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Use of Mechanical Specific Energy Calculation in Real-Time to Better Detect Vibrations and Bit Wear While Drilling

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Abstract

Mechanical Specific Energy (MSE) is now a well-known concept to quantify the cutting efficiency of the rock. Thanks to its simplicity, its utilization has significantly increased over the last few years with electronic drilling recorders, especially in unconventional wells to optimize the drilling process and eventually reduce cost. A typical use is to compare the MSE to the rock strength to see whether the right amount of energy is utilized at the bit and not wasted or dispersed somewhere else. However, MSE alone cannot tell if drilling inefficiency is due to a change in the rock hardness, or due to vibrations, or bit wear or bit balling. This paper presents a new methodology that enables to fill the gap, in combining the MSE to the drilling strength (DS) to detect dysfunctions, such as vibrations or bit wear.

As MSE is mainly affected by the level of downhole torque (TOB), the effect of WOB is often neglected and is not taken into account in standard MSE analysis. In re-introducing the concept of drilling strength (DS) which is a function of WOB, and using the ratio of MSE over DS, a simple methodology can be derived to not only detect drilling inefficiencies but also determine the type of dysfunctions, such as vibrations or bit wear.

This paper shows how the new methodology has been successfully used and validated in unconventional wells.

Introduction

MSE has become a common way to analyze drilling efficiency post-run and, in some cases, make corrections in real-time to improve rate of penetration (ROP)[1]. Much can be learned from studying what has been done in past wells and applying lessons learned to the next well. To be the most effective however, MSE must be combined with other data and field knowledge to determine the root cause of MSE changes which are generally due to a formation change, bit wear, bit vibrations or bit balling just to name a few. A new methodology proposed in this paper reveals an effective way to dig deeper into MSE data and conclude why it could be changing and what can be done to improve drilling efficiency. When used in real-time, this methodology has the potential to save time, improve drilling efficiency, reduce vibration and therefore wear and tear on tools, and make the decision to trip for bit change easier by providing a way to analyze bit-wear at surface.

Terms

Mechanical Specific Energy

The mechanical specific energy or MSE, is commonly defined as the amount of energy required to destroy a unit volume of rock. It is expressed in terms of lbs/in^2 (psi) or N/m^2 (more commonly referred to as a Pascal, Pa). Teale[2] pioneered this methodology in 1964, however it was mostly used by bit vendors to determine the drilling efficiency of drill bit designs[2,3] until 2005 when it was introduced by an instrumentation vendor to the industry for real-time use[1,4,5]. Since that time, its use has expanded within the industry to become an easy to use and understand method of improving ROP and maximizing drilling efficiency.

Teale's equation for mechanical specific energy is defined as the following for the purposes of this paper[2]:

$$MSE = \frac{WOB}{A_B} + \frac{120\pi * RPM * TOB}{A_B * ROP} \quad \text{(Eq. 1)}$$

Where:
MSE = Mechanical Specific Energy, psi
A_B = Bit Area, in^2
RPM = Bit rotation speed, rpm
TOB = Torque on bit, ft-lbs
ROP = Rate of penetration, ft/hr

It is important to mention that the torque term used in the above equation should be the torque on the bit in order to estimate the amount of downhole energy required to cut the rock. If surface torque is used instead, MSE will be highly over-estimated, especially in deviated wells, because of the overall friction along the drill string. Additionally, RPM should always be the bit RPM, therefore when using a mud motor the revolutions per gallon (rev/gal) and flow rate should be used to calculate the bit RPM and then added to the string RPM for use in MSE calculations.

WOB

MSE is made up by adding together two main terms, one dictated by the WOB and the other dictated by the TOB. Often the WOB term is neglected due to its insignificance compared to the TOB term which makes up over 99% of the total MSE