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Simulation Validation, Calibration and Fidelity of a Dynamic Downhole Drilling Phenomenon

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Abstract

This paper presents the simulation of a dynamic downhole drilling phenomenon which resulted in significant non-productive time and unnecessary drilling cost. The consistency of simulation fidelity from one stand to another provides insights as to the application of simulation for the purposes of optimizing drilling technique and recognizing drilling dysfunction. The significance of physical and virtual data characteristics and uncertainties for the purpose of drilling optimization and automation is illustrated.

The dynamic range of drilling forces estimated by typical quasi-static models is often underestimated. Physical sensors also typically cannot be located where drill string failures actually occur. Time-based simulation techniques enable more realistic estimations of dynamic forces and motions at critical drill string locations and their cumulative contributions to drill string fatigue. Simulation has the potential to prevent vibration-related drilling tool failures, invisible lost time related to drilling inefficiency, as well as to enable the optimal placement of downhole friction mitigation tools for greater precision in directional control to reduce wellbore tortuosity which simulations also indicate can reduce production rates.

Physical drilling measurements are compared to their virtual twins in order to calibrate the simulated dynamic drill string forces and severe whirling motions that occurred during a drilling sequence which resulted in an MWD tool failure. The simulation of an alternate operational sequence shows one way that the MWD tool failure and its associated non-productive time could have been avoided. Uncertainties in physical data constrain simulation fidelity and the application of otherwise seemingly convincing colorful dynamic drill string animations. The acquisition of a comprehensive and open-source set of drilling, completion and production data acquired using scientifically prescribed procedures would advance our understanding of the virtual world and help realize the full potential of drilling simulation.

The methodology outlined in this paper demonstrates how novel time-based simulation techniques can realize dynamic drill string behavior. That simulation engineers understand the uncertainties of physical data and the inferences from their own virtual results is critical for validating and calibrating their simulations in order to deliver the fidelity that is necessary for improving drilling decisions.