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Research Article

GRAPHOANALYTIC DETERMINATION OF PARAMETERS RELAXATION DEFORMATION OF ROCKS BY DATA OF DEVELOPMENT OF DEPOSITS

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ABSTRACT

As a rule, to determine the deformation parameters of rocks, the results of the interpretation of the actual data of hydro-gas-dynamic studies of wells are used in the non-static mode. In the article, a technique different from this approach for determining the parameters of the relaxation deformation of rocks according to the data of the development of gas deposits is given. The proposed technique is characterized by its versatility due to the fact that, in contrast to the methods based on specially conducted hydro-gas-dynamic studies of wells, the field development data is used, and also changes in the real properties of the reservoir system, as saturation and super-compressibility factors of the gas.

Keywords: Relaxation deformation, Relaxation time, Compressibility coefficient, Reservoir pressure

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1. INTRODUCTION

Deep-laying hydrocarbon fields are characterized by abnormally high reservoir pressures and the increased temperatures which rocks, being under huge geostatic pressure, in the course of development are exposed to inelastic deformation. The conducted pilot and theoretical studies demonstrate that deformation of rocks in the course of development of fields at essential change of reservoir pressure has not always elastic character, i.e. with decrease in reservoir pressure the considerable deviation of deformation of layer from the classical elastic law is observed. These researches have established a possibility of manifestation of relaxation behavior of deformation of rocks – collectors of oil and gas at pressure decrease [1,2].

When implementing design calculations for the development of such deposits, first of all, it is necessary to know the rheological and other physical parameters of the corresponding petrophysical models of rock deformation. As a rule, in order to determine the rheological parameters of rock deformation, the interpretation of the results of hydro-gas-dynamic studies of wells is used in the unstable regime. In this case, the required parameters are determined, as a rule, on the basis of simplified hydrodynamic models of filtration. On the other hand, in the case of inelastic, in particular, relaxation deformations of rocks, a long time of stabilizing the pressure in the well is required, which greatly depends on the degree of reliability of the obtained parameter values on the basis of these filtration models [3].

2. STATEMENT OF THE TASK AND RESULTS

Taking into account the above-mentioned problems, the establishment of an effective methodology for graphoanalytic determination of rheological parameters of rocks has an important theoretical and practical significance. For this purpose, we propose a technique for determining the parameters of the model of inelastic - relaxation deformation of the rock according to the data of the gas deposit development (on the dynamics of the average pressure over the deposit, accumulated production, etc.).

It is known that in the case of relaxation deformation of mountain rocks, the petrophysical relationship between porosity and reservoir pressure is expressed by the formula [1,3]:

$$m + \tau_m \frac{\partial m}{\partial t} = m_0[1 + \beta_r (p - p_0)] \tag{1}$$

where p_0 and p are respectively the initial and current values of reservoir pressure; m_0 and m - respectively, the initial and current porosity values; τ_m - the relaxation time of porosity; β_r - coefficient of compressibility of the rock.

Hence it is clear that in order to uniquely determine the relaxation law of porosity variation in the dependence of the pressure change in the form (1), in addition to the relaxation time τ_m, the coefficient of compressibility of the rock must also be known, i.e. parameter β_r.

We assume that the dynamics of mean pressure over the deposit and accumulated production are known, as well as data on the gas-oil content, super-compressibility, etc. during the development of the gas reservoir of the round form in the depletion mode. Taking into account these actual data, it is required to determine the above parameters (τ_m и β_r) of the relaxation model of rock deformation in the form (1).

In order to determine the rock strain parameters to be found from the data of the gas field development, the following interpreting equation is proposed:

$$f_1(t) = A + B \cdot f_2(t) \quad , \tag{2}$$

where

$$f_1(t) = \frac{1}{p_0 - p(t)}\left[\frac{Q(t)z(p)}{\sigma(t)p(t)} - \pi h\sigma_0 \frac{m_0 p_0}{z_0} r_k^2 \frac{\beta}{p_{at}} \frac{z(p)}{\sigma(t)p(t)} + \pi h m_0 r_k^2 \frac{\beta}{p_{at}}\right]$$

$$f_2(t) = \frac{1}{p_0 - p(t)}\left[\pi h\sigma_0 \frac{m_0 p_0}{z_0} r_k^2 \frac{\beta}{p_{at}}\left[\frac{z(p)}{\sigma(t)p(t)}\right]_t^{/} - \left[\frac{Q(t)z(p)}{\sigma(t)p(t)}\right]_t^{/}\right]$$

$$A = \frac{\pi h\beta r_k^2}{p_{at}}\beta_r \ , \quad B = \tau_m ,$$

$Q(t)$ - dynamics of cumulative production; $q(t)$ - current production; $p(t)$ - average pressure on a deposit; σ_0 and σ - respectively initial and current values of coefficient of gas saturation; $z(p)$ - coefficient of supercompressibility of gas; r_k - deposit contour radius (it is usually determined as $\sqrt{\frac{S}{\pi}}$; S - area of a gas deposit); h - effective thickness of a deposit; β - temperature amendment; p_{at} - atmospheric pressure.

Equation (2) is obtained by the joint solution of the equation of material balance for gas and equation (1). The obtained equation makes it possible to determine the required parameters of formation deformation by the actual field development data of the gas field, using the coefficients *A* and *B* included in it.

We give the sequence of necessary calculations below:

1) According to actual data, calculations are carried out on time $f_1(t)$ and $f_2(t)$:

$$f_1(t) = \frac{1}{p_0 - p(t)}\left[\frac{Q(t)z(p)}{\sigma(t)p(t)} - \pi h\sigma_0 \frac{m_0 p_0}{z_0} r_k^2 \frac{\beta}{p_{at}} \frac{z(p)}{\sigma(t)p(t)} + \pi h m_0 r_k^2 \frac{\beta}{p_{at}}\right]$$

$$f_2(t) = \frac{1}{p_0 - p(t)}\left[\pi h\sigma_0 \frac{m_0 p_0}{z_0} r_k^2 \frac{\beta}{p_{at}}\left[\frac{z(p)}{\sigma(t)p(t)}\right]_t^{/} - \left[\frac{Q(t)z(p)}{\sigma(t)p(t)}\right]_t^{/}\right]$$

2) Based on these calculated values, a graphical dependence is constructed $f_1(t)$ – $f_2(t)$ (according to the interpretation equation (2), the straight line describing this dependence has

the form: $f_1(t) = A + B \cdot f_2(t)$, and in principle all or most of the obtained curve will be characterized by this direct relationship between the quantities $f_1(t)$ and $f_2(t)$;

3) The coefficients *A* and *B* of this dependence allow to determine parameters τ_m and β_r as follows:

$$\tau_m = B, \quad \beta_r = \frac{p_{at}}{\pi h \beta r_k^2} A.$$

3. CONCLUSIONS

As a main result, we will note that using the given graphic-analytical technique it is possible to identify relaxation model of deformation of rocks to real conditions, and on this basis to solve the specific practical objectives connected, first of all, by forecasting of development of hydrocarbon fields which rocks are deformed with a relaxation.The proposed technique differs from the fact that deformation parameters are determined using the field development data, as well as changes in the real properties of the reservoir system, as saturation and supercompressibility factors of the gas.

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