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The Use of the Industry's First 3-D Mechanical Caliper Image While Drilling Leads to Optimized Rotary-Steerable Assemblies in Push- and Point-the-Bit Configurations

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Abstract

It has been widely recognized that poor hole quality causes tight borehole, packing off, high torque/drag, stick-slip, degraded logging-while-drilling (LWD) and wireline log quality, unpredictable directional performance, and consequently problematic casing runs. Conventionally, borehole quality is monitored with LWD standoff caliper logs and caliper images. In wireline application, multi-arm mechanical calipers are used to create such logs. Until today, it is believed that the use of such equipment is the only way to detect 3-D borehole problems, such as borehole oscillation.

This paper presents the industry's first 2-D and 3-D mechanical caliper image while drilling and back-reaming with rotary-steerable systems (RSS). The near-bit mechanical caliper integrated into the specific RSS [1,2,3] takes measurements 4 ft from the bit in push-the-bit configuration and 7 ft from the bit in point-the-bit configuration. This pad-contact mechanical caliper provides both real-time and memory-based caliper images.

The advantage of this new type of near-bit caliper measurement is that the sensor measures borehole geometry right at the bit as compared to 50-100 feet behind the bit with conventional LWD sensors. Borehole washout, for example, does not necessarily occur at the bit, but could be caused by string stabilizers far away from the bit. The ability to detect borehole washout in real-time helps the operator take immediate corrective action while drilling to maintain borehole integrity since near-bit washout often affects the steerability of RSS.

In this paper, 2-D and 3-D near-bit caliper logs are extensively examined from different RSS assemblies and bits. The downhole data were gathered through controlled non-commercial field tests, as well as commercial runs. Frequency analysis using the discrete Fourier transform is also applied to the depth-based caliper images to identify the BHA and borehole oscillation issues. The effect of bit selection, stabilizer size/profile/geometry, and spacing on borehole quality is analyzed using the 2-D and 3-D near-bit caliper logs. As a result, this new sensor information helped to improve the RSS assembly performance and resulted in optimized BHAs in both push- and point-the-bit configurations for superior steerability, stability and borehole quality.

Introduction

In 1951, MacDonald and Lubinski explained the precise definition of so-called “crooked hole” or “spiral hole” and provided a formula for the maximum drift size (*MaxDrift*) with a given bit (*BitDiam*) and collar (*CollarDiam*) combination.[4,5] According to Lubinski, the maximum drift that can occur in a “crooked hole” is defined as:

$$MaxDrift = \frac{BitDiam + CollarDiam}{2} \quad \ldots (1)$$

Since Lubinski’s study (57 years ago), significant progress has been made in understanding the oscillating or cyclic nature of persistent borehole problems.[6-9] Mechanical calipers obtained from wireline logs and acoustic standoff calipers from LWD logs have accelerated this advancement in understanding the borehole oscillation problems. Pastusek et al. described the three most common forms of borehole oscillations: a) rippling, b) spiraling, and c) hour-glassing.[9] 3-D graphical representation of the three most common oscillation forms is shown in **Figures 1a**, **1b**, and **1c** (Excerpted from SPE 84448).