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Solution of Some Problems of the Elastic Mode by the Method of Superpositions

Bekjonov R.S., SamadovSh.Sh , Kurbanov M.T, Boykobilova M.M, Xidirov J.Ch.

Senior Lecturer, Department of Oil and Gas Administration, Karshi Engineering and Economic Institute.
Assistant of the Department of Oil and Gas Studies, Karshi Engineering and Economic Institute.
Assistant of the Department of Oil and Gas Studies, Karshi Engineering and Economic Institute
Assistant of the Department of Oil and Gas Studies, Karshi Engineering and Economic Institute.
Assistant of the Department of Oil and Gas Studies, Karshi Engineering and Economic Institute

ABSTRACT: This article discusses the application of the method of superposition (imposition) of filtration flows in some problems of unsteady processes under elastic conditions.

KEYWORDS: Dependence. We modify dependence.The pressure increase.As shown by numerous experiments.

I.INTRODUCTION

In the practice of the development and operation of oil and gas fields, unsteady processes associated with the start-up and shutdown of wells often arise in the formations, with a change in the rate of fluid withdrawal from the wells. The nature of these processes is manifested in the redistribution of reservoir pressure, in the change over time in the rates of filtration flows, well rates, etc. The features of these unsteady processes depend on the elastic properties of the formations and the liquids saturating them, i.e. the main form of reservoir energy in these processes is the energy of elastic deformation of liquids (oil and water) and reservoir material [1,2,3].

In order to investigate unsteady filtration processes of an elastic fluid in an elastic reservoir, we will use the equation of the elastic filtration mode [1,2].

Since the differential equation of the elastic regime is linear, then the superposition method is used to solve it, which makes it possible to investigate the interference of wells in the elastic regime as well.

The method of superposition (imposition) of filtration flows is used in problems of unsteady processes under elastic conditions. Suppose that a well with a constant flow rate Q is put into operation in an unlimited reservoir. The pressure drop in the reservoir can be determined, for example, by the formula

$$p_0 - p = \frac{Q\mu}{4\pi bk}\left(\ln\frac{4\aleph t}{r^2} - C_э\right), \qquad (1)$$

Where is the initial pressure; - coefficient of dynamic viscosity; - coefficient of permeability; - the width of the formation; - coefficient of piezo conductivity; is Euler's constant.

After a period of time T after the start-up, the well was stopped. From the moment of stopping, the pressure in it increases, and the disturbance caused by the stopping propagates through the formation. It is recommended to assume that from the moment of shutdown, the flow simulating the well is combined with a source having the same flow rate Q. Let's designate the increase in pressure due to the operation of the source through $\Delta\rho''$. Thus, starting from the moment of time T, in the same place of the reservoir, as it were, operating continuously and continuously operating and injection wells.

Based on formula (1), we have:

$$\Delta p' = \frac{Q\mu}{4\pi bk}\left[\ln\frac{4\aleph(T+t)}{r^2} - C_э\right]$$

$$\Delta p'' = \frac{Q\mu}{4\pi bk}\left(\ln\frac{4\aleph t}{r^2} - C_э\right)$$

Using the superposition method, we find the resulting pressure drop at any point in the reservoir:

$$\Delta p = \Delta p' - \Delta p'' = \frac{Q\mu}{4\pi bk} \ln \frac{T+t}{t} \quad (2)$$

Denoting the pressure at the bottom of the well after its shutdown, we obtain by the formula (2):

$$p_c = p_0 + 0{,}1832 \frac{Q\mu}{bk} \lg \frac{t}{T+t} \quad (3)$$

If the argument of the ordinary logarithm in formula (3) can be taken equal.

Dependence (3), as we will see below, is used in the study of wells, which must be shut down for this purpose. However, stopping them is not always possible and desirable.If a well is investigated without stopping, the mode of its operation is changed, setting, for example, a new flow rate.In this case, the calculation formulas that determine the change in pressure in the well can be derived using the same superposition method [3].

Let the production well in the first mode operate with a volumetric flow rate. When switching to the second mode, the flow rate was reduced and became equal. For example, it can be assumed that in the first mode, instead of one well with a flow rate Q_1, two were operated: one with a flow rate, the other with a flow rate $\Delta Q = Q_1 - Q_2$. At the time of the regime change, one of these wells with flow rate ΔQ was shut down, while the other continues to operate at a constant flow rate Q_2. In the calculation formulas based on formula (1), appropriate corrections are made to the time values, depending on the moment at which the well operation mode is changed.

If a group of wells operates in the formation, including both production and injection wells, the pressure $\Delta\rho$ drop at any point in the formation is determined by adding the pressure drops created at this point by individual sources and effluents representing the wells $\Delta\rho^{(i)}$.

In this way we find

$$\Delta p = \sum_{j=1}^{n} \Delta p^{(i)} = \frac{\mu}{4\pi bk} \sum_{j=1}^{n} Q_j \left[-Ei\left(-\frac{r_j^2}{4\aleph t}\right) \right], \quad (4)$$

where is the number of wells; Q_j - volumetric flow rate of the flow (+) or source (-) per number $j; r_j$ - the distance of a given point of the formation from the well per number j.

Assuming that the values of the arguments Ei in formula (4) are small enough, and using the formulas

$$-Ei(-x) = \ln\frac{1}{x} - C_э, \quad \frac{d}{dx}\left[-Ei(-x)\right] = -\frac{e^{-x}}{x} \text{ and } C_э = \ln 1{,}781,$$

We modify dependence (4) as follows:

$$\Delta p = \frac{\mu}{4\pi bk} \sum_{j=1}^{n} Q \ln \frac{2{,}246\aleph t}{r_j^2}. \quad (5)$$

With the help of formula (5), for example, bk/μ a parameter is determined from the data of the well survey.
Formula (4) was obtained for the case of simultaneous start-up of all wells in the group.
If injection and production wells were launched at different times, formula (4) will look like this:

$$\Delta p = \frac{\mu}{4\pi bk} \sum_{j=1}^{n-1} Q_{j+1} \left[-Ei\left(-\frac{rj+1}{4\aleph (t_1 - t'_{j+1})}\right) \right], \quad (6)$$

Where t'_{j+1} is the start-up time of the well by number $j+1$, and here $t_1' = 0 (j=0)$.

The rate of pressure change in the formation depends on the permeability of the formation as a whole. Therefore, the definition of this parameter is of great importance. Only the study of unsteady processes makes it possible to determine the coefficient of permeability of the formation. As it has been said, the well is examined by changing the mode of its operation. The start-up of an idle well causes an unsteady process of pressure reduction.

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By measuring the changing bottom hole pressure in the well, graphs of pressure changes are built. The study of such graphs - tracking graphs - is the essence of tracking methods.

Graphically expressing the relationship between bottomhole pressure and time, semilogarithmic anamorphosis is used.

Let us derive a formula for plotting the relationship between bottomhole pressure and time during the start-up of an idle well.We take formula (1) and write down the value of the bottomhole pressure drop after the well start-up:

$$\Delta\rho_c = p_0 - p_c = \frac{Q\mu}{4\aleph bk}(\ln\frac{4\aleph t}{r_c^2} - 0,5772) = 0,1832\frac{Q\mu}{bk}\ln\frac{2,24\aleph t}{r_c^2}$$

From here we get:

$$\Delta\rho_c = 0,1832\frac{Q\mu}{bk}(\lg\ t + 0,3514 + \lg\frac{\aleph}{r_c^2}) \quad (7)$$

Dependence (7) is a straight line in the coordinate axes $1g\ t - \Delta\rho_c$. The recovery of bottomhole pressure during shutdown of an operating well, which by the time of shutdown was working under conditions of an unsteady process, is described by relationship (3).

If the well has been operating for such a long time before the shutdown that the pressure distribution in the formation can be taken as steady. We use the superposition method. Let the well flow rate be Q before stopping, and the radius of the reservoir feeding contour r_k.

Let us denote by the steady-state pressure drop preceding the shutdown of the well. Based on the Dupuis formula, we have:

$$\Delta p_c' = \frac{Qy\mu}{2\pi bk}\ln\frac{r_k}{r_c}. \quad (8)$$

The pressure increase after the well shut-in $\Delta\rho_c''$ is calculated by the formula (1).Using the superposition method, we find the pressure drop in the well as follows:

$$\Delta p_c = \Delta p_c' - \Delta p_c'' \quad (9)\text{or}$$

$$\Delta p_c = 0,1832\frac{Q_{y\mu}}{bk}(\lg\frac{r_k^2}{2,246\aleph} - \lg\ t).$$

The graph corresponding to dependence (9) is shown in Fig.one. The process of pressure increase after the launch of the injection well proceeds in the same way as the process of its decrease develops. To calculate the increase $\Delta\rho_c = \rho_c - \rho_0$, we can use the formula (7).Considering the relationship between the decrease (or increase) of pressure $\Delta\rho_c$ in the well and the ordinary logarithm of time t - см. - see equations (3),

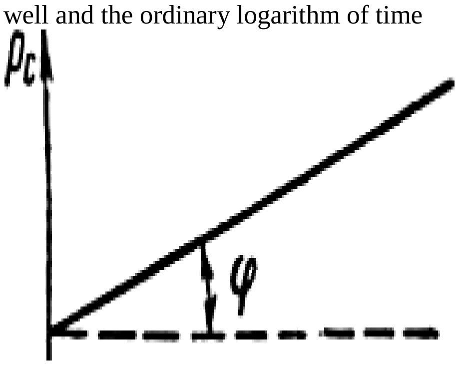

Fig.1. The dependence of the bottomhole pressure on the value - $\lg\ t.$

(7) and (8), we come to the conclusion that the angle of inclination of the straight line to the abscissa η axis is determined using the following equality:

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$$tg\,\eta = i = 0{,}1832\frac{Qy\mu}{bk},$$

From here we get:

$$bk = \frac{0{,}1832 Qy\mu}{i}. \quad (10)$$

Using formula (10), for a given section of the well pressure tracking graph, it is possible to determine the reservoir properties of the formation. Indeed, having established according to the graph of the type shown in Fig.1. the slope of a straight line $i = tg\ \eta$, according to the formula (10) we can calculate the value of the product bk .If at the same time the thickness of the formation is still known, it is easy to calculate b the coefficient of permeability of the formation k.

If, according to the results of laboratory studies, we know the coefficient of elastic capacity of the formation and the viscosity of the liquid, we can use the formula $\aleph = k/(\mu\beta^*)$ for the found to calculate the coefficient k of piezoconductivity $\aleph$.

The graph, built on the basis of the results of real field studies of wells, does not take the form of a straight line immediately.As shown by numerous experiments, if, after stopping the well, the flow of fluid through its bottom from the formation continues, there will certainly be a straight section on the pressure build-up graph of such a well.

Thus, when calculating unsteady processes in wells, you can use the above dependencies.All formulas are valid under the following conditions:

1) reservoir regime - elastic;
2) the reservoir is unlimited and homogeneous;
3) the well is hydrodynamically perfect;
4) at the time of the well shut-in, its flow rate at the bottomhole is zero.

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