SPE 116144

Interpretation of Interwell Connectivity Tests in a Waterflood System

A. V. Dinh and D. Tiab, SPE, University of Oklahoma

This paper was prepared for presentation at the 2008 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, USA, 21–24 September 2008.

Abstract

This study is an extension of a novel technique to determine interwell connectivity in a reservoir based on fluctuations of bottom hole pressure of both injectors and producers in a waterflood system. The technique uses a constrained multivariate linear regression analysis to obtain information about permeability trends, channel and barriers. Some of the advantages of this new technique are simplified one-step calculation of interwell connectivity coefficients, small number of data points and flexible testing plan. However, the previous study did not provide either in-depth understanding or any relationship between the interwell connectivity coefficients and other reservoir parameters.

This paper presents a mathematical model for bottom hole pressure responses of injectors and producers in a waterflood system. The model is based on available solution for fully penetrating vertical wells in a closed rectangular reservoir. It is then used to calculate interwell relative permeability, average reservoir pressure change and total reservoir pore volume using data from interwell connectivity test described in previous study. Reservoir compartmentalization can be inferred from the results. Cases of producers as signal wells, injectors as response wells and shut-in wells as response wells are also presented. Summary of results for these cases are provided. Reservoir behaviors and effect of skin factors are also discussed in this study.

Some of the conclusions drawn from this study are: (1) The mathematical model works well with interwell connectivity coefficients to quantify reservoir parameters; (2) The procedure provides in-depth understanding of the multi-well system with water injection in the presence of heterogeneity; (3) Injectors and producers have the same effect in terms of calculating interwell connectivity and thus, their roles can be interchanged. This study provides flexibility and understanding to the method of inferring interwell connectivity from bottom-hole pressure fluctuations. Interwell connectivity tests allow us to quantify accurately various reservoir properties in order to optimize reservoir performance.

Different synthetic reservoir models were analyzed including: homogeneous, anisotropic reservoirs, reservoirs with high permeability channel, partially sealing fault and sealing fault. The results are presented in details in the paper. A step-by-step procedure, charts, tables, and derivations are included in the paper.

Introduction

Previous study carried out by Dinh and Tiab (2007) has introduced a new technique to infer interwell connectivity from bottom-hole pressure fluctuations in a waterflood system. The technique was proven to yield good results based on numerical simulation models of various cases of heterogeneity.

In this study, an analytical model for multi-well system with water injection was derived for the technique. The model is based on available solution for a fully penetrating vertical well in a closed rectangular multi-well system and uses the principle of superposition in space. Based on analytical analysis, a new technique to analyze data of interwell connectivity test was developed. This technique utilizes the least squares regression method to calculate the average pressure change. Thus, reservoir pore volume, average reservoir pressure and total average porosity can be estimated from available input data. The results were verified using a commercial black oil numerical simulator.

The practical value of interwell coefficients was investigated. In order to derive the relationship between interwell connectivity coefficients with other reservoir parameters, a pseudo-steady state solution of the previously mentioned model was used. The wells were fully penetrating vertical wells flowing at constant rates. The investigation proves that the interwell coefficients between signal (active) and response (observation) wells are not only associated with the properties between the two wells but also the properties at the signal wells. In order to calculate interwell relative permeabilities, we assumed the properties at the signal wells are constant. Thus, by varying permeability between well pairs to match the interwell connectivity coefficient calculated from analytical model and simulation results, the interwell relative permeabilities