

# Prediction of Reservoir Performance Applying Decline Curve Analysis

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**Abstract**—Decline curve analysis is a technique can be applied to a single well, and total reservoir. Decline analysis routinely used by engineers to estimate initial hydrocarbon in place, hydrocarbon reserves at some abandonment conditions, and forecasting future production rate. The remaining reserve depends on the production points that selected to represent the real well behavior, the way of dealing with the production data, and the human errors that might happen during the life of the field. In this study the actual oil rate technique is applied under decline curve analysis (D.C.A) program, and screening data points to calculate remaining and recoverable reserves.

**Index Terms**—Decline curve, production history, initial decline rate, remaining reserve, scenario.

## I. INTRODUCTION

Decline curve analysis is the most currently method used for reserve estimation when historic production data are available and sufficient [1]. The most popular decline curve is that which represent the decline in the oil or gas production rate with time, another common technique is the plot of production rates versus cumulative oil or cumulative gas production, normally termed (rate-cumulative plots). As known, oil production rate will decline with the production time increasing, when there's no other injection job. If oil rate of a production well drop to the economic limit (surface oil rate < 10 bbl/day), the well will be considered to stop production. The two basic problems in appraisal work are the determination of most probable future life of wells and estimation of its future production.

Logical way to find an answer to the two problems mentioned, by extrapolation is to plot this variable production rate either against time or against cumulative production extending the curves thus obtained to the economic limit. The point of intersection of the extrapolated curve with the economic limit then indicates the possible future life or the future oil recovery. The basic of such an estimate is the assumption that the future behaviour of a well will be governed by whatever trend or mathematical relationship is apparent in its past performance.

This assumption puts the extrapolation method on a strictly empirical basis and it must be realized that this may make the results sometimes inferior the more exact volumetric methods [2].

Estimating oil reserves is one of the most important phases of the work of petroleum engineer since the solutions to the

problems it deals with usually depend on a comparison of the estimated cost in terms of barrels of oil [3]. The production decline observed should truly reflect reservoir productivity and not be the result of external causes, such as a change in production conditions well damage, production controls, and equipment failure. stable reservoir condition .must also prevail in order to extrapolate decline curves with any degree of reliability .this condition .will normally be met as long as the producing mechanism is not altered .however ,when action is taken to improve the recovery of oil ,such as infill .drilling, fluid injection, fracturing, and acidizing ,decline curve analysis can be used to estimate the performance .of the well or reservoir in the absence of the change and .compare it to the actual performance with the change [4]. The objectives of this study are prediction of field reserve, type of driving mechanism, and comparing the results obtained to the company results.

## II. METHODOLOGY

The Arps equation 1945, of decline curve analysis approach was proposed more than sixty year 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. The empirical Arps decline equation represents the relationship between production rate and time for oil wells during pseudo steady- state period and is shown as follows[5]:

The decline curve most commonly used to represent or extrapolate the production data are members of a hyperbolic family defined by the following differential equation.

$$\frac{d}{dt} \left( \frac{q}{dq/dt} \right) = -b \Rightarrow \quad (1)$$

where:

$q$ : oil production rate .

$b$ : reservoir Factor

Direct integration of equation (1) gives:

$$\frac{q}{dq/dt} = -bt - \frac{1}{a_i} \Rightarrow \quad (2)$$

where:

$a_i$ : nominal Decline Rate

$t$ : time

The constant "b" is a reservoir constant, which international oil field experience has shown its value to be normally between 0 and 1.0. Equation 2, can be easily integrated using the initial condition of  $q=q_i$  at time  $t=0$ , to give the following general form for production decline in oil

reservoir:

$$q = \frac{q_i}{(1 + a_i b t)^{1/b}} \Rightarrow \quad (3)$$

where:

$q_i$ : Initial oil production rate

Some investigators claim that the value of "b" is directly proportional to the back-pressure test log-log exponent (n).

The three commonly recognized types of decline curves: Constant percentage decline (exponential decline), Harmonic decline, and Hyperbolic decline.

Two main fitting techniques are popular with petroleum engineers; the first is normally used in case of small number of data point, only a pocket calculator is available. It is known as the "Average lines method". The second and more popular method is known as the "least sum of square method". As the name implies, it required that the sum of the square of the discrepancies between the actual and calculated value must be a minimum.

This method has many advantages:

- 1) The equations are simple and their application required only a pocket calculator. It's also available as a direct function on the Microsoft Excel.
- 2) This method can be used easily to fit the data points to any form of equations.
- 3) Finally, it has proven to be the most "reliable" tool for extrapolation out said the range of the measured data in most engineering and scientific problems.

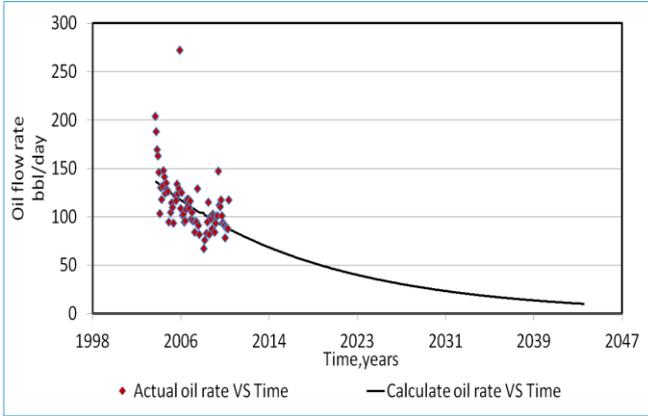


Fig. 1. Screening method

### III. DISCUSSION AND RESULTS

In this study decline analysis was applied for wells, and whole field.

#### A. Wells Decline Curve Analysis

The remaining reserve calculation becomes more reliable whenever data points are well screening. The decline type of well 1 is exponential, and the remaining reserve calculated from end period (5/31/2004 to 3/31/2011) to economic limit is .596,738 bbl. Fig.1 represents screening method, Fig. 2 shows sum error square. vs. b factor, as well as Table. I include economic recoverable reserves, abandonment time, initial decline using D.C.A. program, and Hand calculations.

TABLE I: RESULTS OF WELL 1

Cut-off Criteria: 15 bbl/day Correlated period: .from 5/31/2004 .to .3/31/2011	Hand calculation	D.C.A program
Decline Exponent	0	0
Decline Factor (1/month)	0.00456	0.005507
Initial Decline Rate (bbl/day)	138	138
Economic Recoverable Reserves (bbl)	568,884	564,458
Abandonment Time (years)	33.831	33.61

Well 2 decline type is exponential in period from 11/30/2002 to 3/31/2011, where the remaining reserve calculated from end period to economic limit is 529, 941 bbl. Fig.3 represents screening method, Fig. 4 shows sum error square .vs .b factor, as well as TABLE II includes economic recoverable reserves, abandonment time, initial decline using D.C.A. program, and Hand calculations.

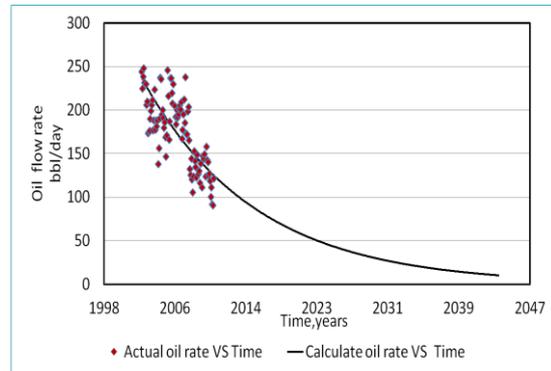


Fig. 3. Screening method

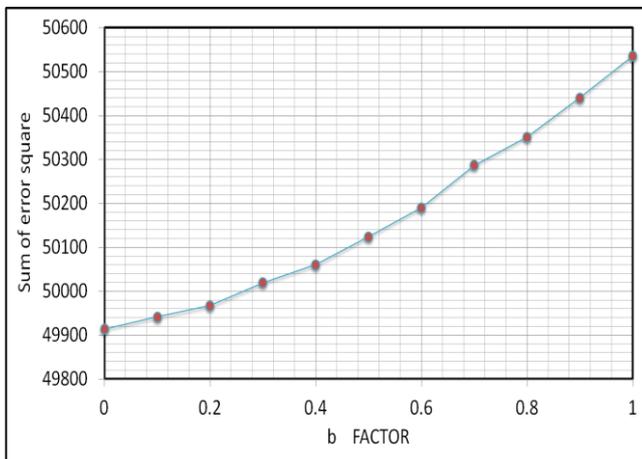


Fig. 2. Sum error square .vs .b factor

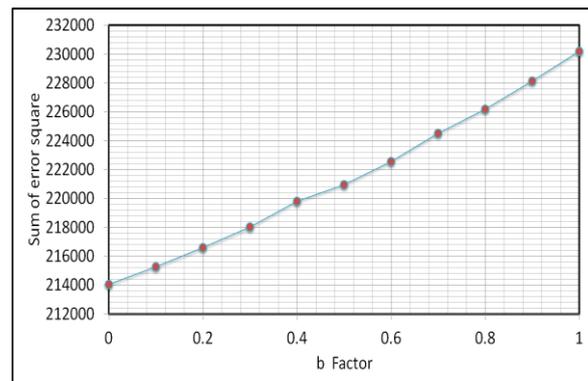


Fig. 4. Sum error square .Vs .b factor

Well 3 study period from 7/31/2002 to 3/31/2011, shows the decline type is hyperbolic, and the remaining reserve calculated from end period to economic limit is 546,768 bbl. Fig. 5 represents screening method, Fig. 6 shows sum error square .vs .b factor, as well as TABLE. III includes economic recoverable reserves, abandonment time, initial decline using D.C.A. program, and Hand calculations.

TABLE II: RESULTS OF WELL 2

Cut-off Criteria:15 .bbl/day Correlated period: .from 11/30/2002 .to : 3/31/2011	Hand calculation	D.C.A program
Decline Exponent	0	0
Decline Factor (1/month)	0.00638	0.006377
Initial Decline Rate (bbl/day)	238	238
Economic Recoverable Reserves (bbl)	506,104	506,291
Abandonment Time (years)	36.118	36.131

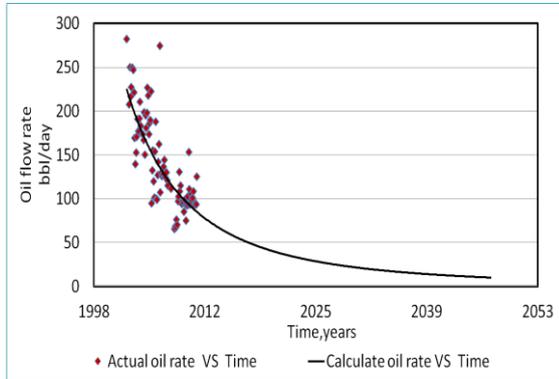


Fig. 5. Screening method

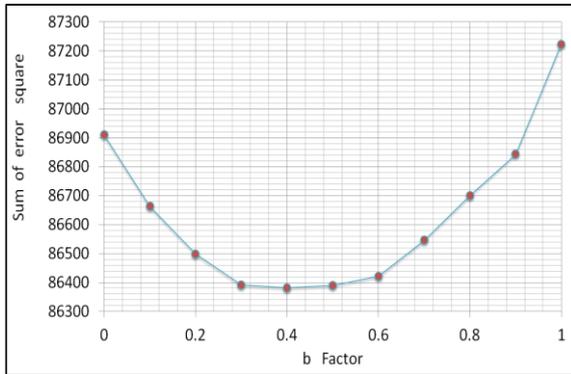


Fig. 6. Sum error square .Vs .b factor

TABLE III: RESULTS OF WELL 3

Cut-off Criteria:15 .bbl/day Correlated period: .from 7/31/2002 .to : 3/31/2011	Hand calculation	D.C.A program
Decline Exponent	0.4	0.4
Decline Factor (1/month)	0.011519	0.01151
Initial Decline Rate (bbl/day)	228	228
Economic Recoverable Reserves (bbl)	504,415	504,842
Abandonment Time (years)	38.44	35.679

From study period (3/31/1999 to 3/31/2011) of well 4, the decline type is hyperbolic, and the remaining reserve

calculated from end period to economic limit is .547,819 bbl. Fig. 7 represents screening method, Fig. 8 shows sum error square .vs .b factor, as well as TABLE. IV includes economic recoverable reserves, abandonment time, initial decline using D.C.A. program, and Hand calculations.

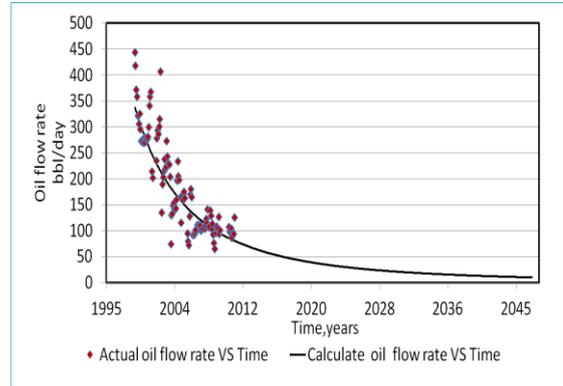


Fig. 7. Screening method

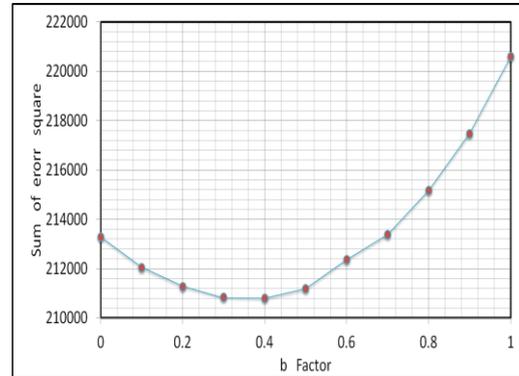


Fig. 8. Sum error square .vs .b factor

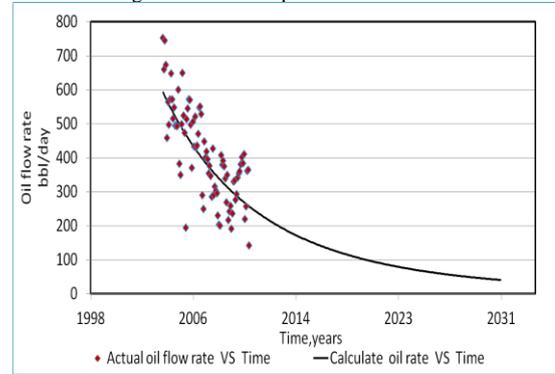


Fig. 9. Screening method

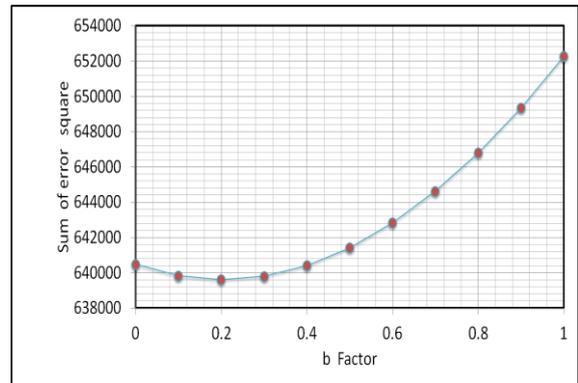


Fig. 10. Sum error square .vs .b factor

### B. Decline Curve Analysis for the Whole Field

The decline type of the field is hyperbolic, the remaining

reserve calculated from end of period to economic limit(from .3/31/1999 to .3/31/2011) is 575, 480 bbl. Fig. 9 represents screening method, Fig. 10 shows sum error square .vs .b factor, as well as TABLE. V includes economic recoverable reserves, abandonment time, initial decline using D.C.A. program, and Hand calculations.

Comparing remaining .reserve of whole field with sum of a wells is 303, 599 bbl, 2,084,788 bbl respectively. There is big difference equal 1,781,189 bbl, due to shutting some wells in time of calculating remaining .reserve, therefore it is necessary to select well by well method during the calculation of decline curve analysis.

TABLE V: RESULTS OF FIELD

Cut-off Criteria: 60 .bbl/day Correlated period:from 4/30/2004 .To : 3/31/2011	Hand calculation	D.C.A program
Decline Exponent	0.2	0.2
Decline Factor (1/month)	0.01101	0.011007
Initial Decline Rate (bbl/day)	601	601
Economic Recoverable Reserves (bbl)	325,369	324,278
Abandonment Time (years)	22.145	22.197

TABLE IV: RESULTS OF WELL4

Cut-off Criteria:15 bbl/day Correlated period: .from 31/30/1999 .to : 3/31/2011	Hand calculation	D.C.A program
Decline Exponent	0.4	0.4
Decline Factor (1/month)	0.013532	0.013534
Initial Decline Rate (bbl/day)	342	343
Economic Recoverable Reserves (bbl)	505,385	505,411
Abandonment Time (years)	38.44	38.446

#### IV. CONCLUSION

The value of reservoir factor (b) is equal to 0.2 which means, that the drive mechanism in the reservoir is a combination drive. The difference from one well to another indicates, that the wells are far from the injector wells. Analysis by D.C.A program takes less time comparing with

hand analysis. The calculated remaining reserve is equal 325,369 bbl. The recoverable reserves estimated, cannot be recovered completely using the existing wells due to a number of wells were shut in for mechanical problems (i.e. ESP failure). It is .recommended to work over there wells, and drill more infill wells to maximize oil recovery. Also it is recommended to optimize the water injection because the water injection will be partially affect water cut during oil production in reservoir, and a comprehensive DCA should be performed to see the effect of the orations procedure on the remaining reserves.

#### NOMENCLATURE

Symbol	Definition	Units
$a_i$	Nominal Decline Rate	1/year
$B$	Reservoir Factor	Unit less
$Q$	Oil production rate at time $t$	BBL/Day
$q_i$	Initial oil production rate	BBL/Day

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