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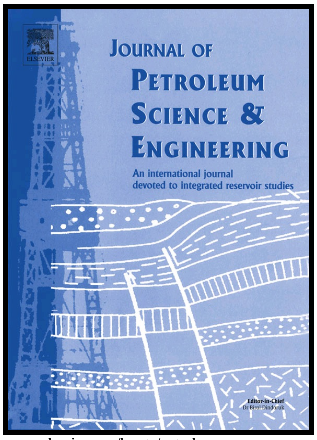

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On Selection of Controlled Variables for Robust Reservoir Management

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Abstract

Reservoir management is subject to pronounced uncertainty, as the subsurface reservoir conditions are often poorly known, especially at the onset of production. Robust optimization is a method for handling uncertainty by optimizing control inputs over a series of model realizations. Well controls can be specified in several ways, most often by liquid rate or bottom hole pressure (BHP), and previous studies have used various types of well control selections. In this paper, we study how different choices of control variables affect robustness with respect to uncertainties. The analysis is supported by self-optimizing control, a well-known process control concept, which allows for systematic analysis of these effects. We observe that when the permeability is the main uncertain parameter, controlling both injectors and producers by rate is the most robust alternative. However, we also observe that this choice is less advantageous when other parameter uncertainties dominate.

Keywords: Robust reservoir management, optimization, uncertainty

1. Introduction

Reservoir model uncertainty is a severe challenge in reservoir management. Model uncertainty may be ignored by using a deterministic model of the system. The solution obtained is then perfectly tailored for the model in consideration. The performance when implemented, however, is closely related to the predictive capabilities of the model. If the model deviates slightly from the true system, the performance can deteriorate significantly. For reservoir management, this is a serious issue, as history matched models may have poor predictive capabilities [1, 2].

Various approaches for handling uncertainty have been suggested in the literature. Most of them are scenario-based, in which optimization is conducted for a set of realizations, optimizing for instance expected net present value (NPV). The uncertainty is described by the spread in the realizations. In most of the published work, optimization is conducted over sequences of control inputs, in which the same control sequence is applied to all scenarios. This is denoted as the robust approach, and will be investigated in this paper. An alternative approach is to use a feedback policy, which in practise means a reactive strategy, see [3, 4, 5, 6].

Traditionally, injectors have been optimized for rate control and producers for either liquid rate or bottom hole pressure. In previous publications on robust approaches, various decision variables are used. In [7, 8], injectors are controlled by rates, while producers are controlled by BHP, while in [9, 10, 11] both injectors and producers are controlled by rates. In [12, 13], both injectors and producers are controlled by BHP, while in a robust well placement study [14], injectors are controlled by BHP and producers by rate. Thus, there exist alternative choices for decision variables. In this paper we will show that some choices of decision variables implicitly provide higher robustness than others. Moreover, the implicit robustness depends on the dominant model uncertainty, for instance if it is related to volume or flow transmissibilities.

Obtaining reservoir models with good predictive capabilities is a key challenge in reservoir management, as the reservoir conditions are only observed directly at the well locations. Well tests, production data, seismic data and geological knowledge are all used to complement the well logs, in order to build reservoir models of the subsurface conditions. Still, these models are inherently uncertain, even after extended periods of production, as reservoirs are heterogeneous and rock properties vary on a length scale much smaller than inter-well placement [15]. This means porosity and permeability can not be determined precisely for the entire reservoir. Most studies on robust reservoir management focus on permeability uncertainty, in this work, however, we also consider indistinct reservoir

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