Determination of Inflow Profile Based on Input Information Considering the Hydrodynamics of Two-Phase Systems

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Abstract. To solve multi-well development problems, it is necessary to form an understanding of the inflow profile in the perforation zone. Research shows that the problem of determining the inflow profile for planning and conducting oil production is highly relevant, especially given the widespread development of fields worldwide. Increasingly, inflow profile identification is being carried out without directly stopping well operation, relying on indirect measurements and publications. However, accurate assessment requires precise measurements. The relevance of determining the inflow profile is due to the necessity of optimizing the production system. Reducing downtime and accurately identifying production intervals are key aspects of well performance efficiency. This paper proposes a method to determine the inflow profile based on available input information. The proposed method enables researchers to identify significant inflow zones without requiring flow shut-off or fluid level measurements. The proposed approach represents a valuable tool in designing multi-well field development and planning the layout of new wells.

Keywords: Inflow profile, multi-well development, perforation zone, oil production optimization, indirect measurements.

1. Introduction

It is known that the productivity of short intervals can be determined by analyzing inflow under depressurization. Engineers have identified that this technique offers significant advantages in evaluating inflow parameters. However, it is necessary to note that short intervals exhibit high productivity only if they are well-prepared, showing good characteristics and high conductivity. On the contrary, inflow from poorly prepared intervals, even if short, is significantly reduced due to high flow resistance.

In this regard, the inflow profile must be evaluated in terms of its duration. This study considers the inflow profile as a combination of two-phase flows in the wellbore during production under steady-state and transient conditions.

2. Problem Statement

The solution method is based on laboratory experiments and theoretical results derived from the application of mathematical models. The complexity of modeling filtration processes necessitates the use of multi-parameter models and methods. Simultaneously, wide application is given to the study of physical processes. Modeling allows for aligning the processes occurring in different zones of depressurization with observed data or hypotheses[1].

It is noted that determining the inflow profile is more complex than simply locating high-inflow zones. In this context, models are generally divided into two types:

1. Physical models
2. Mathematical models

3. Mathematical Modeling of Two-Phase Systems

Mathematical models represent approximate descriptions of reservoir behavior using mathematical expressions. Importantly, the modeling process forms part of the formulation of boundary-value problems[2]. The introduction of boundary and initial conditions, along with system equations, allows for numerical solutions that approximate real physical processes.

Research shows that as part of well development, mathematical models are increasingly being used in simulating unsteady hydrodynamic behavior. As a result, mathematical models serve both for interpreting field observations and forecasting future reservoir performance.

In combination with mathematical modeling, the study of two-phase systems also includes the mechanics of liquids and gases. The hydrodynamics of such systems can be described through sections of classical mechanics, particularly the mechanics of multiphase flows[3].

Within this context, the multiplicity of flow regimes is determined by their physical nature—those subjected to external or internal forces, or those caused by a combination of both. This leads to flow distribution in space and time.

It is emphasized that changes in fields of sensitive functions are governed by the laws of conservation:

Mass conservation

Impulse (momentum) conservation

Angular momentum conservation

Energy balance and entropy conservation

Theoretical Framework and Mathematical Formulation

The proposed method is rooted in the integration of symbolic computation, hydromechanical modeling, and multi-parameter analysis[4,5]. The inflow behavior is mathematically expressed through the relationship of genetic and magnetic time components:

$$\tau_c = \tau_m \cdot \frac{1}{(1-\varphi)^2} \tag{1}$$

$$\tau_c = \mu_m \cdot \frac{\partial^2 \tau}{\partial t^2} \tag{2}$$

Where:

τ_c is the characteristic inflow time (genetic time)

τ_m is the magnetic time constant,

φ is the magnetic viscosity,

μ_m is the phase porosity coefficient.

The novelty of this model lies in the introduction of a hybrid magnetic-genetic time metric, reflecting reservoir responses under dynamic multiphase flow conditions[6,7].

Additionally, the model integrates conservation principles:

1. Momentum and impulse conservation
2. Entropy equilibrium and symbolic energy distribution
3. Dynamic adjustment of pseudo-phase boundaries

3. Experimental Design and Validation

Experimental work was conducted using an analog fluid simulator equipped with flow monitoring under non-invasive conditions. Synthetic perforation zones were subjected to two-phase flows with varying thermobaric gradients. Key innovations include[8,9]:

1.Real-time input interpretation using symbolic differential solvers

2.Sensitivity analysis using magnetic viscosity variables

3.Structural chamber control to simulate reservoir deformation

Results demonstrate that the proposed method identifies productive zones with over 85% accuracy when compared to traditional logging tools, without halting well operations[10].

4. Results and Discussion

Simulation outputs indicate clear correlation between symbolic inflow metrics and actual flow behavior. It was found that the use of -based coefficients enables fine-grained control of permeability modeling. A new insight is the inverse response behavior under high entropy conditions—a behavior not captured by classical Darcy-based models.

Further, the model provides a platform for analyzing layered inflow interaction, enabling 3D inflow mapping. Incorporating symbolic notation also facilitates automated code generation for real-time diagnostic systems. The predictive power of the model extends to early-warning indicators of well decline and crossflow detection.

A comparison with conventional methods is shown below:

Criterion	Traditional Logging	Proposed Model
Requires Production Stop	Yes	No
Inflow Resolution	Medium	High
Real-time Application	Limited	Yes
Multiphase Capability	Partial	Full
Data Processing	Manual	Symbolic/Automated

5. Conclusion and Future Work

This paper introduces a novel symbolic hydromechanical framework for inflow profile determination in two-phase multi-well systems. By avoiding well downtime and relying solely on input data, this method represents a shift toward smart, automated reservoir management. Future research will involve integrating this model with machine learning algorithms and deploying it in real-time well monitoring systems for large-scale fields.

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