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Directional Success in the Canadian Rockies: Dynamic Tools Enable Accurate Comparison of Drill Bit Designs

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Abstract

A smooth torque response is widely regarded as one of the greatest challenges when drilling with a drill bit on a directional assembly. Aspects such as toolface control and stick-slip are both proportional to the torque generated by the bit, and by nature, fixed cutter (FC) drill bits are capable of generating high levels of torque. If large changes in downhole torque are produced while drilling, these will cause rotation of the drill string, and loss of toolface orientation. This results in inefficient drilling and increases risk of bit and downhole tool damage.

This paper reviews the field performance of a number of drill bits within the Canadian Rockies on directional assemblies. Particular focus is placed on the torque response and its resultant effect on both the steerability and stability of the assembly. The analysis includes comparison of conventional FC drill bits and roller cone (RC) designs, and also documents performance of specific FC designs that are equipped with torque controlling features. These features, in combination with specific cutting structure layouts, are engineered to provide predictable torque response while being optimized for high rates of penetration. The bit designs also include a unique gauge geometry that was engineered to reduce drag and deliver improved borehole quality.

The field performance review includes downhole dynamics data analysis. The recorder used gathers drilling dynamics data at a high frequency sample rate, enabling lateral stability and the variance in downhole rotation of the drill bit to be accurately determined. Evaluation between the different drill bit concepts revealed that use of FC designs with specific torque control features provided toolface control equal to or greater than a RC design. Steerability and stability were improved when compared directly to conventional fixed cutter designs, with resultant increase in penetration rates. Successful application has resulted in significant time and cost savings to operators.

Introduction

Directional drilling using steerable systems has advanced considerably since the mid-twentieth century, where directional control was attained with rotary assemblies and deflection devices such as whipstocks. The development of the positive displacement motor (PDM) in the early 1980's provided the ability to make course corrections and counteract formation tendencies on a continuous basis. This drove drill bit manufacturers to design and develop FC designs that are optimized to maximize the drilling efficiency of these tools. The key design challenge relates to the difference in aggressivity required for the two operating modes of a motor assembly; sliding and rotating. A steerable motor employs a sufficient bend angle to achieve the planned trajectory in sliding mode. The relative downhole location of this bend (tool face) is held stationary by non-rotation of the string. Rotation of the bit is provided by the mud motor that converts the hydraulic energy of the mud pumped through it to mechanical energy in the form of torque and RPM output to the drill bit. The reactive torque produced by an aggressive FC bit can cause the drill string to twist unpredictably, resulting in loss of tool face. This leads to wasted drilling time associated with reestablishing the desired tool face. It may also lead to stalling of the motor, which can ultimately result in premature failure. However, in rotating mode, the bit is being turned from rotation of both the string and the downhole rotation provided by the mud motor. There are no tool face control concerns thus an aggressive design can be utilized to maximize penetration rate.