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Research article

Design of continuous circulation sub for gas drilling and the mechanical analysis on the sub body

Feng Ding[a,b,c], Sun Qiaolei[a,b,c], Xia Chengyu[a,b,c,*], Zhang Hong[a,b,c], Chen Min[a,b,c], Tu Yiliu[c]

[a] *Hubei Cooperative Innovation Center of Unconventional Oil and Gas, Yangtze University, Wuhan, Hubei 430100, China*
[b] *Oil and Gas Drilling and Well Completion Tools Research Center, Yangtze University, Jingzhou, Hubei 434023, China*
[c] *School of Mechanical Engineering, Yangtze University, Jingzhou, Hubei 434023, China*

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Abstract

Gas drilling, as an important part of underbalanced drilling, can increase drilling speed. But in the process of conventional gas drilling, it tends to cause cutting settlement, borehole collapse, sticking and other safety hazards because gas circulation has to be interrupted. Therefore, this paper presents a continuous circulation sub which can be installed and removed easily. With this sub, gas circulation will not be interrupted when drilling tools are connected and removed. This sub is composed of body, main valve, bypass valve and side entry sub. The structure design of its key components (i.e. main and bypass valves) were fulfilled. Based on statics analysis on the sub body, its force situations under extension, torsion and internal pressure were simulated by using the ANSYS finite element analysis software. It is shown that its stress distribution trend is consistent with its elastic–plastic mechanics analysis results. Stress concentrates around the two round holes of the sub body, and the maximum deformation amount is still at the stage of elastic deformation. The analysis results are in line with the elastic–plastic mechanics analysis results, and the requirement of body strength is satisfied. This paper provides a new program to guarantee the drilling safety of extended-reach wells, underbalanced wells and narrow-density window wells.

Keywords: Gas drilling; Continuous circulation sub; Main valve; Bypass valve; Sub body; Structural design; Strength check; Finite element analysis

During conventional gas drilling operations, interruption of gas circulation due to the makeup or breakout of the drill pipe may easily lead to cutting settlement, water production, borehole instability, kicks or other safety hazards [1]. The continuous circulation techniques may be deployed to maintain continuous gas circulation during the makeup of joints. In this way, stable gas circulation and continuous discharging of cuttings can be maintained to ensure uninterrupted drilling operations [2]. With the advancement of continuous circulation techniques and improvement of auxiliary facilities and techniques, continuous circulation techniques for gas drilling have attracted more attentions at home and abroad. These techniques play an increasingly important role in the exploration and development of oil/gas fields [3]. Since there are few researches on their application in gas drilling and there are limitations in their applications, this paper presents a continuous circulation sub for gas drilling through studies. The continuous circulation sub is characterized by simple structure and easy application. It may maintain continuous circulation of gas during drilling. In addition to enhancing drilling efficiency, the newly developed sub can effectively minimize drilling cost and eliminate relevant safety hazards. Accordingly, it lays a reliable foundation for the application of the continuous circulation techniques in gas drilling.

* Corresponding author. School of Mechanical Engineering, Yangtze University, Jingzhou, Hubei 434023, China
E-mail address: qlq1010@126.com (Xia CY).
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1. Introduction of continuous circulation technologies

1.1. Continuous circulation technologies abroad

Continuous circulation techniques were proposed for the first time in 1995 by Maris International Corporation of the United States. The company initialized the plan for fabrication of the prototype and implementation of relevant tests in 2000. The plan gained firm supports from major international oil companies, such as BP, Shell and Total, etc. [4]. In subsequent efforts, BP tested the prototype of the continuous circulation system in 2003 [5], and ENI put these techniques into commercial application in the Agri Oilfield of Italy and the Port Fouad Oilfield of Egypt [6]. Currently, there are two types of continuous circulation technologies, i.e. continuous circulation system (CCS) and continuous circulation valve (CCV) [7]. Generally, continuous circulation systems are highly adaptable to common rigs. These systems are difficult to operate due to their complicated structures. In contrast, continuous circulation valves have advantages of simple structure and easy application. Since conventional makeup and breakout techniques can be deployed, continuous circulation valves have better applicability. However, since these valves will be deployed in the borehole together with drill pipes, severe operational environments may present high requirements for safety and reliability of such valves. Without protection of sealing chambers, these valves are also susceptible to safety accidents under high pressures.

1.2. Continuous circulation technologies in China

Though both technologies involve certain problems, continuous circulation techniques have advantages in maintaining open flow of drilling fluids and stabilizing borehole pressures without suspension of pumping operations. Consequently, continuous circulation techniques can effectively reduce the time required for drilling, minimize drilling costs and eliminate safety incidents induced by circulation interruption due to the makeup and breakout of the drill pipe [8]. For these reasons, continuous circulation techniques have attracted attentions of researchers in multiple companies and research institutes in China. Researches have been conducted on the above-mentioned two continuous circulation technologies by CNPC Drilling Research Institute, CNPC Chuanqing Drilling Engineering Company Limited, China University of Petroleum (Beijing), Yangtze University and other organizations/institutes. There are few researches with regard to continuous circulation techniques for gas drilling. Under such circumstances, the authors made in-depth researches on the continuous circulation sub.

2. Structural design of a continuous circulation sub for gas drilling

2.1. Main features

1) Help guarantee continuous circulation during drilling, eliminate pressure surge induced by the interruption of circulation and maintain stable bottom-hole pressure.
2) Help reduce the time required for removing cuttings in bottom hole assembly, and consequently, can enhance gas drilling efficiency.
3) Effectively reduce the time required for pressure build-up and releasing during the makeup or breakout of the drill pipe.
4) Expand the application scope of the gas drilling techniques in water-producing formations.
5) Promote the efficiencies of gas drilling in deep and super-deep wells and complex formations and reduce the possibility of safety accidents during drilling.
6) Being widely applied to under-balanced wells, narrow-density window wells and pressure-sensitive wells.

Generally, the continuous circulation sub may provide an effective way to drill wells in a safe and efficient manner.

2.2. Components

Major components of the circulation sub for gas drilling include sub body, main valve, bypass valve and side entry sub. During gas drilling, continuous circulation sub can be installed between two joints or between two stand pipes. As an integral part of the drill pipe, the sub may be lowered into the well. Specific number of circulation subs can be determined in accordance with the demands of the circulation system. See Fig. 1 for the structure of the sub.

2.3. Working principles

During normal drilling operations, drilling fluid flows into the lower parts of the drill pipe through the upper parts of the drill pipe and the continuous circulation sub. The continuous circulation sub has identical working conditions and functions with the drill pipe (Fig. 1). During the makeup and breakout of

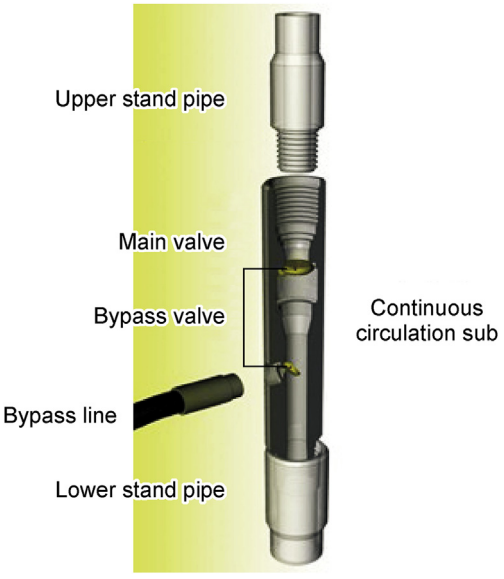

Fig. 1. Structure of the continuous circulation sub.