At-bit high resolution imaging while drilling geosteering system

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In the current oil and gas industry, the horizontal well as a new technique is an inevitable choice for oilfield development, in order to achieve the goal of "less well and high yield", enhance oil recovery and reduce production area. Currently the main techniques used for horizontal well positioning and orientation includes measurement while drilling (MWD) and logging while drilling (LWD), which provide geometric parameters such as inclination, azimuth, toolface, and geological parameters like gamma ray, resistivity, neutron porosity, lithology density and sonic velocity, and so on (Liu S K, 2008). Due to the limitation of the Bottom Hole Assembly (BHA), the measuring points are often far away from the bit by more than 15-20 meters (Bybee K, 2000). Therefore with large hysteresis it is difficult to provide high precision positioning information timely for a variety of reservoirs, especially thin and ultra-thin layers (less than 1 m), causing the bit to be lost from the reservoir under condition of “blind drilling” and resulting in a low probability of penetration. An at-bit imaging while drilling geosteering tool was developed to meet the urgent needs of the oil and gas industry. The tool is assembled in front of the bit to improve the orientation accuracy.

In the at-bit high precision imaging while drilling geosteering system, all sensors are installed as close as possible to the bit, providing immediate information on wellbore attitude and physical properties of the reservoir. The at-bit measurement data used to provide guidance drilling are transmitted to the ground in real time through the conventional MWD tool, and the working principle diagram is shown in Figure 1.

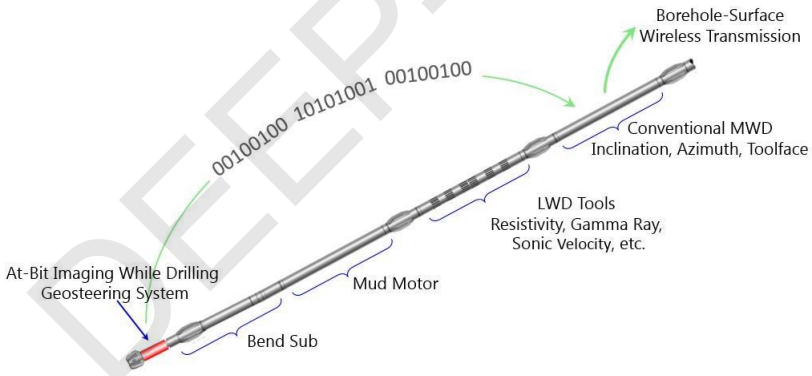


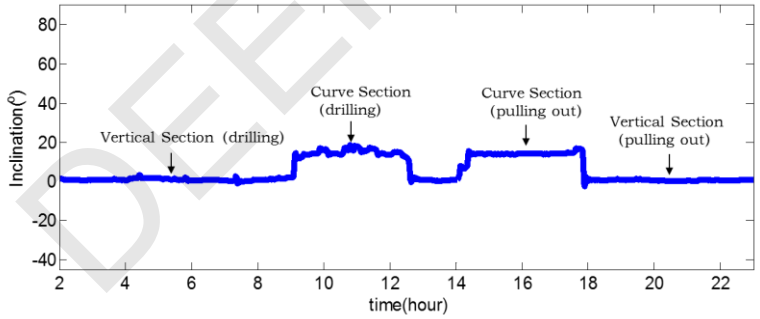
Figure 1. The principle diagram of at-bit imaging while drilling geosteering system

We have overcome several technical difficulties that must be faced in the at-bit measuring environment, including 1) temperature compensation techniques for inertial accelerometers and magnetic sensors, 2) gravity acceleration measurement techniques under strong vibration, shock and high speed rotating environment, 3) geomagnetic field measurement techniques under strong magnetic interference from ferromagnetic material such as bit and bend sub, and 4) 16 sectors gamma imaging with lower data transfer rate. A test prototype of at-bit imaging while drilling geosteering system was developed, which has the function of at-bit dynamic wellbore trajectory and azimuthal gamma imaging measurement. The test prototype has a diameter of 6.75 inches, length of 0.92 m, maximum working environment pressure of 130 MPa, a torque of 42 kN·m, and vibration tolerance of 13 gRMS.

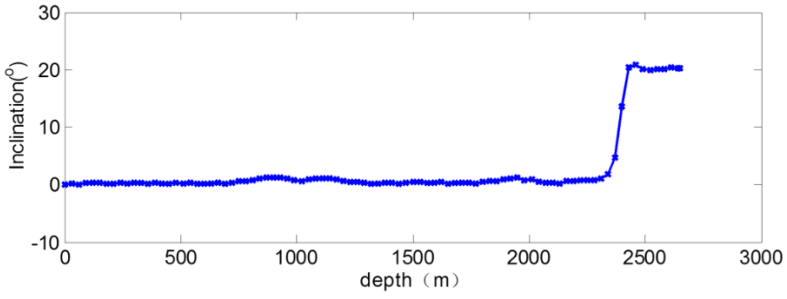
In 2015, two drilling tests were carried out on the at-bit imaging while drilling a geosteering system in the oil field of Karamay, Xinjiang. The instrument worked for a total time of 167 hours and a footage of 2,219.85 meters. The mechanical structure of the instrument is reliable, and all cabins are well sealed. Figure 2 shows the scene where the instrument enters the well and leaves the well.

Figure 2. Drilling test for at-bit imaging while drilling a geosteering system

Figure 3 shows a comparison between the dynamic inclination measured by the at-bit imaging while drilling geosteering system and the stationary inclination measured by wireline logging tools. The results reflect the entire drilling process including drilling in the vertical section and curve section and pulling out the drilling tools. The dynamic inclination angle was 18 degrees in curve section which is consistent with the result measured by wireline logging tools.



(a) Dynamic inclination measured by the at-bit imaging while drilling tool.



(b) Stationary inclination measured by wireline logging tools.

Figure 3. The comparison of inclination measurement results

The at-bit imaging while drilling geosteering technology, with measurement functions of geometric and geological parameters and no hysteresis for measurement point is suitable for geosteering needs in thin and ultra-thin layers. Compared with traditional MWD and LWD technology, this technique has obvious advantages in steering precision and will play an important role in unconventional oil and gas exploration and development.

This study was supported by Supported by the Strategic Priority Research Program of the Chinese Academy of Sciences (Grant No. XDB10040100)