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Analysis of Surface and Downhole Drilling Dynamics High-frequency Measurements Enhances the Prediction of Downhole Drilling Dysfunctions and Improves Drilling Efficiency

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Abstract

Drilling rigs in North America are outfitted with Electronic Data Recorder (EDR) systems that acquire measurements from rig sensors. These systems typically record surface data at low frequency (0.1-1Hz) which makes it difficult to identify high-frequency events that could be occurring downhole. In an effort to fully understand the transmission characteristics of drilling dynamics signals along the drill string, the top-drive saver sub was embedded with high-frequency drilling dynamics sensors, sampled and continuously recorded at either 800Hz or 1600Hz.

Instrumenting the bit, bottom-hole assembly (BHA) and surface saver sub with identical high-frequency drilling dynamics sensors provided a unique insight into drilling dynamics transmission along the drill string. The sensors were identical and outfitted with the same hardware, firmware and software to allow detailed dynamics signal analysis to be undertaken. The signals from the high-frequency surface and downhole sensors were combined with the low-frequency surface rig measurements for pattern recognition and correlation analysis.

All high-frequency surface/downhole drilling dynamics data and low-frequency EDR data were merged and over-laid to identify signal patterns that would be beneficial in understanding surface and downhole generated dysfunction. Vertical, nudge, tangent, curve and lateral sections of the wellbore were analyzed to fully understand the transmission of drilling dynamics from downhole to surface and from surface to downhole. It is discovered that at relatively shallow depths, the signatures of at-bit dysfunction were observed in the high-frequency lateral vibration channels. Even in deeper wells, certain rotation-speed and shock/vibration signatures were detected at the surface.

The novelty of identical high-frequency drilling dynamics sensors at surface and downhole is that the signals generated by each sensor are produced from the same hardware, firmware and software. There is no risk of signals being mis-interpreted because of the use of different sensors or different signal-processing methods downhole and on surface. Merging and overlaying of the signal data with rig EDR allows drilling dynamics patterns to be correlated.

Introduction

During drilling, BHAs are often subjected to severe shocks and sustained high-magnitude vibrations. These downhole dysfunctions can result in equipment failures and associated non-productive time (NPT). The associated reduction in drilling performance and increase in drilling costs has driven extensive research towards gaining a better understanding of the complex downhole drilling dynamics.

Downhole drilling dynamics has been a subject of intensive research using various downhole and surface sensors since the 1960's (Bailey J.J. and Finnie 1960; Deily et al. 1968; Cunningham 1968; Dareing and Livesay 1968).

In the 1980-1990's, downhole drilling dynamics instrumentations began to be integrated into measurement-while-drilling (MWD) tools (Close et al. 1988; Zannoni et al. 1993; Pavone et al. 1994). Some researchers used a surface vibration