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Improved Bottomhole Pressure Control with Wired Drillpipe and Physics-Based Models

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Abstract:
Objectives/Scope: Wired Drillpipe (WDP) technology provides two-way and high speed measurements from bottom hole and along-string sensors. The data offered by WDP technology has maximum benefit when applied in an automation system or as a real-time advisory tool. Improved control is demonstrated for Managed Pressure Drilling (MPD) with the use of high-speed telemetry and physics-based models. Stabilizing and minimizing pressure within an acceptable bound leads to higher and more consistent Rate of Penetration (ROP).
Methods, Procedures, Process: MPD control is challenging due to tight pressure windows and the nonlinearity of the choke and pump response on Bottom Hole Pressure (BHP). This work demonstrates a new Hammerstein-Wiener nonlinear model predictive controller for BHP regulation in drilling. Hammerstein-Wiener models employ input and output static nonlinear blocks before and after linear dynamics blocks and thereby simplify the controller design. The control performance is evaluated in scenarios such as drilling, pipe connections, and kick attenuation. A physics-based drilling simulator, WeMod, is used for model identification and control performance evaluation.
Results, Observations, Conclusions: The control performance of the new nonlinear controller is compared to conventional controllers in various scenarios. Because of the interconnected multivariable and nonlinear nature of the drilling operation, conventional controllers show severe limitations. In a first scenario, the performance of setpoint tracking during normal drilling operation is compared. By changing the setpoint of the BHP, the conventional controller manipulates only the choke valve opening while the nonlinear controller moves choke valve opening, mud pump, and back pressure pump simultaneously. In a second scenario, a pipe connection of a typical drillpipe stand is demonstrated. The conventional controller is not able to regulate the BHP by adjusting the choke valve only. Although a linear version of the controller is able to exploit multivariable relationships, absence of the nonlinear relationships results in severe oscillation when the operational range is shifted outside of the training region. The nonlinear controller maintains a BHP within ±1 bar of the requested setpoint. A third scenario investigates the kick attenuation performance of conventional and nonlinear control algorithms. The nonlinear controller attenuates the kick within well control conditions, without requiring a well shut-in procedure.
Novel/Additive Information: Recent advances in drilling simulators and the reliability of the WDP data highway have enabled tighter BHP control. This study presents a robust method to control BHP by applying Hammerstein-Wiener models in an efficient model predictive controller. The proposed methods have been validated in the downstream industry, but are applied for the first time to drilling with nonlinear control functionality. The multivariable control adjusts three main manipulated variables in MPD simultaneously.
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