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Experimental Design and Response Surface Models as a Basis for Stochastic History Match - A Niger Delta Experience

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Abstract

With the increasing acceptance of stochastic workflows in mainstream reservoir engineering studies, many frameworks have been developed to assist in the history match of reservoir models. This paper describes the application of experimental design and response surface methods, not only in conditioning complex reservoir models to the historical production data but also in refining the reservoir models to improve the overall history match results.

The reservoirs are in the Niger Delta and consist of faulted layers from both the Benin and Agbada formations. The reservoir models envelop all major reservoir uncertainties ranging from static parameters such as structure and porosity to dynamic parameters such as aquifer strength, relative permeability, and even production records. The experimental design combined all the subsurface uncertainties in different realizations and ensembles to construct response surface models capturing the multiple responses of the simulated historical performance. These response surface models serve three main purposes: identification of the “heavy hitters,” improving the reservoir model, and facilitating the stochastic history match.

The history-matched ensemble successfully explained the reservoir and drainage point production performance; identified uncertainties that have the most significant impact on the historical performance and development; established the most likely original water contact for one of the reservoir compartments; explained the connectivity between the different fault blocks; and formed the basis for risk mitigation analysis of further development in the reservoir.

Introduction

The usefulness of a model in supporting future development activities in a reservoir depends largely on how well the model is able to explain past reservoir production performance. This process, known as history match, involves conditioning a reservoir model to the historical production data. However, history match is not only a difficult problem; it is a non-unique and generally time-consuming inverse problem to solve.

This non-uniqueness results in several combinations of model parameters that can adequately explain past reservoir performance. Though these models may satisfactorily explain past performance, they often produce divergent outcomes when used for predicting the future performance of the reservoir. This range of outcomes relates directly to the uncertainty associated with any development option and forms a critical input in business decisions. It is, therefore, desirable to have a method that both capture the widest possible combination of model parameters that explains historical production data and is quick to update.

Considering the time intensive nature of history match and its other limitations, the traditional deterministic approach that relies on a trial-and-error method may be inappropriate in meeting these objectives. On the other hand, the process of stochastic history matching is different from conventional history matching and is more suited to handling uncertainties consistently. It involves creating a response surface model by fitting the outcomes of an experimental design to an equation containing the most influential parameters.

Experimental Design and Response Surface Methods

Since the introduction of the statistical science concepts of experimental design (ED) and response surface methods (RSM) in reservoir engineering practice in the early nineties, their applications in the petroleum industry have increased significantly[1, 2, 3, 4].

The aim of Experimental Design (ED) is to provide maximum information about a system (reservoir) from the least number of experiments (i.e. reservoir simulations). Its main benefits include: