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Compaction in a confined deforming reservoir

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Abstract

A reduction of fluid pressure may lead to altered permeability and reduced thickness. This may lead to reduced well performance and well integrity. In some cases, subsidence and even earthquakes may occur. Although rare, such incidences have occurred many places around the world. The objective of this study is to present results obtained by a simplified analytical model for compacting reservoirs. Based on the constant modulus approach, we present approximate analytical solutions for stress-sensitive deforming reservoirs, and plot the corresponding type curves. We derive the equation for the dynamic behavior of the thickness and show plots of normalized thickness as a function of dimensionless time.

Keywords: compaction; well testing; type curves

1. Introduction

Compaction, subsidence and earthquakes, as result of fluid withdrawal [1–3], have occurred many places around the world. Due to the environmental costs, such problems should be identified and preventive actions taken as soon as possible. Fluid injection, with or without extraction, may mitigate further damage [1].

Some pressure dependent reservoirs show sensitivity for many variables, permeability and thickness included. Compaction may lead to subsidence at the surface and high cost problems. European examples are Venice, Groningen,

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Ekofisk and Valhall [1]. There is also a danger that earthquakes may be triggered [2]. These aspects highlight the need for a screening tool to predict problematic reservoir behavior. This study is an attempt in that direction.

We assume that the permeability and possible compaction may be approximated by exponential functions of pressure. The unspecified variables of the pressure functions are determined by matching to measured results by either matching to measured results from core analysis or well testing. This study is for well testing.

Nomenclature

B	formation volume factor	γ	permeability modulus
C	wellbore storage constant	φ	porosity
c	compressibility	τ	composite modulus
h	thickness	υ	viscosity modulus
k_i	initial permeability	ξ	thickness modulus
p	fluid pressure	η	transformed variable
p_D	dimensionless pressure	ρ	density
q	flow rate		
r_D	dimensionless distance, $r_D = r / r_w$	Indices	
S	skin factor	c	constant rate condition
s	Laplace variable	v	variable rate conditions
t_D	dimensionless time	0.1	order of perturbation

1.1. Previous work

Raghavan et al. [4] proposed a well test model for pressure-dependent rock and fluid properties. They used the pseudo-pressure approach. Pedrosa [5] assumed an exponential relationship between permeability and fluid pressure. He showed that the zero order solution of the transformed variable is the same as the Pd-function for a reservoir without stress-sensitivity. Kikani and Pedrosa [6] matched the same model [5] to real well test data. They argued that the zero order solution is of sufficient accuracy for most engineering problems. This is because the first order solution is multiplied by composite (sum modulus) squared. The composite modulus usually assumes small values.

Jelmert and Selseng [7] showed that the logarithmic transformation method and the pseudo pressure approach is equivalent for exponential pressure functions. They used normalized permeability change as dependent variable, and pointed out that possible negative values are unphysical. Jelmert and Toverud [8] showed that type curve matching by use of MDH type curves might be possible. The modulus for thickness is included in the dimensionless time. The permeability modus is not. Hence, these variables may be quantified separately. Once the value of an elastic modulus is known, the dynamic behavior of the corresponding variable is also known [9].

Ozkan and Raghavan [10, 11] discussed the application of the Laplace transforms to facilitate solutions to the linear diffusivity equation. These are also available for stress-sensitive reservoirs with zero order accuracy. Zhang and Ambastha [12] investigated the Kikani and Pedrosa [6] solutions by a numerical model. They found that the Pedrosa method [6] works better for drawdown than for buildup tests in new wells. Zao et al. [13] presented a three dimensional model for a horizontal well. They verified their model against results obtained by a commercial simulator.

2. Theory

We assume exponential variation with pressure. The elastic modulus of each variable shows up in the exponent as a factor to the pressure change.