A new interpretation of the response of coal permeability to changes in pore pressure, stress and matrix shrinkage

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A new interpretation of the response of coal permeability to changes in pore pressure, stress and matrix shrinkage

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Abstract

Coal permeability is often modelled as an exponential function of the Terzaghi effective stress, that is the difference between stress and pore pressure. However, laboratory measurements of permeability have found that, under constant effective stress conditions, shrinkage with gas desorption or swelling with adsorption (known as the sorption strain) influences the measured permeability. In the derivation of the exponential model these shrinkage and swelling processes were neglected. In applying the exponential model to the reservoir, the stress is replaced by a geomechanical solution for uniaxial strain, constant vertical stress conditions that includes the sorption strain. However, laboratory results indicate that there is a direct influence from sorption strain on permeability. This paper also demonstrates that pore and confining pressures can also operate independently on permeability rather than together as the Terzaghi effective stress. Based on well established theoretical treatments and without invoking new conceptual models, this paper develops a simple extension of the exponential model to include the independent effects of pore and confining pressures and the sorption strain. This new model introduces two new properties over the existing exponential function with effective stress. The new model is tested by applying it to a data base of laboratory measurements of coal core permeability with helium, nitrogen, methane, and carbon dioxide over a range of pore and confining pressures where it was shown to be able to accurately match the observations with generally consistent model properties. Forms of the new model are then developed for uniaxial strain and constant vertical stress reservoir conditions using the Shi-Durucan geomechanical model. The model predictions of reservoir permeability show that the additional sorption strain term acts to increase the rebound of permeability during pore pressure drawdown. The reservoir form of the model is applied to observations of permeability from the San Juan Basin and compared to equivalent Shi-Durucan model results. Additional processes operating within the San Juan act to reduce the permeability rebound below that predicted by both of the permeability models. One explanation for this behaviour is formation damage due to fines production.

Keywords: coal permeability, matrix shrinkage, permeability modelling, gas production