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A new electromagnetic beacon tool for directional drilling in steam assisted gravity drainage horizontal wells

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ABSTRACT

Steam assisted gravity drainage (SAGD) wells require precise separation between the production well and the injection well to ensure the efficient oil drainage of the reservoir. The precise measurement of the distance and direction between the being drilled injection horizontal well and the cased production horizontal well is needed during the SAGD drilling process. This high accuracy downhole surveying is achieved through the use of active magnetic ranging method. Based on this method, a new electromagnetic beacon tool has been invented with the purpose of simplifying the process of the drilling operation and reducing the cost in SAGD projects. A solenoid has been integrated into the beacon as the electromagnetic field source and an "H bridge" circuit has also been designed for alternating the direction of the current in the solenoid. Besides, a telecommunication circuit was designed and configured in the beacon to receive wireless signal. Deployed as the electromagnetic field source in the cased production well, the beacon can induced electromagnetic field for guiding the directional drilling trajectory along a path parallel to the existing production SAGD horizontal well. The electromagnetic beacon tool has a successful experiment in the "shallow well". It can guide the directional drilling process in SAGD horizontal wells and make it possible to drill the injection SAGD horizontal well without any access to the production well.

1. Introduction

In recent years, various techniques utilizing advanced technology have been developed to improve the exploitation of oil and gas. By combining the techniques of horizontal well and steam injection recovery on heavy oil reserves, SAGD (Steam Assisted Gravity Drainage) can increase the exploitation of oil and gas as much as 60%, and improve the recovery ratio by 30 percent (Luo and Sun, 2010; Knoll and Yeung, 2000). The SAGD project is used to boost the production by utilizing a production horizontal well in a reservoir with crude oil of high viscosity and low-mobility. The other horizontal well for steam injection is to be drilled precisely above and in alignment with the cased production well with a separation of about 5 m or more. The steam injection in the upper well causes heated oil to flow toward the production well, and can greatly increase recovery from the reservoir. SAGD was first used in Canada. It was introduced to China especially for Liaohe oilfield of CNPCs. Typically, SAGD horizontal wells drilled in Canada have a horizontal reach of 1.5 km with a separation specified to be 5.0 ± 1.0 m (Kuckes, 1994; Tracy and Grills, 2002). The length of the horizontal section usually ranges from 800 m to 1500 m (Lin et al., 2009; Chen et al., 2011). The MGT (Magnetic Guidance Tool) and the RMRS (Rotating Magnet Ranging System) are the two successful systems that were able to consistently demonstrate the ability to meet the precise tolerances and operational efficiencies required in SAGD horizontal wells. Acquiring a survey with the RMRS is more complex. The system requires continual monitoring for data capture and quality control. MGT can be easily positioned at any point along the well path and can take multiple proximity surveys on demand (Vandal et al., 2004). In China, a lot of research have been conducted on the theories of RMRS and MGT (Diao and Gao, 2013, 2011; Gao et al., 2013). However, the focus of their research was not on application. Since both guiding tools require access to the production well while drilling the injection well, the operation process might have the risk of wearing and damaging the casing of the completed well (Al-Khodhori et al., 2008). To avoid this, a magnetostatic parallel well tracking technique has been developed by magnetizing one or multiple casing joints (Pratt and Hartman, 1994). However, since the strength of the magnetic field is not very strong, the measuring range of this technical is limited. In

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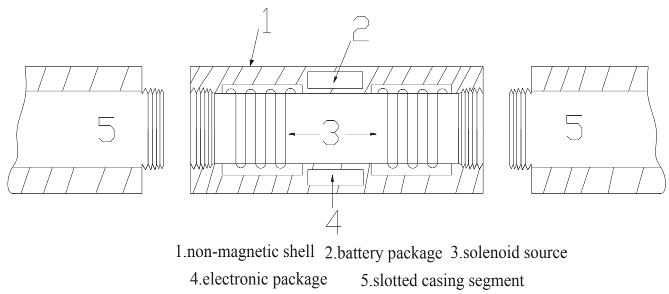

Fig. 1. The composition of the beacon.

order to fully utilize "magnetic joints" in this method, an electromagnetic beacon tool is invented to help determine the distance and direction of the being drilled borehole with respect to the production well.

2. The structure and working principle of the beacon

2.1. Structure of the beacon

An electromagnetic beacon for SAGD process is illustrated in cross-section in Fig. 1. The beacon incorporates a steel shell with female threads at its opposite ends. This coupling method is used to connect two standard slotted liner casing segments. Each beacon incorporates a solenoid coil winded around the circumference of the body of the coupling. The wireless receiving module and battery pack of the electronics package are "potted" in small cavities on the circumference of the coupling. The non-magnetic shell covers around the beacon ensuring the integrity of the magnetic field. After installation each beacon waits for a corresponding initiating signal. Upon receipt of designate signal, the selected beacon generates a corresponding electromagnetic field. The electromagnetic field lasts for a short duration, or burst, long enough to allow the desired measurements.

2.2. The working principle of the beacon

The conventional survey methods need to lower the oil tubes or use a downhole tractor to draw the magnetic source in the cased well. Such a process is time consuming and requires a lot of efforts. Featured by installing beacons at the selected positions along a cased borehole, the new method for measuring the distance and direction between two SAGD horizontal wells needs neither dedicated survey tools nor access to the cased well as shown in Fig. 2. The magnetic field survey instrument is placed inside a probe tube near the bit to measure the magnetic field from the completed borehole. Once the bit comes into range, the magnetic field generated by the beacon can be detected by the probe tube.

The magnetic field is measured, the relative distance data will be sent to the driller. If the results are in the range, the drilling continues in conventional way until it reaches the next beacon 100 or more meters away.

The unit vector **h** shows the direction of high side of the upper borehole as shown in Fig. 3(a). The unit vector **w** stands for the trajectory extension direction of the injection well. According to the right-hand rule, the unit vector **v** is orthogonal to the unit vector **h** and the unit vector **w**. The **w** axis magnetic induction density (B_w) can be detected by the axial magnetic sensor. The radial distance R between the beacon and the probe tube can be deduced from B_w (Diao and Gao, 2011).

A_{hr} shown in Fig. 3(b) stands for the angle between the unit vector **h** and the unit vector **r**, it can be derived from the magnetic induction density data captured by three magnetic components in the measuring tool (MWD). The value of the A_{hr} can be used to calculate the relative position between the two SAGD horizontal wells (Kuckes, 1994).

2.3. Guidance operation process

The production well is drilled along a prescribed course using conventional guidance techniques. During the casing operation, one or more electromagnetic beacons are installed between two casings, which are then deployed at prescribed locations in the production well. A "casing crew" installs these beacon couplers in the same way that ordinary pipe couplings are installed, although the beacon couplers may have a specified "down hole" polarity orientation. These couplers may be installed as a permanent fixture of the production well or as couplings in a temporary "work string" of tubing installed inside the production well. Each beacon has its own telecommunication circuit configured to receive its own "identification code" for example K1 for Beacon I and K2 for Beacon II. In this way, the wireless signal can "awake-up" only the selected beacon at any given time.

Fig. 4 shows Step 1 of the guidance process. After casing has been installed in the production well, the other well of the SAGD pair is drilled along a specified parallel path with respect to the

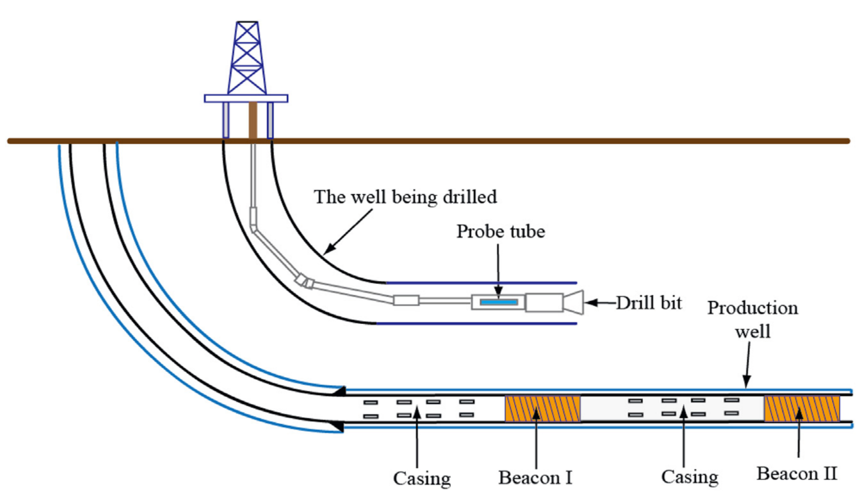

Fig. 2. The working principle of a beacon.