Current situation and key technology analysis of downhole blow-out preventer

Guo Wang\textsuperscript{1,4}, Zhihua Wang\textsuperscript{2}, Xinming Niu\textsuperscript{1}, Song Deng\textsuperscript{3}, Yali Liu\textsuperscript{3}, Hongkang Fan\textsuperscript{1}, Yanfeng Hu\textsuperscript{1} and Dongju Ma\textsuperscript{1}

\textsuperscript{1}SINOPEC Research Institute of Petroleum Engineering, Beijing 100101, China
\textsuperscript{2}Beijing 101 Middle School, Beijing 100089, China
\textsuperscript{3}Changzhou University, Changzhou 231000, China
\textsuperscript{4}E-mail: wangguodri@126.com

Abstract. It is difficult to meet the safety requirements of the existing well control technology with oil & gas exploration and development to deep complex formation. Therefore, it is important to carry out the analysis and research work of new blow out preventers. The downhole blowout preventer can provide a sealing well near the drill bit, which could eliminate the overflow in the bud. Thus, the downhole blowout preventer will be an additional protect barrier for the existing well control procedure. This paper introduces domestic and foreign downhole BOP situation, and analysis the structure and technical features of these downhole BOPs. The author discusses key technology of downhole BOP on the basis of analyzing the defect of the existing technology. It could be helpful for the research of downhole blowout preventer.

1. Introduction
In the process of oil and gas exploration and development, once the formation fluids (oil, gas, water) are out of control, blowouts will occur, causing damage to drilling equipment, endangering the safety of drilling personnel, damaging oil and gas resources, and polluting the natural environment, leading to severe consequences such as the retirement of oil and gas wells. It has brought serious negative social impacts to the oil industry; therefore, well control technology plays an important role in oil drilling engineering, especially for well control technology of natural gas reservoir drilling. With the rapid growth of the world’s demand for clean natural gas, natural gas exploration and development efforts have been significantly increased, and a number of high-pressure and high-production gas fields have been discovered successively, which has put forward new requirements for well control technology. To meet the needs of constructing high-production gas wells, horizontal wells, branch wells, and underbalance / pressure control. The drilling technology is gradually promoted and applied, which makes the existing well control equipment and technology unable to meet the requirements of the new drilling technology.

When there are abnormal conditions such as well surges or blowouts, downhole blowout preventers can control the source of overflow, reduce the difficulty and risk of well control, and provide time and safety guarantee for subsequent operations by shutting down wells in the early stage. The safe drilling of high-sulfur wells is of great significance. At present, this technical study is still in the theoretical analysis and technical.
2. Status of blowout preventer technology in foreign countries
From the 1980s to 21st, three types of downhole blowout preventers were proposed abroad: plug valve
downhole preventers, plug-in valve type downhole preventers, and poppet type downhole preventers.

2.1. Downhole blowout preventer for plug valve
The U.S. patent in the 1980s (US4712613) proposed a plug valve underground blowout preventer [1]
(Figure 1), which has only the principle scheme and no prototype. The basic working principle of its
design scheme is to use mud pulse remote sensing technology on the ground control the downhole tool.
The tool is equipped with a control box for receiving and processing signals. The downhole control
box receives the signal decoding and opens the solenoid valve, and then the drilling fluid drives the
piston to rotate the plug valve 90° to close the drill pipe channel. The hydraulic pressure seals the
barrel expansion seat, and the outer ring of the drill string is sealed. After the barrel seat is sealed, a
signal is transmitted to open the floating valve to circulate the drilling fluid. After the heavy mud
balances the upper and lower pressure difference of the blowout preventer, the ground retransmits the
signal to open the solenoid valve, and the pressure relief of the fluid relieves the drilling inside the
closure cavity.

Figure 1. Schematic diagram of the underground blowout preventer of the plug valve.
Analysis of technical characteristics: using mud pulses to transmit control signals, using solenoid
valves to control the opening and closing of flow channels, drilling fluid as a power source, plug
valves to seal drill strings, and expandable packers to seal the annulus. The disadvantage is that the
plugs are unsealed after unsealing. The valve cannot be opened and normal circulation cannot be
established.

2.2. Plug-in valve underground blowout preventer
The U.S. patent in the 1980s (US4367794) proposed a plug-in valve underground blowout preventer
[2] (Figure 2), which has only the principle scheme and no prototype. The basic working principle of
its design scheme is: After receiving the signal to activate the motor, the control valve (Figure 2) is
driven downward by the screw drive to the position shown in Figure 2(b), and the position of the insert
valve is also changed from the position in Figure 2(a) to Figure 2(b), at this time, the drilling fluid can
expand the barrel through the liquid inlet-channel-expansion hole-channel. When unsealing, the same
An acoustic signal is given. After the control sleeve is returned, the barrel. The internally sealed liquid will be discharged from the channel-the drainage pore-the channel, thereby releasing the pressure and unsealing. The solution after the unsealing failure is: by inserting a small plunger into the drill string, the top of the blowout preventer is cut off. The small sliding sleeve pin moves the small sliding sleeve downward, so that the backup unsealing channel of the packer is opened, and the underground blowout preventer is unsealed.

![Schematic diagram of the underground blowout preventer of the plug-in valve](image)

(a) Drilling status  (b) Isolation status  (c) Solutions in case of failure

**Figure 2.** Schematic diagram of the underground blowout preventer of the plug-in valve.

Analysis of technical characteristics: drill pipe acoustic wave transmission control signal, electric screw mechanism as power source, plug-in packer drill string, expandable packer packer to seal the annulus, and a failure solution backup design is designed. The disadvantages are: There is no circulation channel on the top, the flapper valve cannot withstand high pressure, and the packer and the annulus remain unobstructed.

2.3. **Poppet blowout preventer**

The Norwegian University of Science and Technology proposed a pop-up valve downhole preventer [3-5] (Figure 3) between the 1990s and 2001, given the principle scheme, developed a test prototype, and conducted tests on a simulated well. No new progress has been seen since. The implementation principle of the solution is to transmit control signals through mud pulses. After the control structure receives the control signals, the poppet valve moves downwards under the driving of the electromechanical structure, which seals the inner channel of the drill string and expands at the same time. The liquid inlet and the circulation hole of the cartridge are opened at the same time, and the expansion cartridge seal ring is maintained by pressing inside the drill string, and the fluid circulation above the isolation position is realized.

Analysis of technical characteristics: mud pulse transmission control signal, electromechanical control mechanism as power source, poppet to isolate drill string, expandable packer to isolate the annulus. The disadvantage is that the packer cannot be locked.
3. Status of domestic underground blowout preventer technology

3.1. Poppet valve type inside and outside integrated blowout preventer

Southwest Petroleum University did some related research and initial research work [6-7], analyzed and demonstrated foreign blowout preventers, and applied for two patents based on lift valve downhole blowout preventers: 200910312467 lift valve type downhole internal and external integrated Blowout preventer, 201020037531 lift valve type underground and internal integrated blowout preventer. Among them, patent 200910312467 is an invention patent and patent 201020037531 is a utility model patent. It is an improvement of a foreign lift valve type underground blowout preventer. As shown in Figure 4.

Figure 4. Simplified structure of poppet valve type internal and external integrated blowout preventer.

The basic working principle is: in the case of mud circulation, the ground control system sends mud pulse signals through the mud circulating in the drill pipe to achieve control. After the sensor of the downhole tool receives the signal decoding, it first pushes the poppet valve to drill the pipe. At the same time, the inner channel is closed, and the packer is expanded by mud pressure to close the drill string annulus, thereby achieving the effect of simultaneous sealing of the inside and outside of the drill pipe. At this time, a signal is sent to the downhole tool to open the circulation port on the drill pipe. To carry out mud circulation. When unsealing, first open the inner channel of the drill pipe, and then unsealing the annulus.

Analysis of technical characteristics: mud pulse transmission control signal, electromechanical control mechanism as power source, poppet to seal the drill string, expandable packer to seal the annulus. The disadvantage is that after the successful isolation, the mud cannot be circulated and the mud pulse cannot be transmitted. Unable to open loop hole.
3.2. Pulse valve type underground blowout preventer
SINOPEC Petroleum Engineering Technology Research Institute has proposed an improved pulse valve downhole preventer (2012201947594) design scheme [8] (Figure 5) in response to the problems existing in the poppet downhole preventer. The dual-execution structure method solves the problem of locking and unlocking the BOP in the underground. According to the existing technical conditions of Sinopec Petroleum Engineering Technology Research Institute, the scheme of the mechanism uses electromagnetic wave transmission / mud pulse transmission control signals and electro-hydraulic structure as the execution. Structural scheme.

![Figure 5. Schematic structure of pulse valve underground blowout preventer.](image)

Its working principle is: after the overflow is found, through the command given by the ground, the upward poppet valve moves down to open the expandable cartridge fluid inlet channel, seals the lower end of the drill string, and realizes annulus isolation by pressing inside the drill string; within the set time interval, the upper poppet valve moves upwards to achieve annulus seat seal lock. The lower poppet valve must seal the drill string downwards, open the circulation hole, and carry out mud circulation. The unsealing action is similar to the seat seal action, and will not be described again.

Analysis of technical characteristics: mud pulse / electromagnetic wave transmission control signal, electro-hydraulic mechanism as power source, poppet to isolate drill string, inflatable packer to isolate annulus. The disadvantage is that the structure is too complicated and the cost is high.

3.3. Compression expansion slip sleeve type underground blowout preventer
Through technical research, Sinopec Petroleum Engineering Research Institute has proposed a fully mechanical downhole preventer (2012201932917) design scheme [9], as shown in Figure 6.

![Figure 6. Blowout preventer.](image)

Its working principle is: after the overflow is found, through mechanical operations such as ground pitching, the pressure moves the slide sleeve down, the pressure hole is opened, and the upper and lower cartridges are continuously compressed to achieve a layered packing annulus; continue to press, and open on the upper part of the packing. The circulation channel is established, and when the liquid column pressure is established, the packer is opened and a full-well liquid column cycle is established. Finally, the safety of the full-well liquid column pressure and formation pressure is reached, and safe drilling operations are continued.

Analysis of technical characteristics: full mechanical structure, sliding sleeve control of each channel switch, drilling fluid as the power source, double-layer compression and expansion rubber cylinders to isolate the large annulus. The disadvantage is that the pitching time is longer and the number of sliding sleeve stages is more.

4. Key technology analysis of blowout preventer
In order to realize the function of downhole preventer, there are some key technologies that need to be mastered, including signal transmission, power mechanism, downhole isolation, downhole circulation,
etc. By analyzing and discussing these key technologies, it provides solutions for the research and development of downhole preventer technology.

4.1. Signal transmission technology

(1) Ball pressure and ball pressure transmission control signals. The characteristics of this signal transmission method are easy to implement, simple and reliable, and the disadvantage is that the pitching time [10] is too long, which can not meet the needs of well control operations to quickly shut down the well. In the future, in the research of underground blowout preventer technology, the pitching method will be used as a solution in the event of failure.

(2) Invest in the RFID tag to transmit the control signal [11]. At present, in the oil drilling downhole tools, the RFID tag is often used instead of the pitching method. The RFID tag is very small, and there is no need to consider its subsequent processing. The disadvantage is that it is downhole The mechanism can only be realized by an electric mechanism, and the structure is complex, and it cannot meet the needs of fast shut-in in well control operations. It can be used as a solution to the failure of electric underground blowout preventers in the future research of underground blowout preventer technology.

(3) Drilling fluid pulse transmission control signal [12]. The drilling fluid pulse method has no special restrictions and requirements on the drilling process, and is convenient to combine with the mwd of the currently widely used drilling fluid pulse method to transmit information, thereby forming a two-way surface and downhole. Closed-loop control system for communication. Therefore, the drilling fluid pulse transmission method is the best for signal transmission from the ground to the underground. Disadvantages: it cannot be used when drilling with gas or gas in the drilling fluid.

(4) Electromagnetic wave transmission control signal [13]. The electromagnetic wave is used to transmit the control signal to the downhole blowout preventer. Its characteristics can transmit information at a high rate, and it does not have high requirements for the quality of drilling fluid, the uneven flow of the mud pump, and the pressure. The information sent is not affected by the inflation of drilling fluid. The disadvantage is that the signal is seriously attenuated in the rock, and it is susceptible to interference from drilling equipment and low-resistance rocks.

(5) Drill string acoustic wave transmission control signal [14]. The advantage of this transmission method is the simple structure and low cost. The disadvantage is that the amount of information transmitted by the acoustic wave is very small. At the same time, the change in the diameter of the drill rod and joint will make the acoustic wave generates reflections and interference, which reduces the strength of the signal.

4.2. Power mechanism [15]

(1) Control of hydraulic pressure. The drilling fluid is used as hydraulic power, and the movement of the piston of the hydraulic cylinder is achieved by means of pressure.

(2) Electro-mechanical control. The control mechanism starts the electronic motor to provide rotary motion, the roller realizes the rotary power as the axial movement, and the roller drives the piston to perform the axial movement, thereby providing the power for downhole isolation and unsealing. Features: Complex structure, it is difficult and the control accuracy is high.

(3) Electro-hydraulic control. In the control mechanism, the oil circuit switch of the hydraulic cylinder is controlled by the controller, and the hydraulic pump is controlled by the electric motor to the piston pump hydraulic oil.: Complex structure, great difficulty and high control accuracy.

4.3. Packing technology [16]

(1) Expansion type cartridge. Expansion type cartridge is designed to expand the diameter of the cartridge by a certain internal pressure to achieve the purpose of sealing the annular space of oil and casing. This sealing feature can seal the naked eye The irregular wellbore has a large space between the packing rings. The disadvantage is that the ability to restore the original shape after unsealing is poor.
(2) Compression type rubber cylinder. The compression rubber cylinder generates lateral deformation to achieve the purpose of sealing the annular space of oil and casing. This type of rubber cylinder has the characteristics of fast setting speed, simple structure, and the disadvantage is that it seals the large annular space. Isolation capacity is weak.

(3) Metal sealant cylinder [17]. Expandable metal seal packs use expanded metal elements instead of elastic rubber parts, which can achieve high-pressure sealing on the wall of the pipe, making it possible to seal under severe conditions such as high temperature and high pressure.

4.4. Downhole circulation technology

Above the isolation position, a drilling fluid circulation sub-section needs to be designed. Before the downhole preventer is closed, the circulation sub-section is closed, which does not affect normal drilling operations. After the well is sealed downhole, the circulation sub-section is opened to achieve isolation. The overflow cycle above the position discharges the well killing operation; after the killing is completed, the circulation sub-section returns to the closed state, and the unsealing of the blowout preventer of the downhole does not affect the continued drilling operation. The existing reference technology is a bypass valve, One-time loop short sections, etc.

5. Conclusions

(1) The downhole blowout preventer can provide well closure and killing operations near the drill bit position in the event of a spill or loss, eliminating the overflow in the bud state, and providing an additional protective barrier for the existing well control technology.

(2) As a new type of underground blowout preventer, the underground blowout preventer has a lot of inadequate technology, and it needs a lot of technical research and experimental research to promote its practicality.

(3) Through the investigation and analysis of the current status of domestic BOPs at home and abroad and key technical demonstrations, it can provide thinking and help for the subsequent research and development of BOP tools.

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