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Developing a Stress-Dependent Permeability Model Using a Machine Learning Approach to Reduce Reservoir Production Forecast Uncertainty in the Bakken Formation

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Abstract

Stress-dependent permeability of tight porous media can cause uncertainty in estimating reservoir production. A machine learning (ML) approach was used to examine the permeability-stress relationship dominant in tight fractured strata such as the Middle Bakken (MB) Member to correlate dynamic permeability during reservoir depletion. Laboratory data were collected from wells in the Williston Basin to generate the ML model with the goal of introducing an improved approach to correlate permeability under varied reservoir conditions and geologic configurations. The model can improve coupling geomechanics with reservoir modeling in unconventional reservoirs with a high degree of accuracy and provide more realistic predictions of dynamic flow and long-term production forecasts. Multiple ML algorithms were developed and performed on over 1000 Bakken core data points with varying depths and rock properties. The best XGBoost configuration algorithm was optimized to achieve reliable predictive performance and reduced model complexity. The procedure included collecting data from wells with core sample-measured permeability at varied net confining stresses (NCSs). Data from 31 MB wells from several counties with at least three permeability measurements at different NCSs (500-7000 psi) within 9000-11,400-ft depths were compiled, processed, and used to train the model. A permeability-loading curve was generated and validated to track permeability change at varied depths. The proposed model was used in reservoir simulation for further permeability evaluation. Model assessment parameters included coefficient of determination (R2), mean average error (MAE), and mean squared error (MSE). Results showed that the model could predict permeability values at varied NCS values with an accuracy of 0.843 and an average error of 0.0018. A blind test was conducted with seven wells to validate the model and predict permeability changes with NCS. Results showed the model could identify patterns of permeability changes for the MB Member and predict permeability values with a high degree of accuracy (R^2 of 0.944, MAE of 0.00108, and MSE of 0.001779). The benefits of this mathematical model constructed using a ML approach are 1) more accurate assessments of permeability with complex interference levels; 2) increased certainty in a range of geologic configurations in comparison to conventional approaches; 3) ability to develop a range of permeability-pressure correlations for reservoirs, such as the Bakken, as a reference in reservoir modeling; and 4) achievement of realistic production forecasts and enhanced oil recovery performance evaluation in unconventional reservoirs.