

Next-Gen Proppant Cleanout Operations: Machine Learning for Bottom-Hole Pressure Prediction

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Abstract

In proppant cleanout operations, it's crucial to utilize the optimum bottom-hole pressure to achieve enough annular velocity in the wellbore to lift solids to the surface, make sure no skin damage is created due to excess fluid losses, and avoid stuck-pipe situations. Machine learning models, which offer real-time on-site prediction of bottom-hole pressure, can be used to achieve this. The main goal of this study is to create machine learning-driven models capable of predicting bottom-hole pressure at the coiled tubing nozzle's exit while pumping nitrified fluids in cleanout operations.

Nine machine learning and deep learning models were developed using readily available parameters typically gathered during cleanout operations, which include coiled tubing depth and inside diameter, bottom hole temperature at the coiled tubing nozzle, gel rate, nitrogen rate, and coiled tubing pressure at the surface as inputs. These models are trained utilizing measured bottom-hole pressure data acquired from deployed memory gauges, which serve as the model's outputs. Gradient Boosting, AdaBoost, Random Forest, Support Vector Machines (SVMs), Decision Trees, K-Nearest Neighbor (KNN), Linear Regression, Neural Network, and Stochastic Gradient Descent (SGD) are machine learning algorithms that were meticulously developed and optimized using an extensive data set derived from 48 wells. 33,453 data points make up this dataset, which was carefully divided into two subsets: 80% (26,763 data points) were used to train the algorithms, while 20% (6,690 data points) were used to test their predictive abilities. In addition, the performance of machine learning models is evaluated using the K-fold and random sampling validation procedures.

When comparing predictions of coiled tubing nozzle outlet pressure to actual measurements, the results of the top-performing machine learning models, specifically Neural network, AdaBoost, Random Forest, K- Nearest Neighbor and Gradient Boosting show remarkably low mean absolute percent error (MAPE) values. These MAPE values are, in order, 1.7%, 1.6%, 2%, 2.5%, and 3.2%. Furthermore, these models have remarkably high correlation coefficients (R^2), with respective values of 0.947, 0.943, 0.929, 0.918, and 0.878. Moreover, machine learning models offer a distinct advantage over conventional vertical lift performance correlations, as they do not necessitate routine calibration. Beyond this, these models demonstrated their ability to accurately predict bottom-hole pressure across a wide range of cleanout parameters.

This paper introduces novel insights by demonstrating how using a machine learning model for predicting coiled tubing nozzle outlet pressure while pumping nitrified fluids in cleanout operations can enhance ongoing cleanout operations. Utilizing machine learning models offers a more efficient, rapid, real-time, and cost-effective alternative to calibrated vertical lift performance correlations and deployed memory gauges. Furthermore, these models excel at accommodating a wide spectrum of cleanout parameters and coiled tubing configurations. This was a challenge for single vertical lift performance correlation.