of ultimate recovery and future prediction values in LGM models is good for liner and BDF-type dry gas unconventional wells.

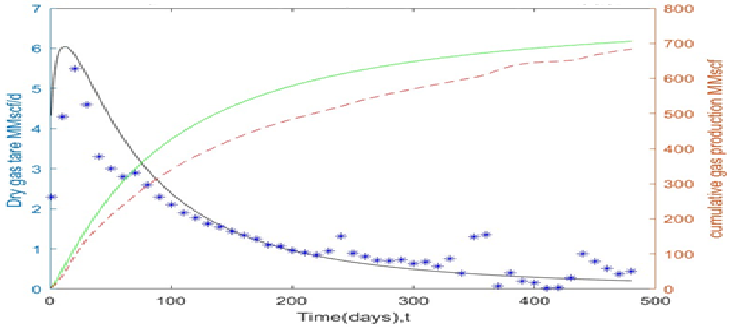

Fig.7.0. Matching of production history data for LGM model before regression

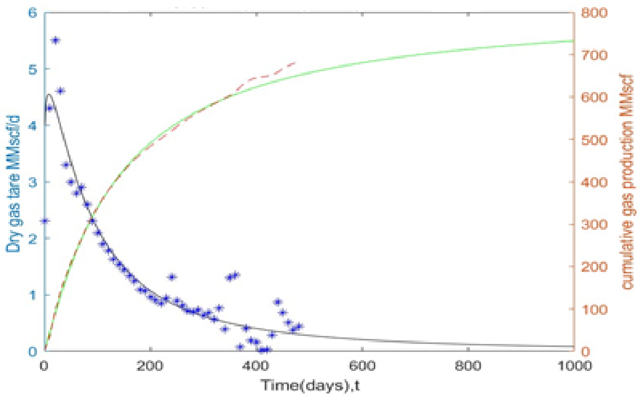

Fig. 8.0. Prediction of production performance using LGM model

2.4 Duong Decline Curve Model Approach

The production data were used for matching (480 days) and the production match results in the logistic growth model before and after regression using MATLAB. Plot qg/Gp versus time "t" on a log–log scale and draw a straight-line fit by using the power law to calculate the a & m values. The results of parameters a, m, and qi initial gas rata are presented in table 6.0.

Table 6.0. Assumed and Regression parameters of Duong's Model

Parameters	Assumes Values	After Regression
q_i	2	0.8765
a	2.7189	3.2327
m	1.341	1.3716

The parameters a, m, and qi values are assumed, and the graph between gas rate and cumulative gas production versus time is used in the Duong model in MATLAB. which gives the regression value and also fine the decline rate and initial production values different from assumed and field history data variation as demonstrated in fig. 9.0. for 480 days in Duong's model.

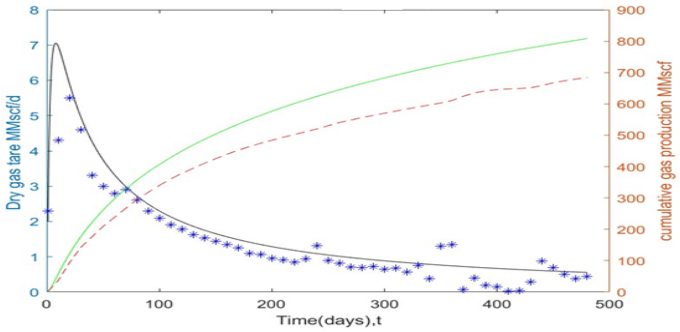

Fig. 9.0. Matching of production history data for Duong model before regression

Parameters a, m, and qi values are adjusted up to the gas rate and the cumulative production curve coincides with the production history cure of dry gas unconventional well in field case. To consider the adjusted values for a, m, and qi and calculate future production prediction for 1000 days in MATLAB and plot the graph between gas rate and cumulative gas production versus time for production data in the filed case and future prediction for 1000 days as shown in fig.10.0 for Duong's model.

The future production values are decreased and cumulative gas production values are increased to with respect time as delineated in fig.10.0. The gas rate and cumulative production rate for 1000 days is 834.2 MMscf/day. EUR for a dry gas well produced from unconventional in Duong's model is 2.63 MMscf/day. This method is good for linear and bilinear regimes and production rates for a long flow period. The estimate of ultimate recovery and future prediction values in Duong's models is good for unsteady state BDF-type dry gas unconventional wells.

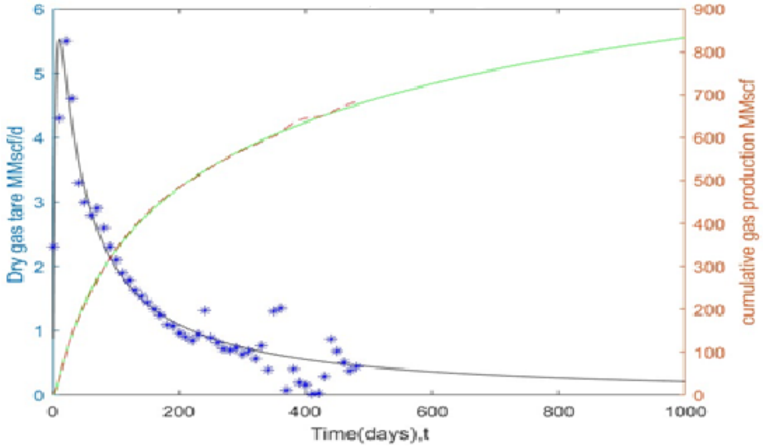

Figure 10.0 Prediction of production performance using Duong's model

2.5 Power Law Exponential (PLE) Decline Curve Model Approach

The production data were used for matching (480 days) and the production match results in the logistic growth model before and after regression using MATLAB. The results of parameter values qi, n, Di, and D∞ are the estimated EUR values displayed in table 7.0.

Table 7.0 Assumed and Regression parameters of the PLE Model

Parameters	Assumed Values	After Regression
q_i	4	6.063074
N	1.2	0.668845
D_i	0.003	0.048295
D_∞	0.00001	1.35E-05

The parameter values qi, n, Di, and D∞ are assumed, and the graph between gas rate and cumulative gas production versus time using the PLE model in MATLAB. which gives the regression value and also fine the decline rate and initial production values different from assumed and field history data variation as exhibited in fig.11.0 for 480 days in the PLE model.

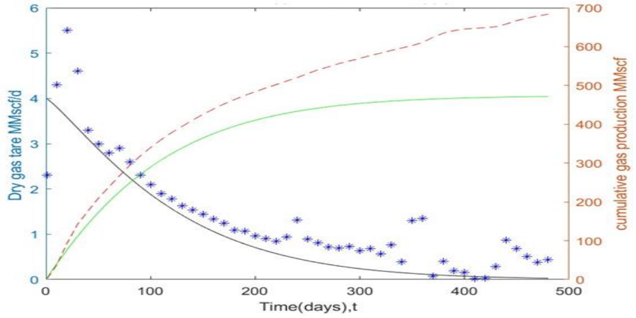

Fig. 11.0 Matching of production history data for PLE model before regression

Parameters qi, n, Di, and D∞ values are adjusted up to the gas rate and the cumulative production curve coincides with the production history cure of dry gas unconventional well in field case. To consider the adjusted values for qi, n, Di, and D∞ and calculate future production prediction for 1000 days in MATLAB and plot the graph between gas rate and cumulative gas production versus time for production data in filed case and future prediction for 1000 days as depicted in fig.12.0 for PLE model.

The future production values are deceased and cumulative gas production values are increased to with respect time as shown in fig. 12.0. The gas rate and cumulative production rate for 1000 days is 725.91 MMscf/day. EUR for a dry gas well producing from unconventional in PLE model is 1.90 MMscf/day. This method is good for linear, bilinear, and boundary dominate flow (BDF) regimes and production rates for a long flow period. The estimate of ultimate recovery and future prediction values in PLE models is good for liner and BDF-type dry gas unconventional wells.

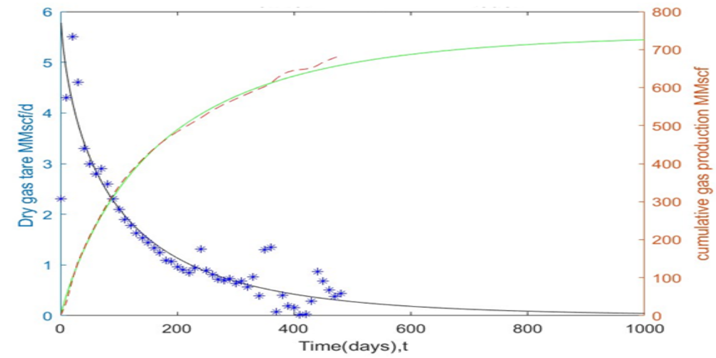

Figure 12.0. Prediction of production performance using the PLE model

2.6. Comparison of All Types of Decline Curve Models:

Fig 13.0 depicts the comparison of all decline curve models Duong's gives more production than other decline models. Next modified Arp's model is giving more production but it is not giving accurate values but non-linear and BDF flow regime. And PLE model gives medium production when compared remaining decline curve models. SPED and LGM give nearly the same production. The discrepancies between methods in predicting the EUR for a dry gas well produced from unconventional play are presented in table 8.0., and the field estimated EUR value is 2.42 MMscf/day. From these EURs, we get that the best model that gets close to the actual EUR is the Duong model and from the simulated data also Duong's model gives more production. The overall conclusion of this case study 2 is that Duong's decline curve model gives more future production for dry gas unconventional wells.

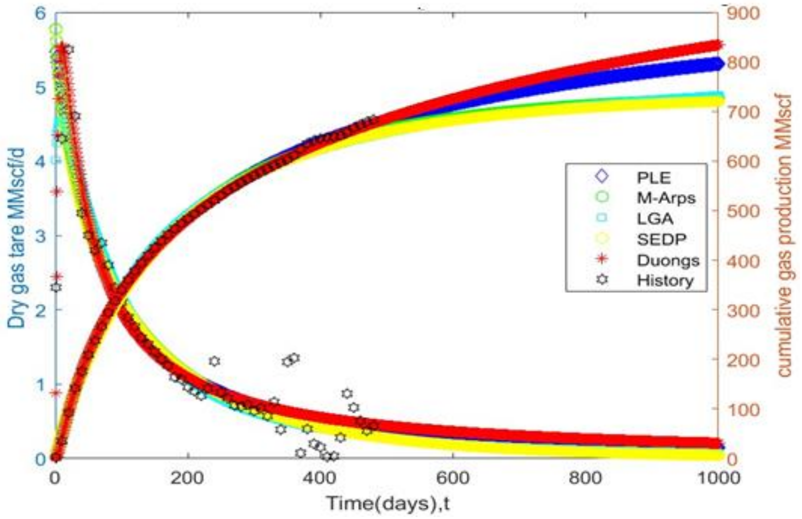

Figure 13.0. Comparison of production performance for all types of Decline Curve Models

Table 8.0 EUR results of Decline Curve Analysis models

Parameter	Modified Arp's model	SEPD model	LGM model	Duong model	PLE model
EUR (MMscf/day)	2.10	1.87	2.03	2.63	1.90

CONCLUSION

The production behaviour of unconventional reservoirs shows long-term transient flow followed by BDF which requires decline curve analysis models other than the Arps model. Modern DCA models have been developed to simulate this behaviour, such as PLE, SEPD, T, LGM, and Duong models. The applications of these models facilitate their usage in matching and predicting the production behaviour of unconventional reservoirs. The Case study found a decline in cure rate and future production forecasting of hydraulic fracture unconventional wells in MBAL simulation. Case study 2 used five (Arp's, PLE, SEPD, LGM, Duong's) for future production performance of dry gas unconventional wells in MATLAB software and used the concept of regression to perform analysis for various decline curve models using MATLAB software for 1000 days for casting. we also calculated EUR for all methods and comparison with the original actual field EUR values. finally, concluded that Duong's model produces more dry gas when compared with the other models.

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