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Advanced Large-Scale Coalbed Methane Modelling Using a Conventional Reservoir Simulator

Thomas Tan, SPE, T.T. & Associates Inc, PetroStudies Consultants Inc

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Abstract

A conventional reservoir simulator was modified to model coalbed methane reservoirs using the approach presented by Siedle where an immobile oil phase is used to represent the bulk coal and the gas volume adsorbed on the coal's surfaces is computed as solution gas-oil ratio. The simulator was validated against published results from coalbed methane models. The speed of the model was tested for a large problem with 120,000 cells. A dual grid system to model gas desorption, flow through low permeability matrix to high permeability fracture cleats in the coal seam was shown to more accurately reproduce initial delay in gas production while dewatering. Enhanced recovery using N₂ and CO₂ injection was simulated using single grid and dual grid systems. Expected incremental recovery of methane was obtained using the single grid system. However no additional recovery was obtained using the dual grid system due to extensive bypassing of the injected gas in the fracture grid system. This indicates additional physical mechanisms are at work.

Introduction

Coalbeds are naturally fractured volumes of coal with the fractures (cleats) usually filled with water. The coal seams have low porosity and low permeability and these micropore spaces too are usually water filled. The methane gas is adsorbed on the coal surfaces. When water is produced from the coalbeds, the pressure drops in the fractures and the coal micropores. The adsorbed gas is released, flows slowly

through the coal microporosity system and then to the high permeability cleats.

The classic method for modelling naturally fractured reservoirs is based on the Warren and Root⁽¹⁾ concept. The reservoir shape and volume is represented by a conventional grid cell system with high grid cell porosity and low permeability. The extensive fracture network system is represented by another set of grid cells of the same shape and volume and depth as the matrix grid system. These fracture grid system cells have a porosity such that the volume of the fracture cells is equivalent to the fracture capacity, and a permeability such that the fracture transmissibility based on the grid cell size is equivalent to the transmissibility of the small natural cracks. The two grid cell systems are connected by means of 'special connections' between each cell of the matrix grid system with the corresponding fracture cell in the fracture grid system in the same physical space. The special connection transmissibility is calculated based on formulas provided by Warren and Root⁽¹⁾, and other authors, Thomas *et al.*⁽²⁾, and this reflects the degree of fracturing or the number of cleats in the volume represented by each of the grid cells. If matrix permeability is present, this is referred to as a dual porosity-dual permeability model.

Modelling such connected dual grid systems presents severe mathematical difficulties. As an approximation, earlier coalbed methane models such as that presented by Sawyer⁽³⁾ *et al.*, and Paul⁽⁴⁾ *et al.* considered only one grid cell system representing the shape and size of the reservoir with fracture permeability and system porosity. The processes that occurred in the matrix system, (desorption and flow of gas through the micropores) are represented by user entered desorption time and diffusion coefficients and then equations presented in the references are used to calculate the amount of gas released into the grid cell system. The amount of gas adsorbed on the coal is described using Langmuir's isotherm.

In a recent paper, Reeves⁽⁵⁾ *et al.* extended the model presented by Sawyer⁽³⁾ to include the matrix grid system. Though the authors referred to it as a "triple porosity, dual permeability model", it is actually a dual porosity (matrix porosity and fracture porosity), dual permeability model, two