Decline Curve Analyses and Oil Production Forecast

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Abstract: ***Any oilfield has a timeline of production history. There are three phases of its production life since first drop of oil till the end of production. First phase is the growth phase, the production will grow fast, other successful wells will help production grow fast and more tonnes of oil will come to surface. Then, with the years passing by, the growth will slow down and the second phase will come. This period will take some 10- 15 years, some time more, it depends on many factors: geologic, economic, reservoir characteristics, company policy and state regulations. The second phase is the plateau phase. The production will be almost unchanged. During this period, maybe more wells may enter in production, but old wells will produce less oil, so we will have almost the same amount of oil produced. The third phase is the decline phase, almost all the wells will produce less oil. A concern of high interest for the company will be to forecast the future production of oilfield. During all the phases of oilfield production there is some method of forecasting future production. DCA is the most successful method to do that during the third phase. In our paper we will use DCA method to study production data from Marinza Oilfield in order to find the DCA model and predict the production for the following years.***

Keywords: oilfield, DCA, production, wells, method

1. Introduction

Hydrocarbons are of the greatest importance to our societies. Since the first discovery and use, our civilisation is addicted to oil energy. Energy of any kind and specially hydrocarbons, oil and gas and others are of the greatest interests to us. Oil companies, states and investors are everyday in search of new oilfields, in optimising today production, estimating oil reserves and resources and predicting future production. Hydrocarbons, oil or gas, or other substances related to them are limited amount in deposits in earth (Hubbert 1956). After their discovery and time after their exploitation and production, this amount of oil and gas will be consumed and finished. We will not be able produce any more amount of oil or gas with the same techniques and technology. This was the initial concept of oil reserves estimation and the initial concept of forecasting future oil production. At the end of the nineteenth century and early years of twentieth century, reserves were estimated based on the simple and poor amount of parameters data, geologic, geographical oilfield borders (Lombardi, 1915; Requa, 1918).

This basic method of evaluating the Reserves became known that the method of saturation.

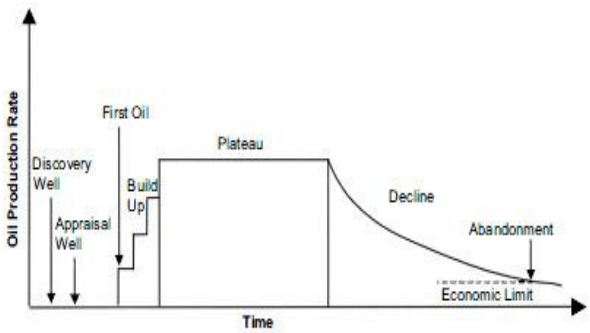

Figure 1: Timeline of oil production phases. SPE 2011

The second method of evaluating oil production began to develop in the early twentieth century. It was first referred to as the method of production decline, but more recently known by the name of Decline Curve Analysis (DCA). Petroleum Engineers had noticed that oil production fell over time, but they did not have a model to work. It was a study from Arnold and Anderson (1908) where for the first time was mentioned the production decline curve. The study noted the decline of oil production as a percentage of initial production was constant in a certain period of time. That was the start of DCA method. This method became widespread in the oil industry due to extraordinary demand for hydrocarbons on the eve of World War I, Lewis and Beal (1918), Requa (1918), Pack (1917), Arnold (1915) and later in the years of World War II (Arps, 1944). Engineers began successfully using the DCA to understand the present production and to forecast future production and reserves quantities. The method was to build the graph of history production data and find the model of decline, figures 2, 3, 4. The model would help to predict the future oil production.

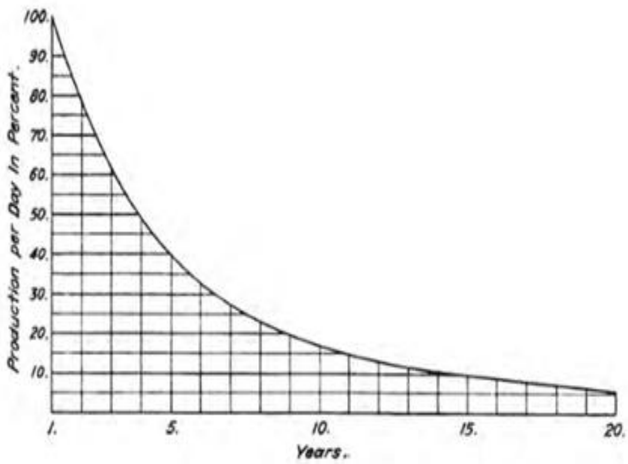

Figure 2: Oil Production Curve. Lombardi, 1915.

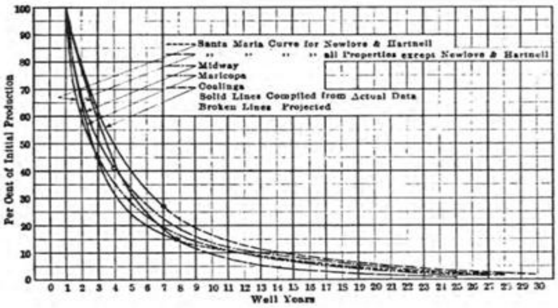

Figure 3: Oil Production Curve. Requa 1915.

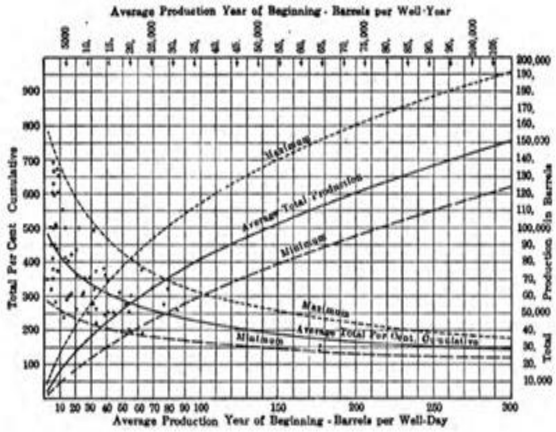

Figure 4: Fall Production Curve. Lewis and Beal 1918

The graph from Figure 2 shows a descending curve that was built by Lombardi on the basis of an oilfield oil production data in California. There were all together seven years of production data from the oilfield, (Lombardi, 1915). X- axes gives the time and Y- axis gives the ratio of oil production in the given time divided by the initial production, to give us the percentage of the decrease in production.

Figure 3 shows a descending curve of oil production from Requa, 1915. The curve goes beyond real data to predict future production.

Figure 4 shows a more advanced method, which includes the uncertainty in predicting the fall of the production method. It shows the production forecast decline in the future as well as the cumulative production as a function of time. In both cases the values of minimum, maximum and average values are included in the graph, (Lewis and Beal, 1918). A paper developed by Johnson and Bollens (1927 is known formally as the starting point of DCA method. Johnson and Bollens noted that the rate of production divided by the change in the rate of production was constant over a period of time during their study. They produced a method to calculate future production:

$$y_n = y_{n-1}\left(\frac{r_n}{r_n+1}\right) \quad (1)$$

where: y =production rate, oil volume / time;
r = ratio of the production rate / change in production rate;
n = interval of time.

Equation 1.1 shows the formula that Johnson and Bollens used to calculate the rate of production at a time. It represents the beginning of the DCA method that is still very much in use today.

2. Materials and Methods

Arps, 1944 implemented some simple mathematical formulas on the data and materials of Johnson and Bollens to achieve the best known and used method in estimating oil production, (Lee 2010). Arps noted that the ratio of production rate divided by change in production rate was constant and, in a semi log coordinative system it was presented by a straight line, so the function was exponential. Arps rewrote Johnson and Bollens equation in a better way:

$$-a = \frac{q}{\frac{dq}{dt}} \quad (2)$$

where: $a =$ exponential constant decline, time; $q =$ production rate, volume / time; t = time. The equation can be rewritten after some identical transformations:

$$\frac{dq}{dt} = -\frac{q}{a} \quad (3)$$

By integrating and making identical transformations will have:

$$\int_{qi}^{q} \frac{dq}{q} = -\frac{1}{a}\int_0^t dt \rightarrow \ln\left(\frac{q}{qi}\right) = -\frac{t}{a} \quad (4)$$

qi initial production rate, volume/time.

By exponentiation of both sides, we get the final Arps equation for exponential decline of oil production, which is very much in use today;

$$q(t) = q_i exp\left(-\frac{t}{a}\right) \quad (5)$$

Equation 1.5 is mentioned as the exponential decline equation or growth.

Arps empirical result is one of the greatest successes in the field of reservoir engineering, particularly on the field of evaluation of reserves. Arp's equation is still the most used mathematical formulas to predict oil production.

3. Case Study: Marinza Oilfield, Driza Sector

Oil production of Marinza started in 1957. The collected data are from the year 1975-1992, for a part of M- oilfield, D- Sector, table 1.

The production history shows all the phases, growth phase, the plateau phase and the decline phase, figure 5.

Marinza Oilfield had its plateau phase at the years. 1970-1974, after that the decline phase started. That was a best point to start DCA.

The data were worked with curve expert software, http://www.curveexpert.net/.

Table 1: Marinza Oilfield, D- sector data.
Real data, from 1957- 1992.
Predicted production, from 1993- 2001.

Years	Prod ton/year	Years	Prod.
1957	542920	1979	1322206
1958	597240	1980	1092732
1959	656880	1981	975654
1960	722680	1982	871120
1961	794920	1983	777786
1962	874440	1984	700708
1963	961800	1985	614656
1964	1057840	1986	465648
1965	1163680	1987	408463
1966	1280160	1988	480000
1967	1408120	1989	380000
1968	1548960	1990	350000
1969	1703800	1991	250000
1970	1874320	1992	180000
1971	2061640	1993	193904
1972	2267720	1994	168593
1973	2494520	1995	146585
1974	2744000	1996	127451
1975	2450000	1997	110814
1976	2168142	1998	96349
1977	1935841	1999	83772
1978	1599869	2000	72837
1979	1322206	2001	63329

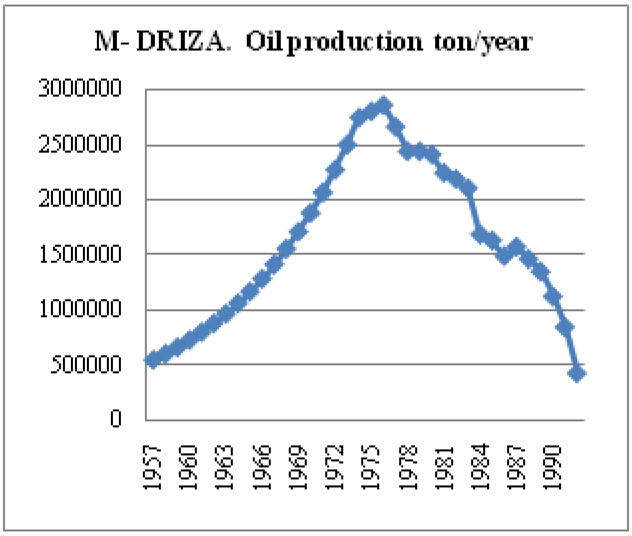

Figure 5: Oil production history, 1957- 1992

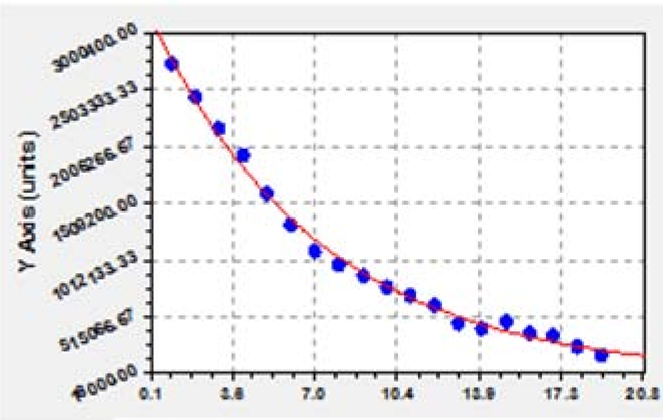

Figure 6: Oil Production ton/ years. 1974- 1992. Decline curve. Exponential function: $y = ae^{bx}$;
$a = 3180916, \quad b = -0.139878$.

4. Result

The graph 5 shows the production history of Marinza Oilfield, Sector D. We have the growth part, the plateau and the production decline part where we are using DCA.

From the curve expert software we have the exponential equation: $y = ae^{bx}$;
where; $a = 3180916, b = -0.139878$.

Table 2 shows the real production data from 1983- 1987 and the data output from exponential function.

The next years, 1993- 2001 are missing from the real data. For these data we have the output from exponential function of DCA. These are predicted oil production data for these years.

5. Conclusion

- The DCA method is very suitable during the phase of decline production.
- Arps' exponential equation suits best to oil production decline and is be useful to future prediction.
- We need all the data we can in order to have the best result and the best prediction of future oil production. More production data will provide a more accurate function parameters.
- The decline curve will find the economic limit line at some time. That will be is the end of oilfield production life, conditioned by present technology, production cost, contracts and state regulations.

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