EAGE

RP07

A Pore Network Model for Evaluation of Permeability, Relative Permeability, Recovery Factor and Sealing Capacity from Pore Size Distribution

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Summary

Permeability, relative permeability, recovery factor and caprock sealing capacity are among the most fundamental petrophysical properties in reservoir characterization, evaluation and modelling. These properties are difficult to measure, whereas pore size distributions are routinely measured by using mercury intrusion. This work presents a newly developed pore network model for evaluation of these petrophysical properties from pore size distributions.

Abstract

Permeability, relative permeability, recovery factor and caprock sealing capacity are among the most fundamental petrophysical properties in reservoir characterization, evaluation and modelling. These properties are difficult to measure, whereas pore size distributions are routinely measured by using mercury intrusion. This work presents a newly developed pore network model for evaluation of these petrophysical properties from pore size distributions.

The developed pore network model has two parts. First, based on the fact that mercury intrusion measures connected pore networks, and that mercury invades pores from largest to smallest, an "inversion" method, to mimic the mercury intrusion, has been developed to arrange the pores of a pore size distribution into a 3D pore network model. In the 3D pore network model, the pore shape is defined by two frusta of cones connected at their base. Pores align at an angle, which is compaction dependent, and the alignment defines the permeability anisotropy. Second, fundamental principles are applied to the constructed 3D pore network model to evaluate the petrophysical properties. The applied fundamental principles include Darcy's law, modified Hagen-Poiseuille equation governing flow in cone-shape pores, the Young-Laplace equation describing the capillary pressure, and mass and energy conservation equations.

As rooted in the fundamental principles applied in the model, the modelled relative permeability and recovery factor depend not only on the viscosity, interfacial tension and contact angle, but also the applied pressure gradient, which is often overlooked. Since pressure gradient depends on fracture space, the model results can be used in fracking design for optimum hydrocarbon production to achieve not only effective extraction but more importantly maximum recovery. The model is also able to explain and model a puzzling phenomenon, "permeability jail", a situation for a low permeability rock that the relative permeabilities to both gas and water are so low that neither phase has any effective flow capacity. The developed model has been successfully applied to 30 limestone samples to calculate their permeabilities, relative permeabilities and recovery factors; and to some mudstones to evaluate their sealing capacities. The effects of the interfacial tension, contact angle and pressure gradient on the relative permeability and recovery factor for the limestone samples have also been investigated.