Research on Rotary Steerable Drilling System

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Abstract

This paper introduces rotary steerable drilling system and its four function units, the four function units are power unit, measure unit, control unit and executive mechanism unit. The structure of turbine generator in the power unit of the system has been stressed. The measure unit has adopted gravity accelerometer and rate gyroscope as sensors, which measure deviation angle, orientation and angle of tool and control angular velocity of axes, whole measure parameters are stored in the storage. The control unit has been controlled with mode of double-loop control by ground computer and downhole microprocessor, and has realized double information flow control of downhole small-closed-loop and whole well large-closed-loop. The monitoring information has been transmit to the ground, which depends on negative going pulse of mud pressure and is achieved by Measure While Drilling (short as MWD), and the pulse-code has been modulated on the ground, the information has been transmit to the downhole, which depend on the negative going pulse of pump displacement and is achieved by pump displacement impulse generator, and the pulse-code has been modulated in the signal receiver of the tool. Through optimization design for the rotary steerable drilling tool, laboratory simulation experiments and field test for the main function units, engineering prototype for field test has been developed successfully. The result of the field tests indicates that the tool has realizes its main function, life of damageable part and anti-interference capability for control unit need to be improved.

Keywords: ROTARY STEERABLE, DRILLING TOOL, FUNCTION UNIT SYSTEM, RESEARCH

1. Introduction

Rotary automatic steerable closed-loop drilling technology is an important symbol of automation and intelligence. In overseas, Baker Hughes, Schlumberger and Halliburton has informed commercial application rotary steerable drilling system respectively, it is Auto-Trak, Power-Drive, and Geo-Pilot [1-8].

In order to adapting the need of oil and gas exploitation, and improving the level of drilling technology in domestic and the market competition in worldwide, rotary steerable drilling system which has the independent intelligent property right is developing, and it will be developed practically step by step [9-13]. This paper focuses on discussing the rotary steerable system.

In this paper, the rotary steerable drilling system is composed of ground monitoring and controlling subsystem, downlink, rotary steerable drilling tool, MWD, and uplink, while the rotary steerable drilling system which is the key is composed of power unit, measuring unit, controlling unit, and executive mechanism unit, and its top is conjunct with MWD short section, and its bottom is conjunct with bit. The structure diagram of the tool is shown in Fig. (1).

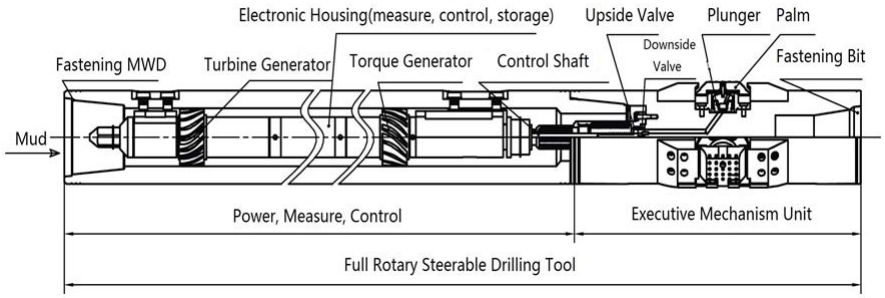

Figure 1. Elements of Full Rotary Steerable Drilling Tool

2. Power Unit

Power unit is composed primarily of turbine generator (top turbine generator) and torque generator (bottom generator), its structure is shown in Fig. (2). The basic structure of two generators are same, the operating condition and the environment is special, so the structure is special, which is different from ordinary generator [11].

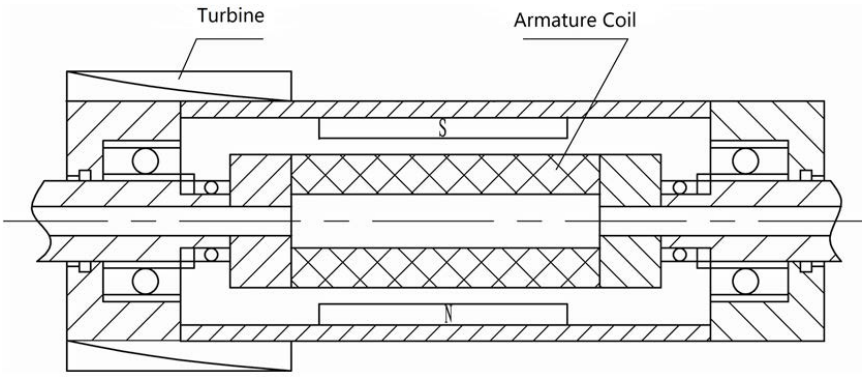

Figure 2. Structure of Turbine Generator

Two downhole turbine generators are both driven by drilling mud, Alternating current which is outputted by top turbine generator is rectified and regulated, then it provides power to the electronic and electrical equipment which is installed in the electronic housing, as well it is the sensing equipment which can transmit the information to the downhole, the instruction is coded and transmitted to the downhole by controlling the mud pump on the ground, the change of current and voltage can be tested by the receiving circuit in download instruction, and the circuit can regulate the code, so that the instruction of the control system can be got. The bottom generator acts as the torque generator, and it can generate the balancing torque or driving torque for the control shaft in the stable platform, so that it can control the tool face angle.

3. Measure Unit

The sensor and circuit of measure unit is installed in the capsule which is in the stable platform section, during the work, MWD can measure the parameters as follow: the real-time parameters of the well track, including well deviation and orientation; controlling parameters, including tool face angle, rotate speed of control shaft, current or voltage of generator; duty parameters of tool, including temperature, pressure, vibration, mud pump and so on. These parameters are stored in storage which is in the electronic housing, and some of them will transmit to the ground.

Well deviation, orientation and tool face angle can be measured by gravity accelerometer and rate gyroscope, then these parameters are sent to the microprocessor, and these information can be transmitted to the ground by MWD, which can provide the basis for large closed loop control and small closed control; actual working status can be known by installed temperature sensor, pressure sensor and vibration sensor; information underground can be received by measuring the current and voltage of the generator, and the parameter of mud pump can be got.

4. Control Unit

Current loop, time loop, and position loop composes the three loop negative feedback, that is, load current of up and bottom turbine generator can be measured by current mutual inductor, then current loop can be formed by comparing the current; rotation rate of the control shaft can be measured by rate gyroscope, then time loop can be informed; tool face angle can be measured by gravity accelerometer, then the position loop can be informed. The diagram of tool control unit is shown in the Fig. (3).

4.1. Small Closed Control

Small closed control can be realized in the downhole. Well deviation and orientation is measured by measure unit, then the parameters is compared with the preset parameter of well by downhole microprocessor, for example, if deviation exceeds the prescribed limit, according to the measured well deviation, orientation, tool face angle, rotation rate of the control shaft, small closed loop control order is given on the basis of the principle in the Fig. (3), then executive mechanism unit acts, tool posture can be regulated; if the deviation dose not exceed the prescribed limit, the executive mechanism unit executes the original motion. This processor is controlled by well microprocessor, which needs no control of the ground, and the reaction of this closed loop control is fast, and the posture is regulated without delay, and the track of well is regular and smooth, however, the reliability of system is required, and it should not make any mistakes, therefore, a breakpoint which is large closed loop interference pri-

mary is set in the control loop, it can test the consistence between the large closed order and small closed order on real time, and it can process priority.

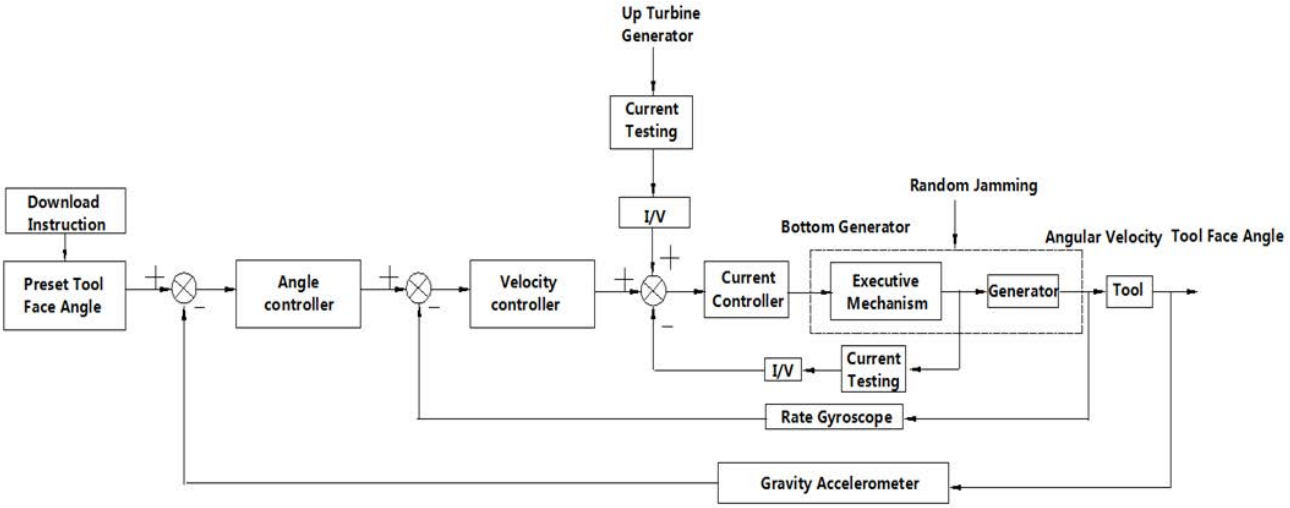

Figure 3. Principle of Control Unit

4.2 Large Closed Loop Control

Tool and ground control center informs the large closed loop control by mud, MWD and ground mud pump impulse generator. While the downhole small closed loop control the speed, measured well deviation, orientation and tool face angle can be transmitted to the ground to control the subsystem by MWD, computer in the subsystem compared these parameters with the preset well parameters and tool parameters, for example, if the deviation exceeds the prescribed limit, according to the measured well deviation, orientation, tool face angle, large closed control order is given, and the order is transmitted to the downhole tool through the ground mud pump impulse generator, the changed current of up turbine generator is measured by measure unit, then it is sent to the downhole microprocessor, then the current(voltage)-mud pump is decode regulated, control order of large closed loop can be got in the downhole, the consistence between the large closed loop order and the small closed loop order can be tested on real time, and it can process priority, executive mechanism unit acts according to the large closed loop control order, tool posture can be regulated; if the deviation dose not exceed the prescribed limit, the executive mechanism unit will received order from the large closed loop and it executes the original motion.

Mud pump impulse generator on the ground sent the order by negative pulse, then changing the three fall three rising pulse mode of the pump and coding, the three fall three rising negative pulse which is 0,1 coded combination can be optimized [12]. This code theory includes 256 information codes, that is 256 control orders. A control order includes level of tool force and 2 parameters of tool face angle. In order to control the working condition of the tool and reducing the regulating and controlling of the tool too often, the tool force and orientation is limited graded, each control order respond to different level of guidance force and tool face angle. The grade condition of the steerable force and orientation has been given based on the 93 control orders in the Fig. (4), in which every point denotes one control order, and every control order denotes different steerable force and level of tool face angle. The dog leg strength% indicates the force, this, in turn, 100% guidance force, 75% guidance force, 50% guidance force, 25% guidance force, 0% hold angle; the step length of level of tool face angle in the range of 360 is that, 10 while the guidance force is 100%, 15 while the guidance force is 75%, 18 while the guidance force is 50%, 30 while the guidance force is 25%. For example, the peak of outer ring in the figure indicates that tool face angle is 0 , dog leg strength is 100%, the tool is strong angle building, the 100% working time of three palms is pushing the side wall in the opposite direction of high side, the tool is full angle building. the peak of second ring in the figure indicates that tool face angle is 0, dog leg strength is 75%, the tool is relatively strong angle building, the 75% working time of three palms is pushing the side wall in the opposite direction of high side, the tool is angle building, however, the 25% working time of three palms is not oriented. And so on, the ability of orientation is regulated by working time.

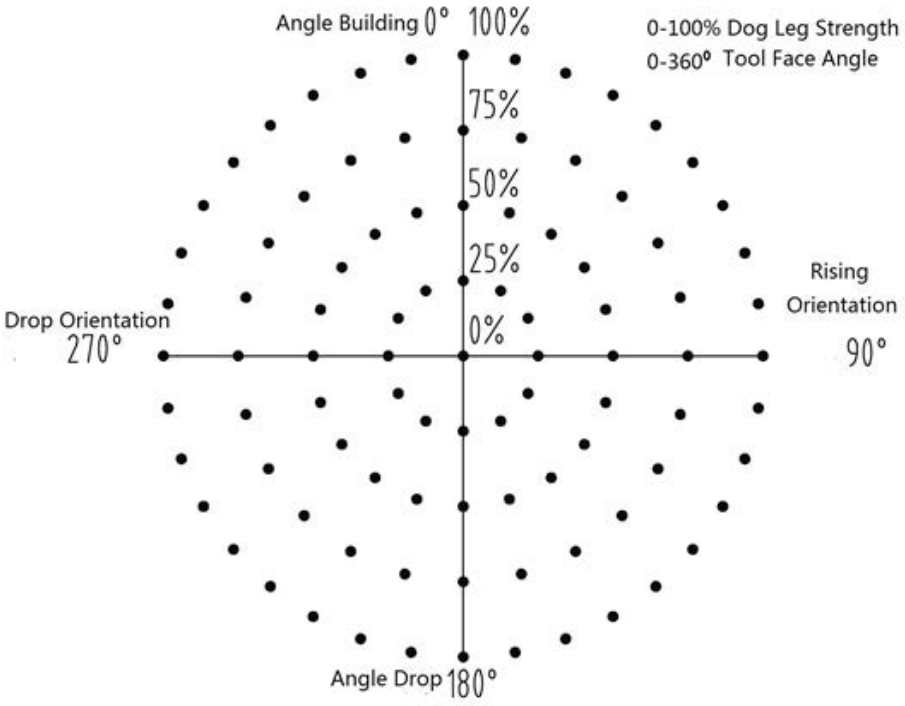

Figure 4. 93 Steerable Points

5. Tool Field Test

This system is test in the Shengli oil field, including ground monitoring subsystem, bidirectional communication subsystem, rotary steerable drilling tool and whole rotary steerable drilling tool, the tools pictures is shown in Fig. (**5**). The parameters as follow: mud pump is 18l/s-22l/s, pump pressure is 4MPa-5Mpa,bit pressure is 120kN-180kN, rotary speed is 40rpm-60rpm,the tested well section is Guantao and Dongying layer. Comparing and analyzing the upload data form MWD and stored data in the tool, the maximum angle building hole rate in this section is 4.2 /30m.

Figure 5. Pictures of Field Test

6. Conclusion

After several years of scientific research, the steerable drilling technology has been developed to satisfy the demand of special oil well such as complicated horizontal well, large displacement well, and three dimensional multi-target direction well.

The control method of rotary steerable drilling system is finished and formed. The ground functional prototype of rotary steerable prototype is developed, and the project prototype is developed and tested successfully on the basis of ground functional test.

The rotary steerable drilling system is initial shaped, including ground monitoring subsystem, bidirectional communication subsystem, rotary steerable drilling tool and so on.

Now, the problem which is exist in the function and field test is rectifying, under the further improving circumstances, the life time of vulnerable part and antijamming capability of control unit can be improved.

Conflict of Interest

The author confirms that this article content has no conflict of interest.

Acknowledgements

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