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Innovative Instrumented Motor with Near-bit Gamma and Inclination Improves Geosteering in Thin-bedded Formations

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Abstract

Drilling horizontal wells in thin-bedded reservoirs with the goal of achieving maximum contact with the reservoir is challenging. Staying within the payzone of the reservoir saves drilling and completions costs and improves recovery from the well. In formations with high gamma ray contrasts, azimuthal gamma ray and continuous inclination are typically used to aid the geosteering process. In a conventional drilling motor BHA (Bottom Hole Assembly), the relevant sensors are placed as far back as 40 ft to 50 ft (12 m to 15 m) behind the bit. Given this large bit-to-sensor offset, and the shallow depth of investigation of gamma ray measurements, it becomes difficult to effectively geosteer the well to maintain maximum reservoir contact.

A recently developed instrumented motor provides azimuthal gamma ray and inclination measurements while drilling, with the sensors located as close as 6 ft (1.8m) from the bit. The bearing assembly is designed with a payload which includes a sensor module, telemetry module, antenna and lithium batteries. Real-time transmission of azimuthal gamma ray and inclination measurements is achieved via wireless transmission from the instrumented motor to the MWD (Measurement While Drilling) tool above the motor and from there to surface using either electromagnetic or mud pulse MWD telemetry. The key benefit of the instrumented motor lies in geosteering applications. With the azimuthal gamma ray and inclination readings so close to the bit, it is possible to steer the motor in thin-bedded formations and to keep the well on an optimal path in the reservoir. In a recent CBM (Coal Bed Methane) application, the instrumented motor enabled the operator to stay in a very thin coal bed for 80% of the well without any sidetracks, compared to staying in the coal only 40% of the well with seven sidetracks when drilling a similar well with an azimuthal gamma sensor spaced further back above a standard motor.

Introduction

It is commonly recognized that increasing the length of a production interval in a gas or oil bearing zone increases the production and ultimate recovery of the reserves. Horizontal wells are most commonly drilled in formations that are somewhat flat with thicknesses ranging from less than one foot up to tens or hundreds of feet. A horizontal well generally has a kick-off point, a curve directionally drilled to a target inclination within the range of 70° to 110° depending on the formation dip of the geological objective, and a reservoir section. In order to maximize recovery and reduce overall drilling risk, it is important to keep the drilled well path within the optimal target formation, and avoid unnecessary deviations up or down into neighboring formations [1]. This process of maintaining the bit within a particular section of the formation using real-time geological and directional information while drilling is referred to as geosteering. The most important data used in geosteering wells with high gamma ray contrast between the zones are azimuthal gamma ray and continuous inclination measurements. Due to the limited depth of investigation of gamma ray measurements and the need to react quickly so as not to get out of the target zone, it is critical that the azimuthal gamma ray and inclination measurements are placed as close to the bit as possible.

Instrumented Motor with Near-bit Azimuthal Gamma Ray and Inclination

A recently developed instrumented motor provides azimuthal gamma ray and inclination measurements while drilling, with the sensors located as close as 6 ft (1.8m) from the bit. The bearing assembly is designed with a payload which includes a sensor module, telemetry module, antenna and lithium batteries (figure 2). Real-time azimuthal gamma ray and inclination measurements transmission to the surface is achieved via wireless transmission from the instrumented motor to the MWD tool above the motor and from there to surface using either electromagnetic or mud pulse MWD telemetry (figure 1)

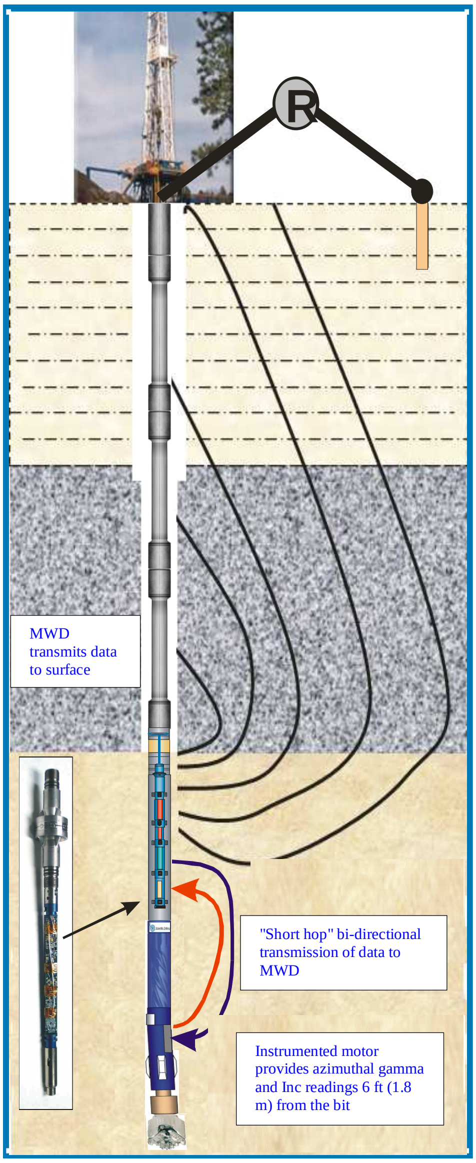

Figure 1: Near-bit Instrumented Motor with wireless bi-directional "short hop" communication and MWD system

Figure 2: Instrumented motor payload showing telemetry module, sensor module and antenna

Measurements

The sensor module which is housed in the payload, has a single scintillation detector that measures the natural gamma ray radiation of the formation. The body of the motor is used to shield the gamma detector, allowing it to only read gamma radiation from one direction (figure 3). Tri-axial accelerometers are used to bin the gamma into two hemispheres. High accuracy tri-axial accelerometers are used for accurate inclination measurements. The sensor module also provides vibration and RPM (Revolutions Per Minute) information. The telemetry module and antenna are used for real-time bi-directional wireless communication with the MWD tool located above the motor. From there, the data are sent to the surface using either electromagnetic or mud pulse MWD telemetry. Data acquisition and transmission electronics are powered by lithium batteries included in the payload.

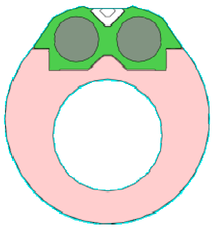

Figure 3: Cross section of instrumented motor showing payload (green)- with motor body acting as gamma shield.

Mechanical Design

The mechanical design of the motor is similar to that of a positive displacement mud motor. However, the integration of the additional sensors into the motor poses significant design challenges. The payload with electronics reduces the space available for mud flow, causing it to flow at high velocities which can lead to erosion of the motor. Minimization of the sensor and electronics components and an innovative motor drive train design have overcome this challenge, so that the instrumented motor is now available in tool sizes of 3 ¾”, 4 ¾” and 6 ½”. Figure 4 shows a shaft design with three different sections to transmit the torque from the rotor connection with eccentric rotation (top side) to the mandrel connection with the bit (concentric rotation, bottom side).

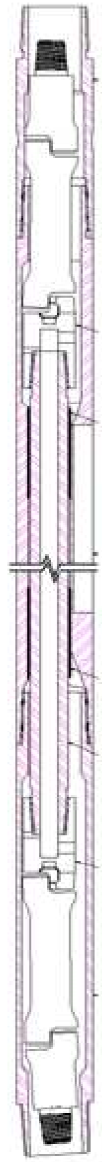

Figure 4: Instrumented motor shaft design overcomes space limitation

Case Study

The following case study describes drilling applications in a coal gas seam with an average thickness of 2 ft to 4 ft with intervals as thin as 1 ft! The operator had previously drilled the coal seam using 'conventional' technology with an azimuthal gamma sensor positioned 43 ft (13 m) behind the bit. Here, the operator was in the coal formation about 40% of the well, with multiple sidetracks and an average ROP (Rate of Penetration) of 12 ft/hr (3.7 m/hr).

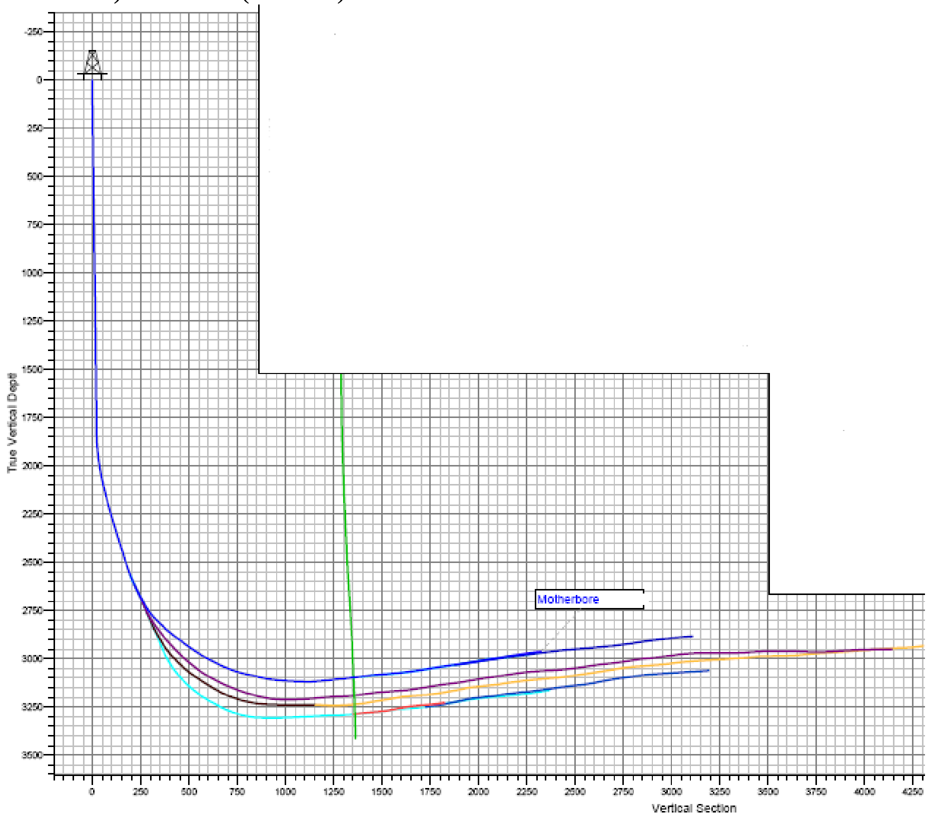

Figure 5: Well plan showing single motherbore with multiple laterals

The next well plan called for a single motherbore and multiple laterals being drilled from the motherbore as shown in figure 5. The instrumented motor was used to drill the laterals. The azimuthal gamma ray and continuous inclination measurements were located 7 ft (2.1 m) behind the bit.

Figure 6 shows a log from the well. Track one shows the API radial gamma ray measurement and Rate of Penetration (ROP). Track 3 shows *Up/Down* azimuthal gamma ray measurements from the instrumented motor with fill-in on the curves. Track 4 shows the gamma image generated from the azimuthal gamma ray measurements. When the shading in track 3 is blue, this indicates that the instrumented motor was 'seeing' higher *Up Gamma Ray* counts compared to the *Down Gamma Ray* counts. This means that the bit was approaching the upper shale formation which has higher gamma counts. This is confirmed by the inclination increasing from 98.12° to 99.49°. In this specific example, the Directional Driller working with the Geologist, decided to slide down back into the formation (the slides are indicated by the gaps on the log). The *Up Gamma Ray* readings start to reduce as the bit gets back into the coal seam. This is confirmed by the corresponding drop in inclination as shown on the log. At the end of the laterals the instrumented motor helped improve the footage in coal to 80%. The laterals were drilled without any correction sidetracks compared to seven sidetracks before when using conventional technology. The average ROP increased by a factor of two supported by faster decision making and drilling with more confidence.

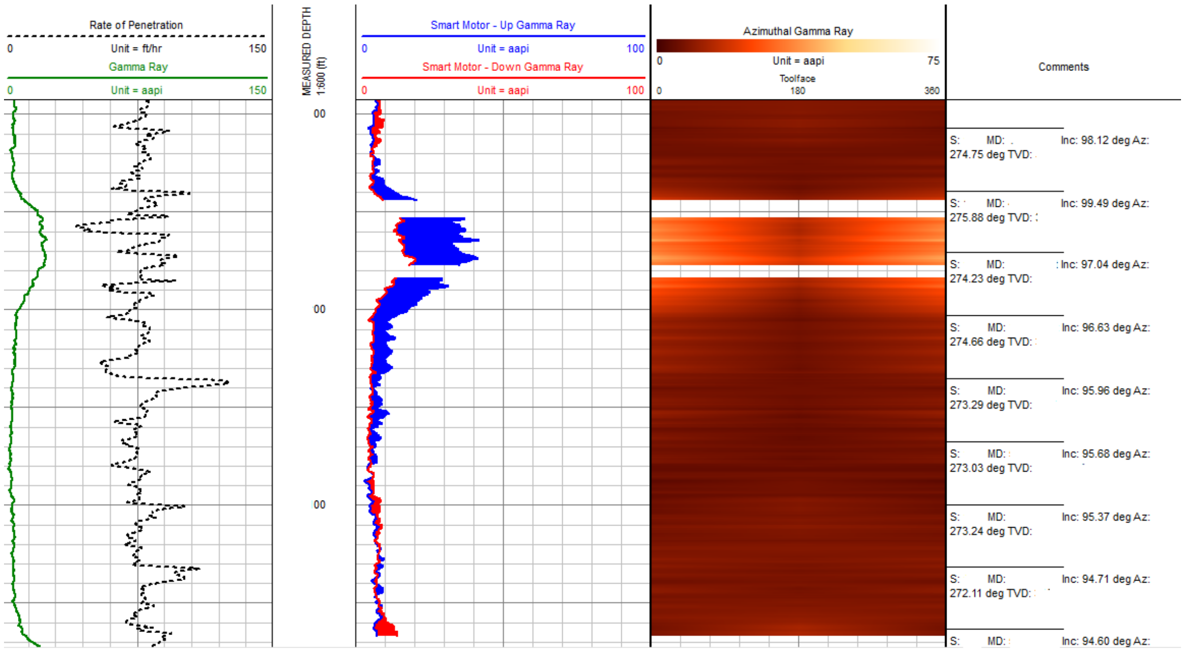

Figure 6: Log Showing Azimuthal Gamma and Inclination measurements

Conclusion

A recently developed instrumented motor with azimuthal gamma ray and inclination with sensors close to the bit is an ideal tool for geosteering laterals (such as CBM) or other drilling applications where tight control of the trajectory is required. Other applications of the technology include early casing point picking or optimizing slide intervals with steerable motors. In a coal seam gas application, the instrumented motor increased coal exposure from 40% to 80%, doubled the average ROP and delivered a smoother well bore for easier completions.

Reference

1. Gleason, B., Hawkinson, B., Lightfoot, J., Suh, A., 2010: “Development of a New Azimuthal Gamma Ray Logging While Drilling Motor with Near bit Inclination for Rotary Acquired Focused Gamma Ray for Optimal Wellbore Placement in a Coal Seam Gas Well”; Tuscaloosa, Alabama, University of Alabama, College of Continuing Studies, 2010 International Coalbed Methane Symposium Proceedings, Paper 1011, May, 2010.