Acta Geotechnica
https://doi.org/10.1007/s11440-017-0624-3

RESEARCH PAPER

An adjoint-based optimization method for gas production in shale reservoirs

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Received: 11 October 2017 / Accepted: 24 December 2017

Abstract
AQ1 In this work, we consider a new model for flow in a multiporosity shale gas reservoir constructed within the framework of an upscaling procedure where hydraulic fractures are treated as $(n-1)$ interfaces $(n = 2, 3)$. Within this framework, the hydrodynamics is governed by a new pressure equation in the shale matrix which is treated as a homogenized porous medium composed of organic matter (kerogen aggregates with nanopores) and inorganic impermeable solid (clay, calcite, quartz) separated from each other by a network of interparticle pores of micrometer size. The solution of the pressure equation is strongly influenced by the constitutive response of the retardation parameter and effective hydraulic conductivity where the former incorporates gas adsorption/desorption in the nanopores of the kerogen. By focusing our analyses on this nonlinear diffusion equation in the domain occupied by the shale matrix, an optimization strategy seated on the adjoint sensitivity method is developed to minimize a cost functional related to gas production and net present value in a single hydraulic fracture. The gradient of the objective functional computed with the adjoint formulation is explored to update the controlled pressure drop aiming to optimize production in a given window of time. The combination of the direct approach and gradient-based optimization using the adjoint formulation leads to the construction of optimal production scenarios under controlled pressure decline in the well. Numerical simulations illustrate the potential of the methodology proposed herein in optimizing gas production.

Keywords Adjoint-based iterative algorithms · Flow sensitivity · Gas adsorption · Gradient-based optimization · Pressure equation · Shale gas reservoir

1 Introduction

For decades shales have been envisioned by the petroleum industry as source rocks of hydrocarbons or barriers for their movement [18, 39, 44, 45]. However, owing to the rapidly increasing demand for global oil and gas resources they have also emerged as alternative hosting hydrocarbon formations. Likewise tight-gas sands, coalbed methane, and heavy oil, shales fall in the category of unconventional reservoirs [23]. Such a terminology refers to hydrocarbon-bearing formations that generally do not produce economic flow rates unless effective stimulation techniques are adopted to enhance permeability at feasible scenarios [42]. The economic viability hinges on effective stimulations techniques to enhance production, such as advanced drilling and completion along with multi-stage hydraulic fracturing which creates complex fracture networks that connect reservoir surface area to the wellbore [23, 42].

Several macroscopic properties of shales are strongly correlated with the microstructure, which still remains poorly understood compared to conventional reservoirs. Among the complex features, we may highlight the presence of multiple substructures associated with multimodal

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