

Downhole Camera Runs Validate the Capability of Machine Learning Models to Accurately Predict Perforation Entry Hole Diameter

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Abstract: In the field of oil and gas well perforation, it is imperative to accurately forecast the casing entry hole diameter under full downhole conditions. Precise prediction of the casing entry hole diameter enhances the design of both conventional and limited entry hydraulic fracturing, mitigates the risk of proppant screenout, reduces skin factors attributable to perforation, guarantees the presence of sufficient flow areas for the effective pumping of cement during a squeeze operation, and reduces issues related to sand production. Implementing machine learning and deep learning models yields immediate and precise estimations of entry hole diameter, thereby facilitating the attainment of these objectives. The principal aim of this research is to develop sophisticated machine learning-based models proficient in predicting entry hole diameter under full downhole conditions. Ten machine learning and deep learning models have been developed utilizing readily available parameters routinely gathered during perforation operations, including perforation depth, rock density, shot phasing, shot density, fracture gradient, reservoir unconfined compressive strength, casing elastic limit, casing nominal weight, casing outer diameter, and gun diameter as input variables. These models are trained by utilizing actual casing entry hole diameter data acquired from deployed downhole cameras, which serve as the output for the X' models. A comprehensive dataset from 53 wells has been utilized to meticulously develop and fine-tune various machine learning algorithms. These include Gradient Boosting, Linear Regression, Stochastic Gradient Descent, AdaBoost, Decision Trees, Random Forest, K-Nearest Neighbor, neural network, and Support Vector Machines. The results of the most effective machine learning models, specifically Gradient Boosting, Random Forest, AdaBoost, neural network (L-BFGS), and neural network (Adam), reveal exceptionally low values of mean absolute percent error (MAPE), root mean square error (RMSE), and mean squared error (MSE) in comparison to actual measurements of entry hole diameter. The recorded MAPE values are 4.6%, 4.4%, 4.7%, 4.9%, and 6.3%, with corresponding RMSE values of 0.057, 0.057, 0.058, 0.065, and 0.089, and MSE values of 0.003, 0.003, 0.003, 0.004, and 0.008, respectively. These low MAPE, RMSE, and MSE values verify the remarkably high accuracy of the generated models. This paper offers novel insights by demonstrating the improvements achieved in ongoing perforation operations through the application of a machine learning model for predicting entry hole diameter. The utilization of machine learning models presents a more accurate, expedient, real-time, and economically viable alternative to empirical models and deployed downhole cameras. Additionally, these machine learning models excel in accommodating a broad spectrum of guns, well completions, and reservoir parameters, a challenge that a singular empirical model struggled to address.

Keywords: machine learning; artificial intelligence; perforation entry hole diameter; gun; well completion; neural network



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