Simulation, Optimization and Application of Computer Drilling Technology

Gaihai LI, Gang HUANG, Hongjie MA
[1]College of Computer & Information Technology, Northeast Petroleum University, DaQing, 163318, CHINA
[2]Department of The Assets Mangagement, Northeast Petroleum University, DaQing City, 163318, CHINA

Abstract: With the development of petroleum exploration and development, it places greater demands on drilling technology and its safety performance is also facing a severe test. In order to solve these problems, the simulation optimization and application research of computer based on drilling technology is proposed. Compared with the traditional method, this study with practical value and significance can greatly improve the exploration and development technology and reduce cost, which ensures the safety of the workers' lives.

Keywords: Drilling Technology; Petroleum Exploration; Safety; Optimization

1. Introduction

With the development of exploration and development of oil and gas, the target of exploration and development is gradually developing to complex areas and deep-layer. Complicated geological conditions have brought many new technical difficulties to the drilling project, among which the slow speed and long cycle of deep drilling are the main bottleneck factors to limit rapid exploration and development. At the same time, with the gradual rise in oil prices, the global exploration and development investment grow quickly. From 1990 to 2005, the exploration and development investment doubled and the drilling costs accounted for more than 50% of the total investment. Drilling project is characterized by intensive capital and technology and high investment risk. [1-2] Therefore, the drilling level has a very significant impact on petroleum exploration and development benefit. The study result of development trend of the world's drilling technology shows that the real-time optimization and the remote monitoring technology is one of the important directions to speed the drilling technology in the future. Although the speed increase of China's drilling technology has produced certain effect, but with the increasing difficulty of drilling, high monopoly by other countries of advanced technology and equipment, an effective method to further speed up the drilling is lacked. In order to reduce drilling cost and improve the benefit of exploration and development, a new, simple and practical way of drilling parameter optimization and speed which is readily popularized and can explore the potential of the drilling speed.

Well control simulation originated in the 1980 s. "In the 1960s and 1970s, accidents often occurred in oil drilling, which caused great danger to people's life and national property. Therefore, from the beginning of 1980 s, well control technology began to get attention, and the international oil companies began to pay attention to training of well control technology." However, the training in early time is limited to classroom teaching and students couldn't carry out the actual operation training. With the development of electronic technology and computer technology, training simulator of well control technology appeared in the world. Among them, the 1:1 full-size drilling simulator DS-200 from American Simtran Company is most representative. The simulator had equipments such as driller's console, the driller's dashboard, blowout preventer console, throttle control box, throttle manifold and killing well manifold. And it can drill normally, unload drill, produce kick and train the driller's method and engineer's method [3]. In the middle of 1980s, many oil fields jointly introduced about 10 sets of this simulator, but the effect is not satisfactory. This is mainly because all the simulation functions of this simulator is designed with analog electronic circuits, which are of simple model and incomplete functions. In the training, instructors select content by all kinds of switches and knobs on the set control panel. Because of the complex operation process and the expensive maintenance costs, these simulators are almost in a paralyzed state[4-5]. In addition, many mathematical models of drilling engineering are empirical formulas, which have certain applicable scope and limitations, so they cannot be used directly to analyze simulation and guide the practice of China's drilling." Therefore, we must establish a mathematical model for the oil field drilling in China, develop computer simulation technology, and develop the computer simulation training device which is in accordance with the actual drilling system of China.

In order to reduce the occurrence of drilling accidents in the drilling process, the drilling workers should be trained in simulated environment before drilling. In order to simulate the process of drilling and well control, the

display of the corresponding drilling scene and well control picture creating a more realistic drilling environment for the trainees and tracking the operational circumstances of the trainees is needed to achieve the purpose of simulation training. “In order to achieve this goal, the dynamic display of 3D scene in the process of drilling and display of various well control images are required.” On the basis of deep research and understanding of oil drilling and well control technology, this paper uses the advanced computer technology, digital simulation technology and multimedia technology to simulate oil drilling and well control process. On this basis, computer animation technology and its application in the process of drilling and well control simulation is the focus of this study.

2. Computer Drilling Simulation Systems for Petroleum Exploitation

Drilling is the main way to establish channel of oil and gas resources. The object of drilling is various layers which will be pierced in the process of drilling, so the cognition degree of the geological factors of these layers is one of the important factors that affect the success of the drilling. The research shows that the factors affecting the drilling speed, the cost and the quality can be divided into uncontrollable factors and controllable factors. Uncontrollable factors are the objective factors that can only be recognized but cannot be changed, such as the litho logy of drilled layer, buried depths, formation drill ability, grind ability and formation pressure. Controllable factors are the ones that can be controlled and changed by certain means of equipment and technology, such as pump equipment on the ground, bit type, performance of drilling liquid, drilling pressure, rotary speed, pump pressure and displacement. From the point of drilling process, the geological characteristic parameters (litho logy, physical and chemical properties, ground stress, pressure characteristics, drill ability, anisotropy and rock mechanics, etc.) of drilling determined by the geological environment are the basic data for the optimization design and construction control of the drilling How to extract the strata information is one of the key technical problems generally concerned by technical personnel, which is directly related to the quality, safety and benefit of the project. Especially when the complex formation with high temperature and high pressure is drilled, the ability to accurately grasp the characteristics of the formation parameters is directly related to the success of the drilling engineering or reservoir development program. Facing the complex drilling problems, the current research and technology situation is still lack of scientific understanding and efficient technical means, which greatly affect the speed and efficiency of complex drilling, and even cause enormous losses. Therefore, if the oil industry is still organized and directed in the traditional way, huge cost and price must be paid. At the same time, with the complexity of geological conditions, a large amount of data generated in the process of drilling needs to be analyzed and processed to form a regular understanding which can improve and optimize the drilling process technology.

The simulation of drilling system is at least 30 years behind simulation in other scientific fields, and its simulation in China is at least 10 years behind other counties. On the basis of long-term exploration and scientific implementation of drilling, AMOCO and other oil companies in America in1980 proposed the concrete scheme of developing the drilling simulation research and drilling engineering simulator, and then realized super simulation of the drilling process in 1983. After the introduction of drilling engineering in the early 1980s, flexible and various dynamic simulation experiments of the drilling process can be carried out on the computer. The results of the drilling simulation experiment on the computer provide scientific basis to reduce the cost and improve the speed. In addition to the drilling system analysis, design of drilling system and theoretical verification, the drilling system simulation is more important for personnel training. "In the course of drilling, complex accidents underground often occur, and most of these accidents are related to operator error." Therefore, from the aspects of economy, efficiency and safety, training simulator can be used to train operation and management personnel. It can reproduce a real system to be operated and managed by trained personnel.

In China, the research of the simulation training device of drilling well control started in the middle of 1990s, which is mainly transformed from drilling simulator imported from other countries in 1990s, set up with shell of original simulator, equipped with circuit driver and programmed with corresponding software of drilling and well control. There are many examples. The shell of SWPI--1 training simulator of drilling engineering developed by the Petroleum Engineering Department of Southwest Petroleum Institute [9] is from original Digitran simulator. Based on the Ds-450 drilling and production simulator of original simtran, Drilling Research Institute of Daqing Petroleum Administration Bureau developed Ds-100 drilling simulator. And University of Petroleum transformed the DS-200 drilling simulator of original Simtran for China Offshore Oil Nanhai West Corporation and Bohai Oilfield. The common feature of these systems is that the structure still follows the pattern of other countries, making no use of the latest computer technology and information technology. As time goes by, these transformed simulators are old, falling behind the new development of drilling technology. The liquid-controlled box of miniature throttle control is shown in Figure 1.

In short, the drilling simulation is developing in the direction of diversification and miniaturization, and the

simulation content of the drilling process involves all aspects of the drilling process. In the future, drilling simulation system will take the advantages of information technology. Especially with the development of virtual reality technology and human-machine interface technology, the drilling simulation system will be more realistic and immersive. The training function will be more abundant, and the system will be more perfect.

Figure 1. The liquid-controlled box of miniature throttle control

3. Functions of Well Control Equipment

Well control equipment is a set of special equipment, instrumentation and tools which can prevent blowout, and carry out pressure control technology for oil and gas wells after blowout. Well control equipment has the following functions:

(1) Rapid control of the blowout, overflow. After the well surge and blowout, quickly shut the well, carry out the well killing operation and make new pressure control for oil and gas well.

(2) Find the overflow in time. The oil and gas well should be monitored to find out the warning signs and take control measures as soon as possible.

(3) Preventing blowout. Maintain the pressure of mud column in wellbore more than that of formation pressure to prevent the formation of blowout condition.

(4) Dealing with complex situations. Carry out fire fighting and rescue operations when the oil and gas well is out of control.

The general situation of common well control equipment is shown in Figure 2.

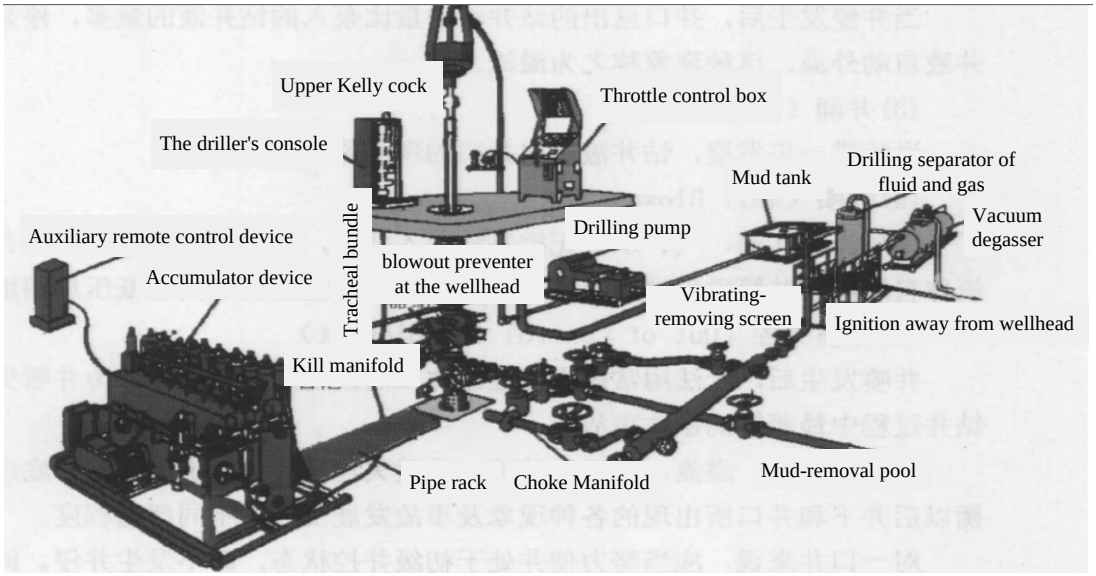

Figure 2. Schematic diagram of well control equipment

4. Computer Simulation and Optimization of Drilling Process

In the process of drilling, the drill can be set to drill from a certain depth of the well. Operator should first open the pump to circulate mud, and then open the rotary table to drill. And in this process, brake should be controlled to increase the drilling pressure. As the drill breaks the rock in the bottom of the well and the depth of well increases, drilling should be stopped to make a connection when the depth reaches to a stand(about gm), and then restart the drilling. Repeat this process until the drilling reaches to the designed layer.

In the drilling process, the devices need to operated are pump, turntable and brake. The parameters need to be shown are outlet pressure of the pump(standpipe pressure), pump speed, rotary speed, rotary torque, cumulative pump punch, casing pressure, drilling pressure, hanging weight, flow coefficient of outlet, drilling speed of machines, depth of the well and so on. The screen

need to be displayed is the progress of rotary and connection. The sound need to be played is that of pump sound, turntable and winch.

4.1. The Cycle System of Drilling

In the drilling process, the drilling fluid (mud) is very important. It can carry suspended debris, stabilize shaft, and cool and flush bit. And more important is that the mud density can be adjusted in a large range, so as to establish a balanced pressure with the formation of liquid column pressure, to prevent the spray, leakage, collapse and other complex conditions. More than that, mud density can be adjusted in a large range, establishing a liquid column pressure which can balance the formation pressure to prevent complex situation in the well such as blowout, collapse, block and leak. Drilling fluid sometimes is compared to the flood of drilling. The drilling operation cannot continue when the mud stop cycling. The cycle system of mud is shown in Figure 3.

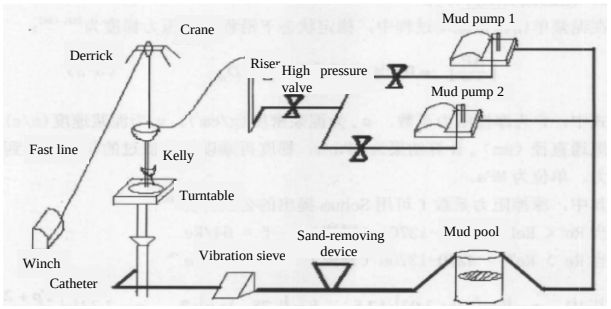

Figure 3. The cycle system of drilling

The mud in the mud pool goes through mud pump, hoses and taps into the drill pipe, through drill collar and drills to annulus, though annulus back to ground, and at last through vibration back to mud pool. Under normal circumstances, the amount of mud in the well is almost equal to that back to ground, so the height of the liquid the mud tank is almost unchanged.

4.2. Simulation Animation of Computer Drilling Pressure Control

Because both kill manifold and choke manifold are composed with components such as valve, four links and pipelines. Its distribution and work process is shown in Figure 4-5. Manifold is completed in this process.

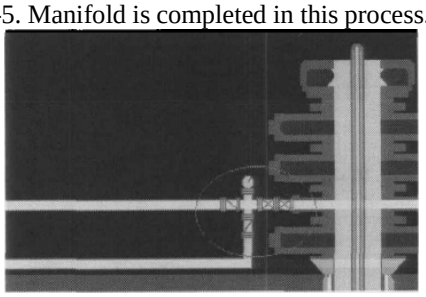

Figure 4. Kill manifold diagram

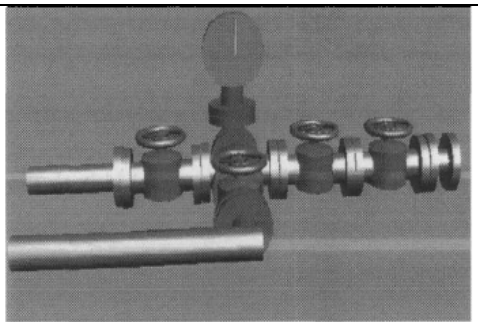

Figure 5. Three dimensional animation stereogram of kill manifold

Blowout prevention simulation of well control system

The blowout prevention unit is composed of a combination of four wellhead blowout which are in the turn of annular blowout preventer, lock beat Kelly packer(upper lock beat), lock beat oil-well packing, lock beat Kelly packer(under lock beat). The upper lock beat and under lock beat are of the same structure, so they can be replaced with the same lock beat Kelly packer. First set a Kelly packer in the view, latter copy another Kelly packer with a command of Shift+removal. Then select the merge command in the file command line, merging into a full-packed blowout prevention on the lock beat and put it in the above turn. Merge command can merge annular preventer and put it topside. The four parts are connected by four links, as shown in Figure 6 and Figure 7.

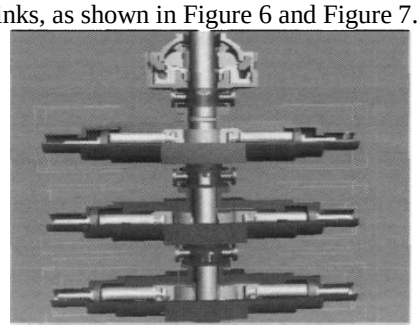

Figure 6. Drilling blowout prevention process

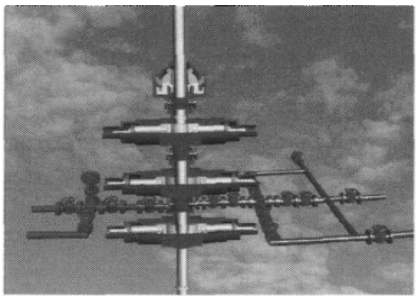

Figure 7. Composite diagram of manifold bar

Merge the prepared choke manifolds and kill manifolds through merge command and connect the right sides of choke manifolds and four lines between under lock beat and full-packed lock beat. Then connect the left sides of

kill manifolds and four lines between lock beat and full-packed lock beat and put the bar on the position as shown in Figure 7.

5. Conclusion

Improving drilling speed and reducing drilling cost is the goal that the drilling engineering has been pursuing. This thesis is aimed at the safety performance defect in the oil production In the course the drilling of deep well, in order to ensure the safe and effective exploitation, the simulation and optimization of the drilling process is carried out by computer simulation. The results show that the study is forward-looking and more scientific, reasonable, effective, practical and meaningful than the traditional drilling technology in personnel and machines.

Acknowledgement

This work was supported in part by a grant from the Research Foundation of Education Bureau of Heilongjiang Province, China (Grant No.12541087)

References

[1] Rongchao Cheng, Haige Wang, Fucheng Zhang, Ge,Zhixue Chen. Optimized Cluster Directional Drilling Technology Achieves Great Success in the Low-Perraeafeility Gas Field in Ordos Basin, West China. SPE 135583, IA0C/SPE Asia Pacific Drilling Technology Conference and Exhibition in Vietnam held in Ho Chi Minh, 1-3 November 2015.

[2] Miguel Armenia. Idetifying Inefficient Drilling Conditions Using Drilling-Specific Energy, SPE 116667,2014.

[3] Teale R. The Concept of Specific Energy in Rock Drilling[J]. International J. Rock MEch.Mining Sci, 2013, Vol 2’ pp 57-73.

[4] Galle E.M. and Woods A.B. Best Constant Weight and Rotory Speed for Rotary Rock Bits. Drill. And Prod. Prac., API 2013, pp 48-73.

[5] Bourgoyne A.T.Jr., Young F.S. A Multiple Regression Approach to Optimal Drilling and Abnormal Pressure Detection. SPE 4238,2014.