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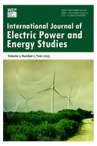
Publishing

International Journal of Electric Power and Energy Studies
ISSN: 3006-2004 (Print), ISSN: 3006-0826 (Online) | Volume 3, Number 1, Year 2024
DOI: https://doi.org/10.62051/ijepes.v3n1.04
Journal homepage: https://wepub.org/index.php/IJEPES/index



The Impact of Surface Conditions on Natural Gas Filtration Process under Reservoir Conditions

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ABSTRACT

The analysis indicates that by this time, the term "model" has already been widely disseminated. Using such models, different process details can be defined to obtain necessary parameters or verify proposed assumptions. It is important to note that modeling does not replace the study of the object; rather, it serves as a supplementary source of information about the reservoir or well, and it is also used in modeling.

KEYWORDS

Permeability; Contour Lines; Bottomhole Pressure; Dynamics; Viscosity; Flow Rate; Density; Temperature.

1. INTRODUCTION

To address this issue, classical modeling methods were used, with the primary task being to describe physical processes. The next step involved introducing necessary simplifications for laboratory or theoretical scenarios. Today, computational tools are essential for advancing modeling, helping to tackle increasingly complex problems. As computational technology expands, modeling will push the boundaries of complex problem-solving.

Key engineering problems that reservoir and well modeling can solve include:

1) What do oil companies need for optimal hydrocarbon production?

2) What is the best method of well stimulation?

3) Where should hydrocarbons be extracted from?

4) How can oil recovery be enhanced?

5) How should enhanced oil recovery (EOR) projects be implemented considering economic factors?

6) What field data is needed for optimized operations?

The analysis shows that models must be tailored to the study's goals, and physical science distinguishes between physical and mathematical models.

2. PROBLEM STATEMENT

In physical models, one can differentiate between models whose behavior is described by the same physical laws as the object being studied. Additionally, there are models based on analogies between different physical laws.

The primary filtration models considered are:

1) Practical, natural physical models;

2) Simulation models;

3) Applied mathematical models.

3. THE MAIN PART

Physical models are widely used in the scientific community to replicate the properties of objects under study, enabling smaller-scale laboratory investigations of similar phenomena. These models aim to derive filtration characteristics under reservoir conditions based on experimental data, adhering to principles of similarity with natural processes. In laboratory settings, the model's size, formation properties, and fluid types are selected based on geometric and physical similarities to the natural object, ensuring that variables like pressure and temperature are proportionally matched. Laboratory results can be recalibrated for the reservoir using similarity coefficients.

These models closely mimic natural filtration processes, facilitating the exploration of fundamental mechanisms by adjusting parameters in controlled experiments. However, due to the complexities of real reservoirs, fully accurate modeling is nearly impossible, making reservoir modeling largely an approximation. This study focuses on a mathematical model that provides an approximate description of fluid behavior, emphasizing steady and unsteady single-phase fluid filtration in a homogeneous porous medium-a classical yet relevant approach in underground fluid mechanics.

The extraction of natural gas and the development and operation of gas fields under complex conditions necessitate advanced mathematical models that incorporate additional processes in the near-wellbore area and the intricate geometry of gas flow. The isothermal process, where the gas temperature equals that of the medium and remains constant, is essential to note; filtration occurs slowly, with temperature changes during movement caused by pore resistance and gas expansion from pressure drops, balanced by heat exchange with surrounding rock. As stated by Professor B.B. Lapuk, the isothermal process can often be analyzed without including the energy equation.

To address challenges in gas fields, comprehensive initial data on the formation's structure, near-wellbore properties, and well performance indicators are crucial for input into filtration models. Constructing a three-dimensional geometric model of the reservoir based on study interpretations, including porosity and permeability from hydrodynamic analyses, is vital for effective modeling.

The radial spherical model, a three-dimensional representation of the reservoir, will help determine the volume and mass flow rate of natural gas while accounting for the wellbore's impact. Assuming an open well at the top of the formation with constant pressure at the bottom, and significant gas reservoir thickness, we can identify a surface with a radius of constant pressure where gas inflow equals the well’s production rate. With steady flow and a hemispherical surface as the boundary, the filtration velocity at any point between the boundary and well bottom is directed towards the sphere’s center. This arrangement exhibits spherical symmetry, simplifying the filtration equations into the following form:

$$v_g = \frac{k}{\mu}\frac{dP}{dr} \tag{1}$$

where v_g is the filtration rate of the air stream;

k-Stratigraphic permeability;

μ-Dynamic gas viscosity;

$\frac{dP}{dr}$-pressure gradient.

Multiplying the left and right sides of this equation by the cross-sectional area of the formation, we have:

$$Q = \frac{k}{\mu} 2\pi r^2 \frac{dP}{dr} \tag{2}$$

To solve this equation, we add the equation of state to this model the head of the cloud:

$$\rho = \rho_0 \frac{P}{P_0} \frac{TZ}{T_0} \tag{3}$$

Where is $\boldsymbol{\rho_0}$ the atmospheric pressure;

$\boldsymbol{T_0}$-Atmospheric temperature;

P-Set the pressure;

$\boldsymbol{\rho_0}$- River Density of the gas in atmospheric conditions;

Z - coefficient of hypercompression of the gas, taking into account the deviation of the state of the ideal gas from the real one. Note that this coefficient depends on the given pressure and temperature.

For the initial case, we assume that the process is isothermal under standard conditions, i.e. Z=1.Then we have [1-6].

$$\rho = \rho_0 \frac{P}{P_0} \tag{4}$$

By solving these equations together, we arrive at:

$$Q\rho = \frac{k}{\mu} \rho_0 \frac{P}{P_0} 2\pi r^2 \frac{dP}{dr} \tag{5}$$

Considering that gas volume changes with temperature, the computational model should incorporate the concept of mass flow rate. Thus, we have:

$$\frac{M\mu P_0}{2\pi k \rho_0} \frac{dr}{r^2} = PdP \tag{6}$$

Let’s assume the reservoir has a wellbore area surrounded by a region with varying permeability due to drilling or operations. A small near-wellbore zone often experiences additional pressure drops because of the hydrodynamic connection between the well and the formation. Wells that do not fully penetrate the formation or communicate through limited perforations are considered hydrodynamically imperfect.

The openness of the formation is crucial in gas field development, as it affects near-wellbore resistance and well productivity. The skin effect, caused by wellbore imperfections and permeability changes, leads to complex flow patterns. Contamination near the bottomhole also worsens filtration, reducing reservoir energy and gas flow to the well. This effect persists throughout the well's lifecycle. Solving for these factors, we adjust for the skin effect in mass flow rate calculations.

Then, solving the equation:

$$r = R_c \quad P = P_c$$

$$r = R_s \quad P = P_s$$

$$r = R_k \quad P = P_k$$

Considering the skin region$\left(\frac{1}{R}\right)$, finally we get the values.

$$M = \frac{\pi k \rho}{\mu P_0} R_c \frac{\left(P_k^2 - P_c^2\right)}{\left[S + \left(1 - \frac{R_c}{R_k}\right)\right]} \tag{7}$$

Where R_c -Well radius;

R_k- contour radius;

P_c - pressure at the bottom of the well;

P_k - circuit pressure;

S - skinning factor.

The value of skin factor is determined by the following equation:

$$S = \left(\frac{k}{k_s} - 1\right)\left(1 - \frac{R_c}{R_S}\right) \tag{8}$$

Where k_s is the superficial permeability of the near-wellbore section;

R_s is the radius of the near-wellbore skin zone.

If S = 0, then we have an equation for gas inflow to the well without a skin factor.

Considering $\frac{R_c}{R_k} \ll 1$, the final equation to determine the mass flow rate is as follows:

$$M = \frac{\pi k \rho}{\mu P_0} R_c \frac{(P_k^2 - P_c^2)}{S + 1} \tag{9}$$

This equation can also be solved using the volume flow rate:

$$Q = \frac{M}{\rho_0} = \frac{\pi k}{\mu P_0} \frac{(P_k^2 - P_c^2)}{S + 1} \tag{10}$$

In future work, it will be necessary to apply this problem to other models of the real gas.

4. CONCLUSION

1) A calculation method for gas wells considering spherical skin zones radial model.

2) This technique makes it possible to determine the main parameters of the gas well, the such as mass and volume flow rate of the gas well.

3) After determining the value of the skin factor, it is possible to perform additional work on the facial production wells to increase their productivity.

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