Original Article

Oil Reservoirs and Exploitation of Oil Reservoirs

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ABSTRACT

Well testing entered petroleum engineering in 1937 as a tool to understand the actual behavior of the reservoir in the face of changes in the well. Artificial neural networks with a hidden layer have the ability to solve most nonlinear problems. In this study, an artificial neural network with a hidden layer was used to determine the reservoir model from pressure-derived diagrams. The number of neurons in the output layer is equal to the number of reservoir models considered, while the number of hidden layer neurons is an optimization problem and the problem is complexity, the complexity of the relationship between input and output, the amount of data available for network training, and the amount of noise. Educational data depends on different factors. A small number of them may not be able to converge the network to the desired error, while a large number may lead to the network not becoming popular. The minimum data required for network training based on an exploratory method should be ten times the number of links in the network. In leading networks, if the mean relative error and the square error of the test data are plotted against the number of hidden layer neurons, a structure that provides the minimum measurement error value and the appropriate value of the regression coefficient are selected as the optimal structure. The appropriate training algorithm is determined by identifying the algorithm that requires the least time for training. In other words, an algorithm with the minimum required training time is considered the optimal algorithm.

Introduction

In this category of tests, the well discharge rate is plotted in terms of well flow pressure. Then, based on its diagram, it is possible to guess the discharge of the well at a certain pressure and also to obtain the maximum discharge of the well or the discharge of the well at the pressure of leaving the reservoir, pressure at which extraction from the reservoir is no longer cost-effective [1-5]. The basis of the work is the estimation of future production based on quasi-empirical equations, for example, the Vogel equation or the Fotkovic equation, which obtain the unknown parameters of these equations based on existing pressure and flow data, and then assume this [6-9]. The desired equation with the obtained parameters is also valid for this well in Dubai and other pressures [10- 15].

For Oil Tanks

The following cases are considered:

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1- Productivity index test;
2- Flow performance test into the well;
3- Flow changes in long production time;
4- Flow changes in a short production time; and,
5- Changes in discharge in a short time of production and closing of wells [16-19].

For Gas Tanks

The following cases are considered:

1- Dubai changes in long production time;
2- Flow changes in a short production time; and,
3- Flow changes in a short time of production and closing of wells [20-22].

Production Efficiency Index Test

This test is used to measure the efficiency index, which is equal to the ratio of flow to pressure drop over the life of the tank. This index indicates the inherent ability of the reservoir to produce, the higher its value indicates the high ability of the reservoir rock to pass the reservoir fluid [23-26].

Test the Flow Performance into the Well

This test is a graph of well flow pressure in terms of discharge, which is similar to the efficiency index test for oil reservoirs at pressures higher than the bubble point pressure [27-30]. That is, their graph is linear, and for reservoirs whose pressure is below the bubble point pressure, they follow the Vogel equation. Based on this equation, the pressure equation in terms of flow can be obtained for the tested well [31-35].

Dubai Changes in Long Production Time

For this test, wells are produced in different discharges, and for each discharge, enough time is given to the well to stabilize the flow pressure at the bottom of the well, i.e. its changes are very small [36-39]. After repeating this task 4 or 5 times in different discharges, they draw a diagram of the stabilized flow pressure at the bottom of the well based on the discharge, based on which the unknown parameters of the Fotkovic equation are obtained. Then, based on this corrected formula, the discharge of the well can be guessed at any other pressure [40-45].

Dubai Changes in a Short Production Time

One of the problems of the flow change test in long production time is the long time to stabilize the pressure inside the well. For this reason, in the short flow production test, they produce from the well for a certain time in a certain flow and then after measuring the pressure, the well is closed to return to the initial pressure and then in the other two discharges they do the same with the same production time in the first discharge. Finally, they allow the well pressure to be stabilized with a specific flow rate. The data are then processed similarly to the flow change test over a long production time. The only difference is that the graph is drawn only from the fixed point of pressure [46-50].

Dubai Changes in a Short Time of Production and Closing of Wells

This test is similar to the previous test, except for the time of closing the well, the time is equal to the production time and do not allow the pressure to return to the initial pressure of the tank, which also reduces the test time. For gas tanks, the same tests are performed in the same way as for oil tanks [50-55].

Transient Pressure Tests (Pressure with Time)

Transient pressure testing is an important diagnostic tool that provides valuable information to the reservoir engineer. A transient test begins with a change in the well (for example, a change in flow) and then the pressure is recorded and observed at different times. Properly covered, it will withstand a great deal of adverse conditions [56-59].

A transient pressure test does not always give unique answers. There are usually abnormal changes in the reservoir system that affect the experiments and cause multiple results to be inferred from the pressure data. In this case, transient pressure test data should be used alongside other diagnostic methods or other data to determine its capability [60-64].

In the next two sections, two very common test methods, i.e. pressure rise test and pressure reduction test, are introduced [65].

Pressure Rise Test

In this experiment, a well that is being produced with a constant flow rate is completely closed (production is virtually stopped) and then the bottom pressure of the well is measured with a pressure recorder and recorded on time. It is also necessary to consider the production time before the test. The time to close the well is between two to three days so that the pressure is almost the same in all parts of the reservoir [66-70]. The advantage of this method is that the flow can be easily reduced to zero and there are no disadvantages of oscillation in the flow [16]. How the pressure changes over time in this experiment is shown in Figure 1.

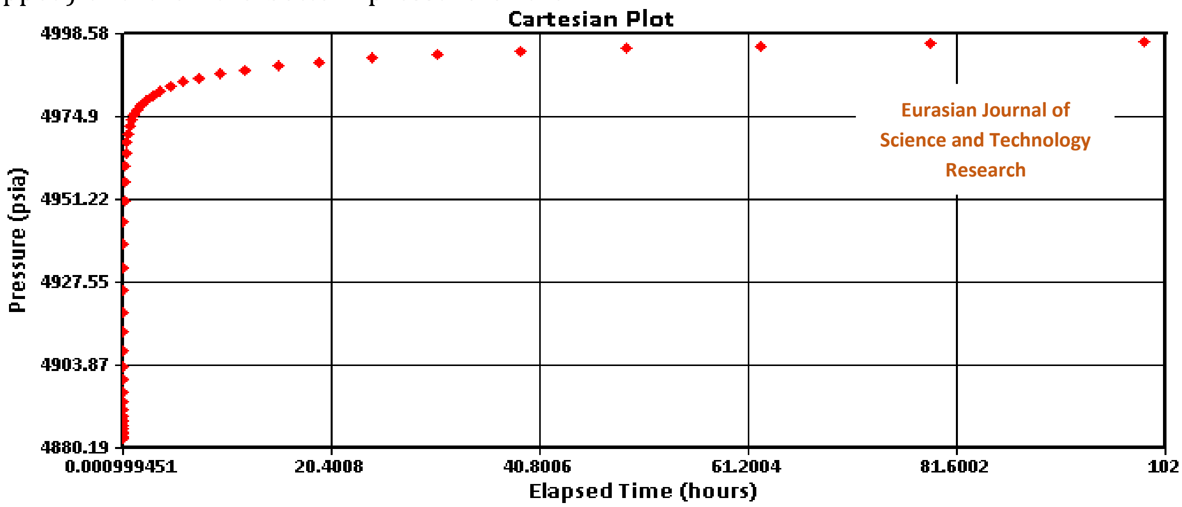

Figure 1 Diagram of pressure change with time in the pressure rise test [14]

Ideally, we assume that the test well operation is performed in a homogeneous, single-phase, slightly compressible reservoir with uniform and infinite properties in all respects whose boundary effect does not appear during the test [71-75]. The infiltration equation by which the fluid flow in porous media is managed and obtained from a combination of the law of mass survival, the law of Darcy, and the equation of state is expressed by Equation (1).

$$(1) \quad \frac{\partial p}{\partial t} = \frac{k}{\phi \mu C_t}\left[\frac{\partial}{\partial r}\left(\frac{\partial p}{\partial r}\right) + \frac{1}{r}\left(\frac{\partial p}{\partial r}\right)\right]$$

In Equation (1): p: pressure, t: time, k: permeability, μ: viscosity, C_t: Compressibility coefficient, ø: porosity, l: distance

This type of test well is divided into two types, ideal and real, each of which is described below [76-79].

Ideal Pressure Rise Test

In an experimental well, the ideal pressure rise is assumed to be the reservoir in a finite state, in a homogeneous and isotropic environment that consists of a fluid with low compressibility and a single phase with constant properties. If the well is closed t_p , the flow in the reservoir will be completely closed Δt. If the well has at the time of production and closes at the time, the multi-location rule is used, which is related to the vertical well with equation 2 [17]:

The above equation is converted to Equation (1-9) after mathematical simplification.

(2)
$$P_i - P_{ws} = -70.6\frac{q\mu B_0}{kh}\left[\ln\left(\frac{1688\phi\mu c_t r_w^2}{k(t_p+\Delta t)}\right)-2s\right]+70.6\frac{q\mu B_0}{kh}\left[\ln\left(\frac{1688\phi\mu c_t r_w^2}{k\Delta t}\right)-2s\right]$$

(3)
$$P_{ws} = P_i - 70.6\frac{q\mu B_0}{kh}\ln\left[\frac{t_p+\Delta t}{\Delta t}\right]$$

(4)
$$P_{ws} = P_i - 162.6\frac{q\mu B_0}{kh}\log\left[\frac{t_p+\Delta t}{\Delta t}\right]$$

The slope of this line $m = \frac{162.6 q \mu B_0}{kh}$ is used to determine the permeability of the reservoir [80-85].

In the above equations:
q: Dubai
q: Oil formation coefficient
P_i: Initial tank pressure
P_{ws}: Tank pressure at any point in time
r_w: Well radius
t_p: Production time before testing
Δt: The time of closing the well to record data

Real Pressure Rise Test

In a real pressure rise well, there is a complex curve instead of a straight line. In this test well, three different areas can be identified [86].

- **Initial area:** The pressure is transient around the well and the flow is affected by the storage inside the well [87].
- **Middle zone:** The flow is in the volume of the formation but has not yet reached the reservoir boundary [88].
- **Final time zone:** In this part, the flow has reached the boundary of the reservoir and the check radius is equal to the reservoir radius [8].

Deviation from the Ideal State

Infinite reservoir is an ideal concept. In fact, most reservoirs reach the reservoir boundary during production. There is usually no single-phase fluid in the tank [89-92]. In the best case, the tank fluid has some twin water. In addition, when the well has a high gas to oil ratio, it creates a hump-like pattern when the pressure increases. No reservoir is homogeneous and isotropic and usually the average rock and fluid properties in the reservoir are selected [7].

Methods of Interpreting the Pressure Rise Test

The methods of interpreting the pressure rise test are of two types, each of which is used in specific cases [1].

A. Herner Method

In this method, P_{wf} it is used when the well is open and in production and P_{ws} is used when the well is closed and its production is stopped.

(5)
$$P_{ws}(\Delta t = 0) = P_{wf}(t_p)$$

(6)
$$P_i - P_{ws}(\Delta t) = \left[P_i - P_{wf}(t_p+\Delta t)\right] - \left[P_i - P_{wf}(\Delta t)\right]$$

By placing it in Equation (6) and writing the relation based on the functional units of the American system, Equation (6) is obtained [9].

(7)
$$P_i - P_{ws}(\Delta t) = \frac{162.6 q\mu B_0}{kh}\log\left(\frac{t_p+\Delta t}{\Delta t}\right)$$

According to Equation (7), the relationship of pressure difference in terms of $\log\left(\frac{t_p+\Delta t}{\Delta t}\right)$ is a straight line. The value *kh* can be obtained through the slope of this line [93-95].

The following is done to determine the shell coefficient.

(8)

$$P_i - P(1hr) = \frac{162.6 q \mu B_0}{kh} \log(t_p + 1)$$

Where P (1hr) is the measured pressure one hour after the well is closed [96].

(9)

$$P_i - P_{wf} = \frac{162.6 q \mu B_0}{kh} \left(\log t_p + \log \frac{k}{\varphi \mu c_t r_w^2} - 3.23 + 0.87 s \right)$$

From the sum of two relations (8) and (9), the shell coefficient can be obtained [18].

Determination P_i : If the production time is short before the well is closed, assuming that the pressure drop has not reached the reservoir limit; the initial value of the reservoir pressure can be obtained by extrapolating the semi-logarithmic diagram [97].

If at the time of production, $\left(\frac{t_p + \Delta t}{\Delta t} \right)$ the pressure drop reaches the reservoir limit (towards one mile), no matter how long the well is closed at the same time, it still does not reach the initial pressure - unless it has a very strong discharge - the pressure obtained is *P*.

B- MDH Method

This method is used when the production time t_p is longer than the closing time of the well. In other words, the pressure drop has reached the reservoir limit at the time of production. Equation (10) is used for this case. is method is used when the production time is longer than the closing time of the well. In other words, the pressure drop has reached the reservoir limit at the time of production. Equation (10) is used for this case [98-100].

(10)

$$P_i - P_{ws}(\Delta t) = -\frac{162.6 q \mu B_0}{kh} (\log \Delta t - \log t_p)$$

According to Equation (10) and by plotting the pressure difference in terms of logΔt, the permeability and conductivity of the well can be obtained [18-20].

Pressure Reduction Test (Flow)

The flow test is the opposite of the pressure rise test. In this experiment, the closed well is opened with a constant flow for production and then the pressure information against time is recorded. This test is usually performed immediately after the pressure rise test [19].

How pressure changes with time in a flow test is shown in Figure 2. From this it is quite clear that in the flow test, the well pressure decreases steadily over time.

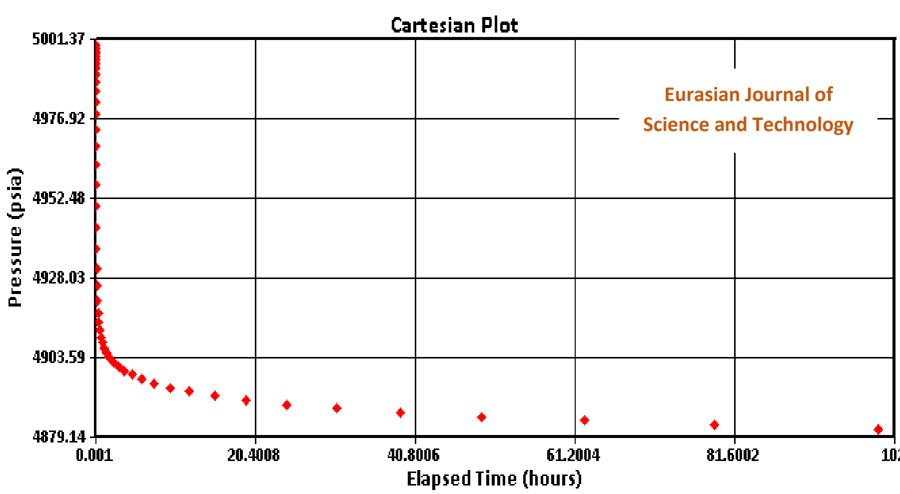

Figure 2 Diagram of pressure change over time in flow test [14]

Equation 11 shows the time-varying pressure changes in a flow test well when the flow rate is constant. The mentioned relation is in terms of Darcy units [18].

Using derivative diagrams simultaneously, logΔP in logΔt and log (dp / dt) in logΔt can be compared. Dimensional time and dimensionless pressure are commonly used to derive graphs [29].

(12) $$t_D = \frac{0.000264kt}{\phi \mu c_t r_w^2}$$

(13) $$P_D = \frac{kh}{141.2\, q\, \mu\, B_0}(P_i - P_{wf})$$

Examples of Application of Pressure Derivative Curves

Figure (3) does not show the pressure graph over time, but the derivative diagram shows the fact that the well is close to an impenetrable boundary, such as an impermeable fault [15].

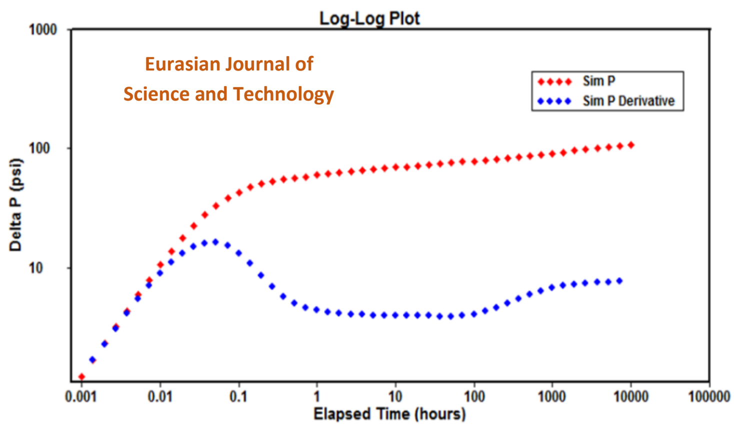

Figure 3 Doubling the slope indicates the presence of a fault [15]

In Figure 4, the pressure diagram does not show specific information in terms of time, but its derivative diagram shows the difference between the two flow tests and the pressure rise. In the rise test, the pressure difference decreases and in the flow test, the pressure difference increases.

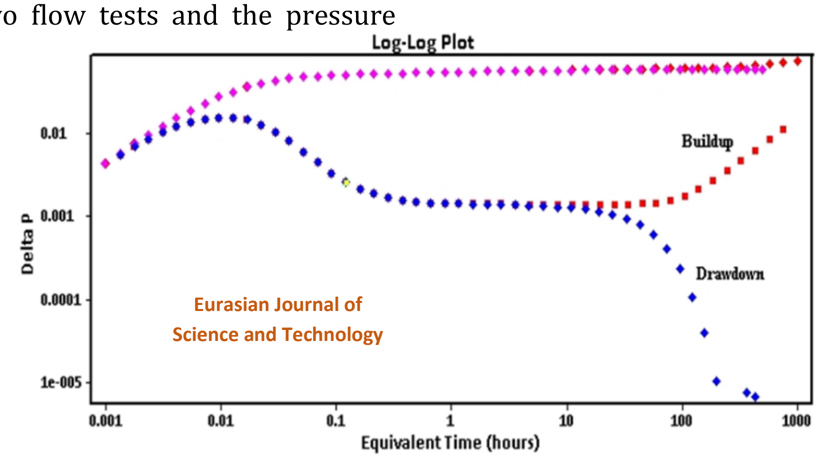

Figure 4 Difference between pressure rise and flow well [20]

Figure 4 shows the state in which the well reaches a constant pressure area at one of the boundaries, in which case there is no pressure drop due to a strong discharge or a strong gas cap at the reservoir boundary. The derivative diagram illustrates this well.

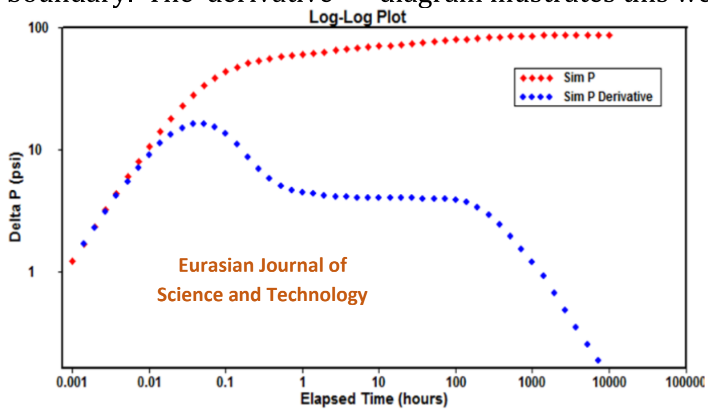

Figure 5 View of the final region of a constant pressure boundary [20]

In Figure (5) the well is drilled in a reservoir with closed boundaries. In this case, in the final region of the test well, the pressure derivative diagram changes with a slope of 1 with respect to time.

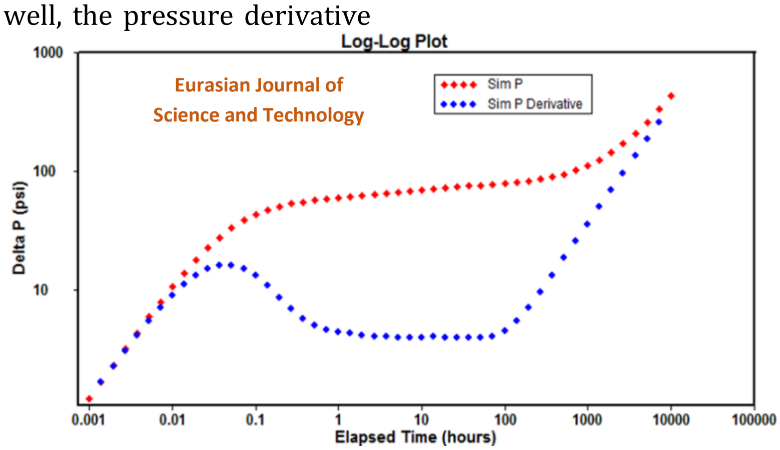

Figure 6 Well test diagram in case of pressure drop in a reservoir with impermeable boundaries [15]

Another case study is that first after the affected area of in-well storage and shell coefficient in the reservoir there is a radial flow and the slope is zero, but after reaching the first fault, the slope of pressure drop increases and then the flow under the influence of two The fault is located. The slope is doubled (Fig. 7).

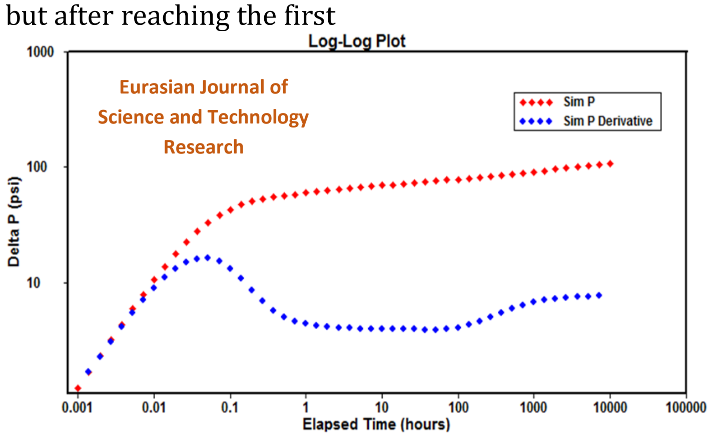

Figure 7 An illustration of the existence of two impermeable faults at the outer boundary of the reservoir [15]

If the fault is not completely permeable, it can be understood according to the derivative, as seen in Figure 8 [15].

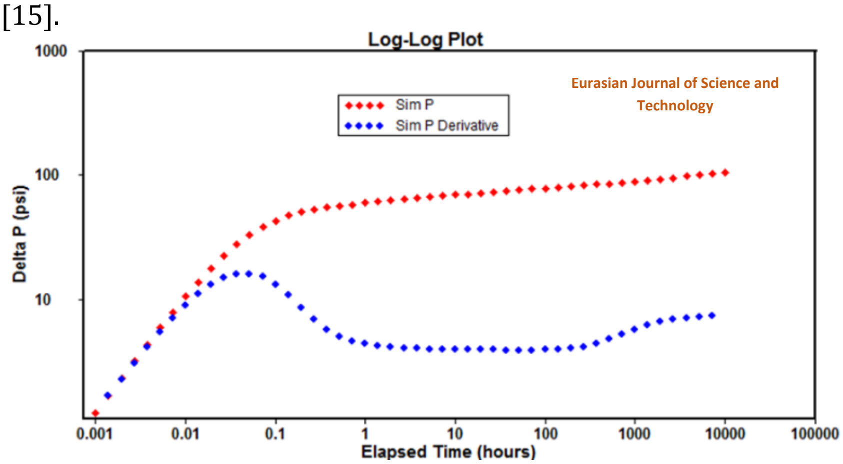

Figure 8 View of well pressure changes near a semi-transient fault [15]

Types of Wells in Reservoirs

In different hydrocarbon reservoirs, according to the reservoir conditions, production rate and economic estimates, different drilling is done in the reservoirs. The most common wells that are drilled in the reservoirs are: Wells Vertical, wells with hydraulic failure and horizontal wells.

Vertical Wells

Vertical wells are the most common drilling in various reservoirs and the cost of drilling this well is lower than other wells. This type of well is usually drilled if the tank has a high permeability and there is no problem in the production process from the tank.

Wells with Hydraulic Failure

This type of well improves the production of the reservoir by increasing the effective radius of the well and is usually used in reservoirs with a permeability of less than one millisecond. This is done by injecting a high-pressure propane stream in the form of symmetrical fractures around a vertical well.

Horizontal Wells

In recent decades, horizontal wells have found more applications because they have performed better than vertical wells. The horizontal well increases the contact surface between the well and the reservoir and also one of its important functions is to delay the phenomenon of gas and water cone (lowering the gas level and raising the water level), which causes its production to become more than a tank. These wells allow high production speeds at lower pressure drops and permeability is increased by increasing the number of capillaries and surface tension. The productivity of natural wells is proportional to the permeability and thickness of the reservoir and is the reason for the low production of low permeability and the shape of the reservoir thickness. Factors that affect the performance of horizontal wells include: Well length, vertical to horizontal permeability ratio, reservoir thickness and well height.

Horizontal well pressure analysis is much more difficult than vertical wells for the following reasons:

- In most models of horizontal wells, it is assumed that the well is completely horizontal and parallel to the upper and lower boundaries of the reservoir. In general, drilling a horizontal well is rarely horizontal.

- It measures the effective pressure in the end production of a horizontal well. The flow regimes that occur in horizontal wells during production are greater than in vertical wells.
- It is very difficult to accurately estimate production in horizontal wells.
- Calculations are not easy and correct because the horizontal well shell coefficient is negative.

In the next section, we discuss flow regimes in horizontal wells. During testing on a horizontal well, three specific flow cycles can be detected, provided that the storage effect of the wellhead or the boundary effect of the discharge area is not obscured.

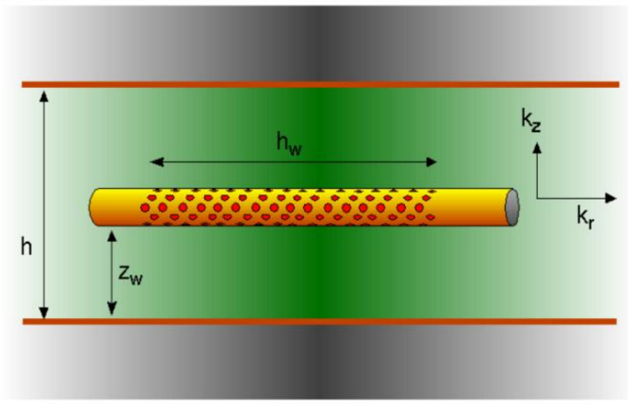

Figure 9 View of a horizontal well [13]

Primary Vertical Radial Flow Period

The compressible zone created by the change in flow rate first expands in a plane perpendicular to the well. The corresponding current is the radius created by the in-well storage and depends on the vertical and horizontal permeability. This flow ends when it reaches the retaining beds or when the effect of the well end on the flow is felt. Figure 10 below shows the state of this flow regime.

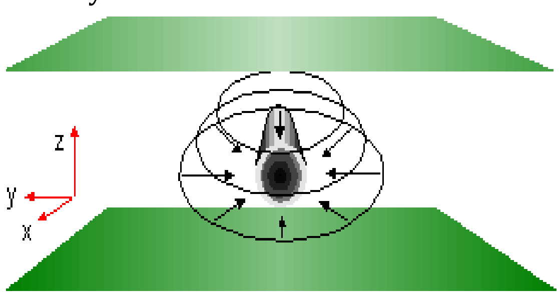

Figure 10 of vertical radial flow [13]

Intermediate Linear Flow Period

In many cases the length of the horizontal well is greater than the thickness of the reservoir, in which case the flow regime becomes linear. In this flow, the effect of upper and lower boundaries is felt in the well and will not develop if the length of the horizontal well is not large compared with the thickness of the reservoir. Figure 11 below illustrates this flow regime [101-105].

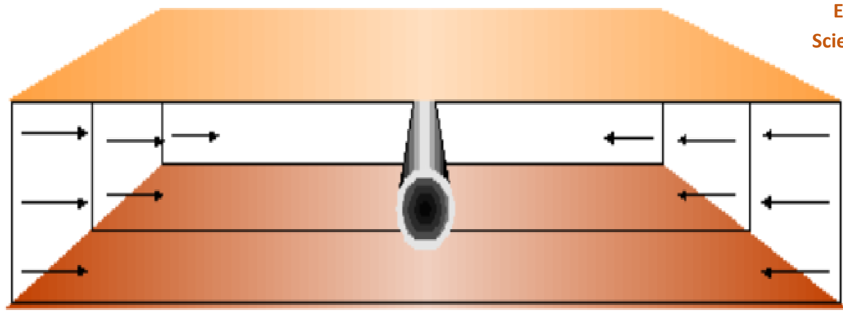

Figure 11 Intermediate linear flow regime [13]

Terminal Quasi-radial Flow Period

After the previous two regimes have elapsed over a period of time, the potential lines, like the lines around a vertical well, form vertical cylinders. Since then, the flow has been radial and in circles on horizontal planes. In this type of regime, the flow radius is larger than the length of the horizontal well and vertical permeability has a great effect. When the reservoir boundaries are felt, in this type of flow, the geometry of the well has no effect on production and the performance of the vertical and horizontal wells are no different. Note the shape of the flow regime [106-109].

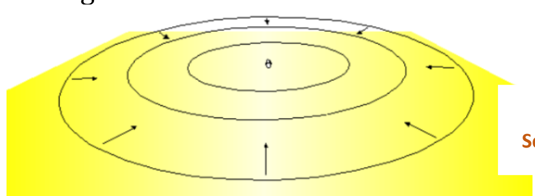

Figure 12 Quasi-radial flow [13]

Equations of Time of Different Regimes in Horizontal Wells

Many researchers have provided equations for different horizontal well regimes, including the Tambainayagan well of Odeh and Babu and Joshi. Here we refer to the equations presented by Odeh and Babu [110-112].

- The duration of the initial radial flow may be obtained approximately from the following equation:

(14) $$t_{e1} = \frac{1800 \o c_t \mu_o d_Z^2}{k_v}$$

or

(15) $$t_{e1} = \frac{125 \o c_t \mu_o L^2}{k_v}$$

- Start and end time of intermediate linear flow

(16) $$t_{e2} = \frac{1800 \o c_t \mu_o D_Z^2}{k_v}$$

and

(17) $$t_{e2} = \frac{160 \o c_t \mu_o L^2}{k_x}$$

- Start and end time of quasi-radial flow

(18) $$t_{e3} = \frac{1480 \o c_t \mu_o L^2}{k_x}$$

and

(19) $$t_{e3} = \frac{2000 \o c_t \mu_o \left(\frac{L}{4}+d_x\right)^2}{k_x}$$

Conclusion

Borehole pressure data over time cannot be used directly to identify oil reservoir models. The data obtained from the simulation should be converted to pressure-derived data by appropriate algorithms. Leading neural network training is possible on most common computers. In this study, the leading neural network with an overall accuracy of 97.05 has shown good performance against noise data as well as data that are not in the specified range of changes. But it is better that more data should be used for network training and therefore, when the number of models is high and their similarity to each other is high, it is recommended to use the classification method to get better results [112-114].

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