HYDRAULICALLY FRACTURED WELL TEST ANALYSIS pdf

1: Fluid flow in naturally fractured reservoirs -

Although it is the most common methodology for analyzing hydraulically fractured well, type-curve analysis still has some limitations. First, type-curves for analysis of hydraulically fractured wells are usually based on solutions for constant-rate drawdown tests.

Because of the different fluid storage and conductivity characteristics of the matrix and fractures, these reservoirs often are called dual-porosity reservoirs. Fortunately, it has been observed that a real, heterogeneous, naturally fractured reservoir has a characteristic behavior that can be interpreted using an equivalent, homogeneous dual-porosity model such as that shown in the idealized sketch. These models differ conceptually only in the assumptions made to describe fluid flow in the matrix. Most dual-porosity models assume that production from the naturally fractured system comes from the matrix, to the fracture, and then to the wellbore i. Furthermore, the models assume that the matrix has low permeability but large storage capacity relative to the natural fracture system, while the fractures have high permeability but low storage capacity relative to the natural fracture system. Warren and Root [1] introduced two dual-porosity parameters, in addition to the usual single-porosity parameters, which can be used to describe dual-porosity reservoirs. Interporosity flow is the fluid exchange between the two media the matrix and fractures constituting a dual-porosity system. The interporosity flow coefficient is a measure of how easily fluid flows from the matrix to the fractures. On the other hand, for the multilayered or "slab" model shown in Fig. Consequently, the storativity ratio is a measure of the relative fracture storage capacity in the reservoir. Two common models, pseudosteady-state and transient flow, that describe flow in the less-permeable matrix are presented here. Pseudosteady-state flow was assumed by Warren and Root [1] and Barenblatt et al. Intuition suggests that, in a low-permeability matrix, very long times should be required to reach pseudosteady-state and that transient matrix flow should dominate; however, test analysis suggests that pseudosteady-state flow is quite common. A possible explanation of this apparent inconsistency is that matrix flow is almost always transient but can exhibit a behavior much like pseudosteady-state, if there is a significant impediment to flow from the less-permeable medium to the more-permeable one such as low-permeability solution deposits on the faces of fractures. Pseudosteady-state matrix flow model The pseudosteady-state flow model assumes that, at a given time, the pressure in the matrix is decreasing at the same rate at all points and, thus, flow from the matrix to the fracture is proportional to the difference between matrix pressure and pressure in the adjacent fracture. Specifically, this model, which does not allow unsteady-state pressure gradients within the matrix, assumes that pseudosteady-state flow conditions are present from the beginning of flow. Because it assumes a pressure distribution in the matrix that would be reached only after what could be a considerable flow period, the pseudosteady-state flow model obviously is oversimplified. Again, this model seems to match a surprising number of field tests. One possible reason is that damage to the face of the matrix could cause the flow from matrix to fracture to be controlled by a sort of choke the thin, low-permeability, damaged zone and, therefore, is proportional to pressure differences upstream and downstream of the choke. In the next two sections, semilog and type-curve analysis techniques are presented for well tests in naturally fractured reservoirs exhibiting pseudosteady-state flow characteristics. Semilog analysis technique The pseudosteady-state matrix flow solution developed by Warren and Root [1] predicts that, on a semilog graph of test data, two parallel straight lines will develop. The initial straight line reflects flow in the fracture system only. At this time, the formation is behaving like a homogeneous formation with fluid flow originating only from the fracture system with no contribution from the matrix. Consequently, the slope of the initial semilog straight line is proportional to the permeability-thickness product of the natural fracture system, just as it is for any homogeneous system. Following a discrete pressure drop in the fracture system, the fluid in the matrix begins to flow into the fracture, and a rather flat transition region appears. Finally, the matrix and the fracture each reach an equilibrium condition, and a second straight line appears. At this time, the reservoir again is behaving like a homogeneous system, but now the system consists of both the matrix and the fractures. Because the permeability of the fractures is much greater than that of the matrix, the slope of the second line is almost identical to that of the initial line. Similar shapes are predicted for pressure buildup tests Fig. The lower curve, A, represents the ideal buildup test plot predicted by Warren and Root. Wellbore storage almost always obscures the initial straight line and often obscures part of the transition region between the straight lines. The upper curve, B, in Fig. The reservoir permeability-thickness product, kh [actually the kh of the fractures, or kh f, because kh m is usually negligible], can be obtained from the slope, m, of the two semilog straight lines. Although presented in variables for slightly compressible fluids liquids , the same procedure is applicable to gas well tests when the appropriate variables are used. From the slope of the initial straight line if present or final straight line more likely to be present , determine the permeability-thickness product, kh. In either case, the slope, m, is related to the total kh of the system, which is essentially all in the fractures. The permeability-thickness product is given by Vm usually can be assumed to be essentially 1. Type curve analysis technique Particularly because of wellbore-storage distortion, type curves are quite useful for identifying and analyzing dual-porosity systems. Initially, test data follow a curve for some value of CDe2s where CD is the dimensionless wellbore storage coefficient. When equilibrium is reached between the matrix and fracture systems, the data then follow another CDe2s curve. After Bourdet et al. During intermediate times, there is a transition region as the matrix begins to produce into the fractures. At later times, the system again is behaving like a homogeneous system with both matrix and fractures contributing to fluid production. Test data that follow this pattern on the derivative type curve can reasonably be interpreted as identifying a dual-porosity reservoir with pseudosteady-state matrix flow a theory that needs to be confirmed with geological information and reservoir performance. Pressure and pressure derivative type curves can be used together for analysis of a dual-porosity reservoir. The pressure derivative data are especially useful for identifying the dual-porosity behavior. Manual type-curve analysis for well in naturally fractured reservoirs is tedious, and the interpretation involved is difficult. Most current analysis uses commercial software. After Bourdey et al. Only at late times should pseudosteady-state flow be achieved, although a matrix with a thin, low-permeability damaged zone at the fracture face may behave as predicted by the pseudosteady-state matrix flow model even though the flow in the matrix is actually unsteady-state. A semilog graph of test data for a formation with transient matrix flow has a characteristic shape different from that for pseudosteady-state flow in the matrix. Three distinct flow regimes have been identified that are characteristic of dual-porosity reservoir behavior with transient matrix flow. Flow regime 2 occurs when production from the matrix into the fracture begins and continues until the matrix-to-fracture transfer reaches equilibrium. This equilibrium point marks the beginning of flow regime 3, during which total system flow, from matrix to fracture to wellbore, is dominant. The same three flow regimes appear when there is pseudosteady-state matrix flow. The duration and shape of the transition flow regimes, however, is considerably different for the two matrix flow models. Flow regimes 1 and 3, which correspond to the classical early- and late-time semilog straight-line periods, respectively, have the same slope. Flow regime 2 is an intermediate transitional period between the first and third flow regimes. The semilog straight line of flow regime 2 has a slope of approximately one-half that of flow regimes 1 and 3. If all or any two of these regimes can be identified, then a complete analysis is possible using semilog methods alone. Certain nonideal conditions, however, may make this analysis difficult to apply. Flow regime 1 often is distorted or obscured by wellbore storage, which often makes this flow regime difficult to identify. Flow regime 2, the transition, also may be obscured by wellbore storage. Flow regime 3 sometimes requires a long flow period followed by a long shut-in time to be observed, especially in formations with low permeability. Furthermore, boundary effects may appear before flow regime 3 is fully developed. Semilog analysis techniques Serra et al. They found that the existence of the transition region, flow regime 2, and either flow regime 1 or flow regime 3 is sufficient to obtain a complete analysis of drawdown or buildup test data. Further, they assumed unsteady-state flow in the matrix, no wellbore storage, and rectangular matrix-block geometry, as Fig. The rectangular matrix-block geometry is adequate, although different assumed geometries can lead to slightly different interpretation results. The major weakness of the Serra et al. In many cases, flow regimes 1 and 2 are partially or even totally obscured by wellbore storage, making analysis by the Serra et al. Despite this limitation, the Serra et al. These calculations of the Serra et al. Type curve analysis technique Bourdet et al. The type curves are useful supplements to the Serra et al. Early fracture-dominated data are fit by a CDe2s value indicative of homogeneous behavior. Finally, data in the homogeneous-acting, fracture-plus-matrix flow regime are fit by another CDe2s curve. Analysis ordinarily uses commercially available software to analyze these kinds of tests after the reservoir model has been identified.

2: Advanced Well Test Analysis

Hydraulic fracturing has been used extensively over the past 15 yr to stimulate low-permeability oil and gas wells. A considerable amount of fractured well performance theory has accumulated during this period. Transient drawdown solutions for vertically fractured liquid wells based on numerical.

Fracture linear flow Fig. During this flow period, most of the fluid entering the wellbore comes from fluid expansion in the fracture, and the flow pattern is essentially linear. The duration of the fracture linear flow period is estimated by [1] Most of the fluid entering the wellbore during this flow period comes from the formation. The duration of bilinear flow depends on dimensionless fracture conductivity and is given by Eqs. After a sufficiently long flow period, the fracture appears to the reservoir as an expanded wellbore consistent with the effective wellbore radius concept suggested by Prats et al. At this time, the drainage pattern can be considered as a circle for practical purposes. The larger the fracture conductivity, the later the development of an essentially radial drainage pattern. If the fracture length is large relative to the drainage area, then boundary effects distort or entirely mask the pseudoradial flow regime. These flow patterns also appear in pressure-buildup tests and occur at approximately the same dimensionless times as in flow tests. The physical interpretation is that the pressure has built up to an essentially uniform value throughout a particular region at a given time during a buildup test. For example, at a given time during bilinear or formation linear flow, pressure has built up to a uniform level throughout an approximately rectangular region around the fracture. At a later time during elliptical flow, pressure has built up to a uniform level throughout an approximately elliptical region centered at the wellbore. At a given time during pseudoradial flow, pressure has built up to a uniform level throughout an approximately circular region centered at the wellbore. The area of the region and the pressure level within that area increase with increasing shut-in time. Example 1 illustrates how to estimate the duration of flow periods for hydraulically fractured wells. Estimating duration of flow periods in a hydraulically fractured well For each case, estimate the end of the linear flow period and the time at which pseudoradial flow period begins. Table 1 gives the data for each case. Flow geometry and depth of investigation of a vertically fractured well Fluid flow in a vertically fractured well has been described using elliptical geometry. Hale and Evers [3] defined a depth of investigation for a vertically fractured well. Their definition is based on a definition of dimensionless time at a distance bf, the length of the minor axis: The elliptical pattern of the propagating pressure transient can be fully described in terms of the lengths of the major axis, af, the minor axis, bf, and the focus, Lf. Using the estimate of bf from Eq. Furthermore, the area, A, enclosed by the ellipse at time, t the area of the reservoir sampled by the pressure transient , is given by Fracture damage Two major types of fracture damage are frequent: The choked-fracture damage means that the fracture has a reduced permeability in the immediate vicinity of the wellbore Fig. In this case, kf is used for the permeability in the propped portion of the fracture farther along the wellbore, and kfs for reduced permeability near the wellbore, out to a length, Ls, in the fracture. The choked-fracture skin factor, sf, is [4] The equation for fracture face skin is [4] Specialized methods for post-fracture well-test analysis Generally, the objectives of post-fracture pressure-transient test analysis are to assess the success of the fracture treatment and to estimate:

3: Fluid flow in hydraulically fractured wells -

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4: Well Test Analysis of Hydraulically Fractured Gas Wells - OnePetro

For hydraulically fractured wells, well test analysis can be performed before and after hydraulic fracture stimulation. Before fracturing tests (pre frac tests) offer a workable mechanism for permeability determination in very low *permeability reservoirs.*

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