SPE/IADC 92576

Unique ROP Predictor Using Bit-specific Coefficient of Sliding Friction and Mechanical Efficiency as a Function of Confined Compressive Strength Impacts Drilling Performance

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This paper was prepared for presentation at the 2005 SPE/IADC Drilling Conference, held in Amsterdam, The Netherlands 23-25 February 2005.

Abstract

It has become standard practice to plan wells and analyze bit performance by using log-based rock strength analysis and/or the specific energy theory. The most widely used characterization of rock strength is unconfined compressive strength (UCS), but this is somewhat problematic because the apparent strength of the rock to the bit is typically different than UCS. Those who understand bit performance are aware of this problem, but to date there is not an industry standard or widely used methodology to address it. The specific energy theory has been used for bit performance assessment for years. One of the challenges of application of the specific energy theory, however, is uncertainty or lack of consistency in reasonable values for the input variables.

Globally applicable solutions and methods to address these problems have been developed and implemented by ChevronTexaco. A new method to calculate rock confined compressive strength (CCS), based on both conventional and somewhat innovative rock mechanics principles, has been developed. A new method to determine input variables for bit performance prediction based on the specific energy theory and CCS has been developed. These have been integrated to provide new capability for rapid and accurate log-based determination of the expected or achievable rate of penetration and operating parameters for all bit types. The new models have proved valuable, improving drilling performance and reducing well cost by improving bit performance prediction, bit selection, and the determination of optimum drilling parameters. The methods are robust, based on fundamental and/or first principles, and require little or no calibration. Any required calibration is intuitive and simple. This document presents background, theory, research results, new methodologies, and field and lab data that validate and illustrate the methods.

Introduction

During the late 1990s, Chevron Exploration and Production Technology Company (EPTC) initiated work on a project to improve drilling performance and pre-drill drilling performance prediction based on a mechanical earth model (MEM). Required components of this project were pre-drill bit selection, rate of penetration (ROP) prediction, and bit life prediction. Another objective of the project was the integration of this capability into tools/processes for rapid well design, planning, and cost estimating. People who understand what is necessary to build a MEM know that it requires an investment. A MEM is not always available or warranted, but its use is gaining popularity and proving to add value, especially with some of the major capital projects in more challenging and high cost drilling environments.

As is typical of such endeavors, the existing literature was reviewed, various experts were consulted, and processes used by suppliers were reviewed. EPTC, as well as other operators and bit suppliers, had some capability in this regard but EPTC believed there were still considerable inaccuracies, subjectivity, or extensive local calibration required in the existing processes. EPTC concluded that the industry lacked relatively accurate yet simple and intuitive methods based on first principles for calculating the apparent rock strength to the bit and achievable ROP for predominant bit types. These were fundamental requirements needed to meet the EPTC project objectives. The EPTC Rock Mechanics team, consisting of rock mechanics, drilling engineers, and earth scientists, worked together to develop simple, robust, and globally applicable solutions for apparent rock strength (to the bit) and bit performance prediction methods.