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History Matching for Determination of Fracture Permeability and Capillary Pressure

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Abstract

For naturally fractured reservoirs, it is very difficult to quantify the future prediction without proper fracture properties and capillary pressure. Capillary pressure and fracture permeability can interact in a way which can produce non-unique results. For example, strong imbibition capillary curve with high fracture-matrix permeability contrast can behave similarly as weak imbibition capillary curve with low fracture-matrix permeability contrast. Evaluation of core data may provide us with some information about imbibition capillary pressure curves; however, quantification of fracture permeability is largely determined by matching the production data.

This paper presents an integrated approach to history matching of naturally fractured reservoirs by adjusting the fracture permeability of individual fractures and the water-oil capillary pressure curves. By matching production data by minimization of a weighted least squares objective function, we generate estimates of fracture permeability, and water-oil capillary pressure curves. All of implementations are incorporated into a commercial simulator (ECLIPSE) and iterated in the automatic history matching scheme. The adjoint method and an efficient direct solver were used to decrease CPU time for calculating the sensitivity coefficient matrix. A Middle East reservoir model was used to validate our method.

Introduction

Anisotropy and heterogeneity present challenges during the development of hydrocarbon reserves in naturally fractured reservoirs. Predicting primary reservoir performance and planning drilling development all require accurate estimates of reservoir properties and the prediction of future reservoir behavior. Naturally fractured reservoirs have received much attention in the last decade because of low oil recovery in many of these reservoirs and the potential to improve oil recovery from such reservoirs. Fluid flow characteristics in naturally fractured reservoirs are largely controlled by the

distribution, orientation, and interconnectivity of the fracture system. A great deal of effort has been made in the characterization of the geological fracture network system based on the analysis, interpolation, and extrapolation of the fracture information acquired in wells and derived from seismic data, sometimes complimented by outcrop analogue data. As a result, there has been a great amount of work to diagnose and characterize fractured reservoirs and to develop viable techniques to utilize the fractures effectively. It is obvious that the reservoir characterization, modeling and simulation of naturally fractured reservoirs present unique challenges that differentiate them from conventional, single porosity reservoirs. Not only do the intrinsic characteristics of the fractures, as well as the matrix, have to be characterized, but the interaction between matrix and fractures must also be modeled accurately.

In naturally fractured reservoirs the capillary pressure curves play a much more important role than that in conventional reservoirs. Capillary forces in fractured reservoirs are an extremely important component of the driving mechanism, while the dynamic role of the capillary forces in a conventional reservoir is much more limited. In a fractured reservoir, capillary forces may contribute to the displacement process through imbibition, or may oppose it through drainage.

It is essential to represent the capillary pressure curves properly. Capillary pressure data are measured often using porous-plate, centrifuge, and mercury injection techniques. These methods are based on the availability of the core data and suffered limitation due to scale over which the data are collected. It will be very useful if the capillary pressure curves can be extracted from the production data through the history matching process.

Generally, geological models for naturally fractured reservoirs derived from static data alone cannot reproduce the field production history. This can be ascribed to the insufficient consideration of the fracture effects on flow, insufficient dynamic characterization of the distribution of fracture systems and insufficient consideration of the interaction between the matrix and fractures. In other words, the hydrodynamic properties of the fracture network system and capillary pressure curves need to be characterized properly using the dynamic production data.

Reconciling geologic models to the dynamic response of the reservoir is critical to building reliable reservoir models which are very important in future performance, reservoir management, risk analysis and key economic decisions making. Classical history matching procedures whereby the