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Structural Optimization Design of Modular Double Drill Pipe

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Abstract: Aiming at many drilling blocks with pore pressure coefficient □1.05 in China (shale gas surface layers in Tarim Basin and Sichuan Basin, depletion of reservoirs and gas reservoirs in developed oil and gas fields in China), the narrow window of drilling fluid density in such blocks will directly lead to wellbore instability, difficulty in carrying rock debris and serious formation losses. In order to control the fluctuation range of formation pressure, on the basis of conventional managed pressure drilling technology, gas lift positive circulation drilling technology and Marine double gradient drilling technology are integrated to form gas lift positive circulation drilling technology. The double drill pipe is one of the key equipment to realize the above drilling technology. Under this background, a double drill pipe for gas lift positive circulation drilling technology is designed. In this paper, the key equipment of gas lift positive circulation drilling technology is analyzed and its structure is optimized.

Keywords: Gas lift positive circulation drilling technology, Double drill pipe, Technical analysis, Structural optimization, Application Trends.

1. Introduction

Gas lift positive circulation drilling technology is a method of gas lift drilling by using double drill pipe and other auxiliary drilling equipment. The annular space formed by the inner and outer pipe of the double drill pipe provides another channel for fluid flow, which can be used either as a drilling fluid or air injection channel or as a central pipe for drilling fluid or air injection channel. It can also be used in reverse circulation drilling, where drilling fluid is circulated to the surface through the inner pipe of the double drill pipe. Therefore, the double-pipe drilling method can be applied to a variety of drilling environments, and both positive circulation and reverse circulation can be carried out [1-2].

In view of the research on double-pipe drilling, domestic and foreign oil companies and scholars have carried out research and practice on a certain type of drilling method and supporting equipment. In 2002, K2 Energy, a Canadian company, successfully applied the double-wall drillpipe reverse circulation drilling technique to two experimental Wells in the underpressure bow Island formation in northern Montana, and obtained hydrocarbon displays [3]. Canadian company PressSol [4] patented a double-walled rod drilling system in 2003 and applied this technology to oil and gas drilling. Since the drilling fluid carrying cuttings is returned from the inner pipe of the drill pipe, the drilling fluid can avoid damage to the oil and gas formation. Reel Well drilling technology [5-6] was developed in 2004. Statoil and the Scientific Research Council of Norway carried out theoretical research on the technology, research and testing of supporting equipment, and started field feasibility research on the technology in 2005. Drilling a shallow horizontal well with two-channel drill pipe offshore Norway demonstrated the ability of the RDM method to achieve a constant downhole pressure gradient [7-8]. In 2006, Liaohe Petroleum Exploration Bureau in China applied for a patent -- double-wall drilling pipe low-pressure drilling technology [9]. This drilling method uses air hammer or drill bit at the lower end of concentric double-wall drilling string to drill, and has been applied in many domestic oil fields. Hebei Shitan Machinery Manufacturing Co., LTD. [10] developed and designed a gas-lift reverse circulation double-wall drill pipe in 2013, which was applied to geothermal Wells, shale gas Wells and coalbed methane Wells. In 2015, Li Yuanling et al. [11] studied the gas reverse circulation drilling technology of double-wall drill pipe and successfully conducted tests in oil and gas drilling projects. In 2019, Kang Bo et al. from China University of Petroleum proposed a new leak-through drilling technology with gas lift and efficient pressure relief [12-13]. At present, there are many technical problems that need to be solved urgently in domestic double-deck drill pipe used in positive circulation drilling. Therefore, aiming at the problems of poor compatibility and poor applicability of existing double-wall drilling tools, a gas-lift positive circulation central pipe gas-injection double-layer drill pipe with simple structure, reliable radial positioning, low manufacturing cost and excellent performance was developed to provide technical support for the stratum with a narrow window between pore pressure and rupture pressure.

2. Technical Analysis

2.1. Gas lift positive circulation drilling technology

The gas-lift positive circulation drilling technology uses the double drill pipe. While the mud pump pumps the drilling fluid into the annulus between the inner pipe and the outer pipe of the double drill pipe, the air compressor injects compressed gas from the inner pipe of the double drill pipe. Or the air compressor injects compressed gas from the annulus between the inner and outer pipe of the double drill pipe while the mud pump pumps the drilling fluid into the inner pipe. When the drilling fluid flows through the bit and returns to a certain depth of the leakage zone in the annulus hole, it mixes with the compressed air injected by the gas box to the leakage zone. The two-phase flow density of the gas and drilling fluid is less than the density of the drilling fluid, resulting in an unstable "U" shaped tube effect in the wellbore, so as to reduce the pressure of the liquid column at the bottom of the hole, and finally realize the positive circulation drilling process of gas lift, as shown in Fig.1. This technology was previously used in offshore drilling. Due to the narrow window between formation pore pressure and fracture pressure, gas-lift positive circulation drilling can greatly increase the density range of drilling fluid and ensure drilling safety. This technology can be transplanted to the land environment, as well as the numerous low pressure reservoirs and pressure depletion formations on land. Advantages of the process:

(1) Reduce the damage to the oil and gas reservoir, effectively protect the oil and gas reservoir, and improve the production of oil and gas Wells.

(2) There is always a continuous liquid flow from wellhead to bottom hole, so the performance of conventional downhole dynamic drilling tools and MWD instruments is not affected, and normal well trajectory control can be carried out [9].

(3) It is a way to control pressure drilling, which is suitable for drilling strata with narrow pore pressure and rupture pressure window, and increases the drilling depth.

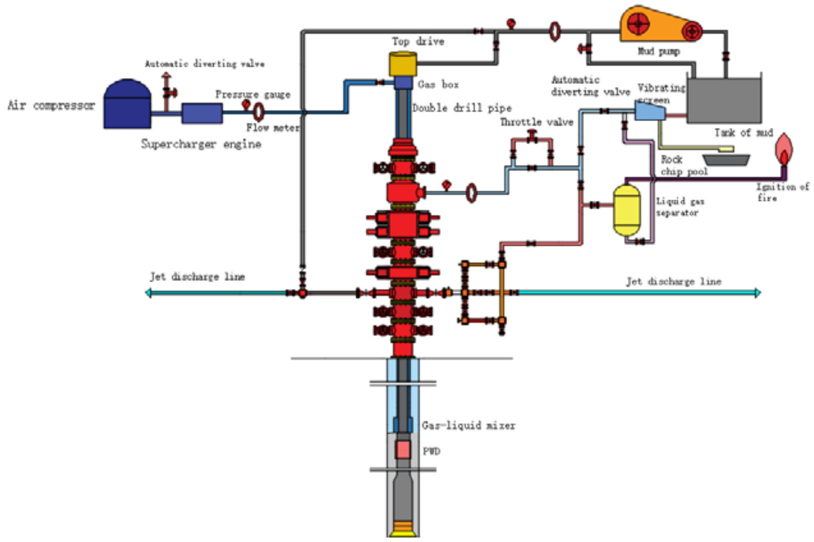


Figure 1. Schematic diagram of gas lift positive circulation drilling process.

2.2. Design requirements of double drill pipe

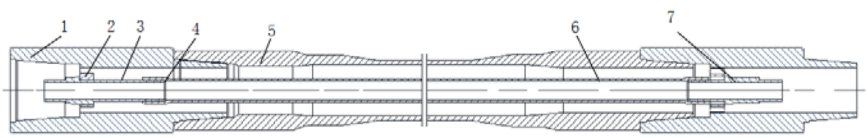
In order to meet the technological requirements, a modular assembly of double drill pipe is proposed and designed. Unlike conventional drill pipe, the double drill pipe not only serves as a circulation channel for drilling fluid, but also provides a downflow channel for compressed gas. The double drill pipe structure is the key to the smooth progress of gas lift positive circulation drilling. According to the relevant technological requirements of gas lift positive circulation drilling, the design mainly follows the following principles:

(1) It is necessary to facilitate the loading and unloading of drill pipe. The size and specifications of drill pipe should meet the standards of oil and gas industry. While ensuring the reliability of the process, existing drill pipe should be used as a component of double drill pipe as far as possible to facilitate the design and manufacturing and save costs.

(2) The material selection of the outer pipe and joint of the double drill pipe should meet the standards of the oil and gas industry, and the inner pipe should be made of high-strength seamless steel pipe to ensure that the strength and toughness of the drill pipe meet the strength requirements of drilling construction;

(3) Good sealing performance of drill pipe to ensure the sealing of inner pipe and outer pipe annulus and inner pipe passage; At the same time, the drill pipe needs to be centered to prevent the inner pipe from wearing out, bending out of shape, or even breaking.

Based on the above design principles, the double drill pipe is composed of outer pipe, inner pipe, drill pipe joint, positioning ring, inner pipe nipple and sealing parts. The outer pipe of the drill pipe is connected by thread, the inner end of the inner pipe nipple is connected with the inner pipe by pipe thread, and the other end of the inner pipe nipple is inserted into the female buckle of the inner pipe nipple of the next double drill pipe, which is a non-rigid connection structure. The outer pipe of the double drill pipe is the existing drill pipe conforming to the industry standard. The drill pipe connector is a short joint connected with API standard threads, and the inner pipe is a high strength seamless steel pipe. The schematic diagram of modular double-layer drill pipe structure is shown in Fig.2. The outer diameter of drill pipe should be 127mm, and the thickness of outer pipe body is 9.19mm. The basic dimensions and main parameters are shown in Table 1.



1. Drill pipe joint 2. Positioning ring 3. Inner pipe sub of upper joint 4. Sealing ring
5. Ordinary drill pipe 6. Inner pipe body 7. Lower connector inner pipe sub

Figure 2. Schematic diagram of modular double drill pipe overall structure.

Table 1. Technical parameters of 127 mm modular double drill pipe.

category	Outer diameter /mm	inner diameter/mm	Wall thickness/mm	The length of the/mm	Material
Outer pipe body	127	108.62	9.19	9500	26CrMo
Outer rod male (female) connector	190.5	95.25	47.6	405 (381.5)	42CrMo
Drill pipe joint	190.5	95.25	47.6	464.3	42CrMo
Inner tube body	-	-	9	9614	ZT380
Inside pipe joint	-	-	9	76	42CrMo
Upper (lower) inner pipe sub	-	-	9	264.3(200)	42CrMo

In order to realize the inner pipe coaxial positioning, a sinking step is arranged on the drill pipe joint of the double drill pipe, and the positioning ring is installed on the step. The positioning ring is the key component of the inner pipe axial and circumnavigational positioning. Its role is to place the inner pipe joint of the upper (lower) joint in the positioning ring, the convex block of the positioning ring is placed on the drill pipe joint, and the inner pipe joint of the inner end is connected with the inner pipe body thread. To prevent the inner tube from axial channeling, the outer end joint has a number of groups of C-shaped combined sealing rings to ensure its sealing performance.

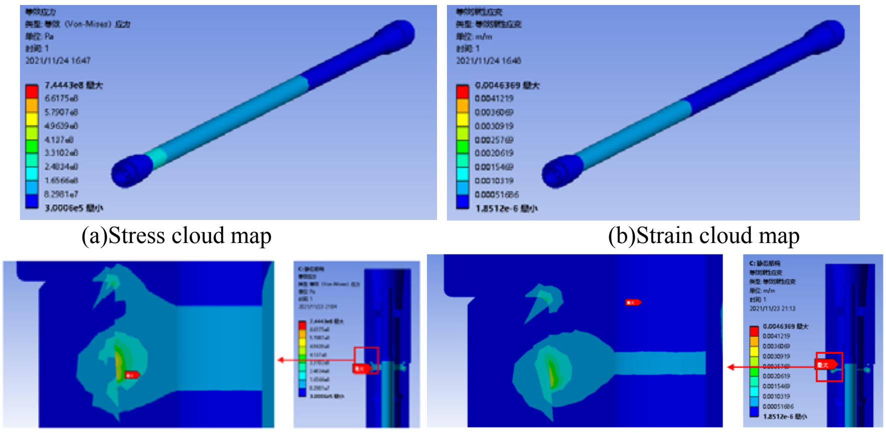
The drill pipe and drill pipe joint are made of API SPEC 5DP Drill Pipe Specification S135 steel material, which has high strength and toughness, good hardenability, no obvious tempering brittleness, high fatigue limit and impact resistance after tempering treatment, and good impact toughness at low temperature. The inner pipe is ZT380 steel class pipe body in GB/T 16950-2014 "Geological Core Drilling Tool" standard.

3. Modular Double Drill Pipe Structure Optimization Analysis

The double drill pipe is an important part of the drill string assembly. It is located in the upper part of the drill string and the lower part of the top drive. The double drill pipe is not only the channel of drilling fluid, but also the channel of air injection. It is subjected to the complex stress of tensile force, torque, bending moment and vibration load. The double drill pipe is an intermediate joint structure connecting the top drive and the drill bit. Since the bottom of the drill pipe is connected with the drill bit, the load during the working process of the drill bit will be transferred to the drill pipe through the connection between the drill pipe and the drill bit, which requires that the connection between the drill pipe and the drill bit must be able to withstand huge internal and external pressure, distortion, bending and vibration. Therefore, the finite element analysis of the double drill pipe is required. Check whether its strength and stiffness meet the design requirements, in order to avoid the phenomenon of stuck and dedrilling in the drilling process.

3.1. Statics analysis of modular double drill pipe

The drill pipe is subjected to a combination of pressure, torque, and internal and external pressure during drilling. Three-dimensional modeling software UG was used to establish the three-dimensional model of double-layer drill pipe, and the model was imported to Workbench for analysis. When adding constraints, the actual force of the double drill pipe is considered to define the boundary conditions, and the applicable range of the gas lift positive circulation drilling process is considered only when the drill pipe is run within 1500m. The fixed constraints are applied to the conical surface where the drill pipe joint (internal thread) is located and the external thread surface of the inner pipe nipple of the upper joint. The pressure load of 30kN is applied to the conical surface where the drill pipe joint (external thread) is located and the external thread surface of the inner pipe sub of the lower joint. The external pressure of 15Mpa is applied to the outer surface of the double drill pipe, and the internal pressure of 20Mpa is applied to the outer surface of the inner pipe at the inner surface level. The rotating speed of the double drill pipe is 200r/min. The overall torque rating of 22kN.m is applied, and the influence of the overall dead weight is considered. The stress-strain nephogram is shown in Fig.3.



(a)Stress cloud map (b)Strain cloud map

(c)Local stress nephogram (d)Strain local cloud image

Figure 3. Stress-strain nephogram of modular double drill pipe.

The common drill pipe material of modular double-deck drill pipe is 26CrMo, the yield strength is 835 MPa, the safety factor is 1.15, and the allowable stress is 726MPa. The drill pipe joint, inner pipe body, upper (lower) inner pipe sub and positioning ring are made of 42CrMo, yield strength is 930 MPa, safety factor is 1.15, and allowable stress is 808MPa. The local stress-strain nephogram was taken respectively to analyze the maximum stress-strain, as shown in Figure 5. At the upper end of the modular double-layer drill pipe, stress concentration occurred at the male link of the drill pipe short section and the female link of the drill pipe joint. The maximum stress at the male link of the drill pipe joint was 744MPa, less than the allowable stress of the material. The maximum stress of the female joint of the outer bar is 248MPa, which is less than the allowable stress of the material. The maximum deformation of the male link of the drill pipe short section and the female link of the drill pipe joint is 4.6mm, which is caused by the weight on bit applied to the double drill pipe along the borehole direction. The deformation is less than the allowable deformation of 5.1mm in the body length direction, so the strength and stiffness of the modular double drill pipe can meet the application requirements. In conclusion, considering the strength and stiffness of the overall structure, the drill pipe short joint thread can be strengthened to meet the needs of complex working conditions.

3.2. Numerical analysis of pressure loss

Compared with conventional single-layer drilling pipe, modular double-layer drilling pipe has a larger pressure loss in the process of drilling fluid flow. In order to better verify the feasibility of gas-lift positive circulation drilling technology and which drilling fluid injection scheme is more advantageous in technology, it is necessary to conduct a comparative analysis of pressure loss between internal drilling fluid injection scheme and annular drilling fluid injection scheme. In this paper, CFD software is used to analyze and optimize the pressure loss of the flow passage inside the double drill pipe, and the rule of pressure loss when drilling fluid passes through is studied.

Any flow of matter must satisfy the continuity equation. This paper mainly studies the flow characteristics of fluids in the pipeline. Fluids in the basin are incompressible and in a turbulent state in the pipeline, and the movement of fluids conforms to the law of fluid mechanics. Therefore, the following governing equations [14-15] are provided.

(a) Continuity equation:

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0 \tag{1}$$

Where, u, v and w are the velocity components in the x, y and z directions, ρ is the density.

(b) Momentum conservation equation:

$$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_j}(\rho u_i u_j)=-\frac{\partial \rho}{\partial x_j}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial u_i}{\partial x_j}-\rho\overline{u_i' u_j'}\right)+S_j \tag{2}$$

Where, u_i, u_j is the average velocity, i, j=1, 2, 3; μ is the dynamic viscosity; ρ is the instantaneous pressure;- $\rho\overline{u_i' u_j'}$ is the Reynolds stress term; Is the source entry.

(c) Standard k-ε equation:

$$\mu_t=\rho C_\mu \frac{k^2}{\varepsilon} \tag{3}$$

Where, μ_t is turbulent viscosity; C_μ is the empirical constant, which is 0.09; ε is the turbulent kinetic energy dissipation rate; k is the turbulent kinetic energy.

(d) Transport equation of turbulent kinetic energy k:

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_i}\left[\left(\mu+\frac{\mu_t}{\delta_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k-\rho\varepsilon \tag{4}$$

Where, G_k is the generation term of turbulent kinetic energy k caused by the average velocity gradient, $G_k=\mu_t\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j}$,and δk=1.0 is taken here.

(f) Transport equation of turbulent kinetic energy ε:

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_i}\left[\left(\mu+\frac{\mu_i}{\delta_\varepsilon}\right)\frac{\delta_\varepsilon}{\delta x_j}\right]+G_{1\varepsilon}\frac{\varepsilon}{k}G_k-G_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{5}$$

Where, μ is the hydrodynamic viscosity, and G1ε, G2ε and δε are empirical constants with values of 1.44, 1.92 and 1.30, respectively.

3.2.1. Annular drilling fluid injection analysis

When the drilling fluid flows from the annulus of the modular double drill pipe, the positioning ring adopts the design of three fulcrum. Due to the existence of the positioning ring, the annulus injection drilling hydraulic loss needs to be analyzed. In the analysis process, only the change of pressure loss of a single length of the modular double drill pipe is studied. 3D software UG was used to establish the models of inner pipe with outer diameter of 20mm, 30mm, 40mm, 50mm and 60mm, respectively, and imported them into FLUENT. After drilling fluid runner was extracted, grid division was carried out. The k-ε model was used to set the flow rate of drilling fluid as 20L/s, 25L/s, 30L/s and 35L/s, the viscosity of drilling fluid as 10mPa·s, the density of drilling fluid as 1.2g/cm3 and the outlet pressure as 0MPa. The obtained dot plot of the influence of different inner pipe outer diameter on pressure loss is shown in Fig.4, and the watershed velocity vector diagram of drilling fluid inlet and outlet is shown in Fig.5.

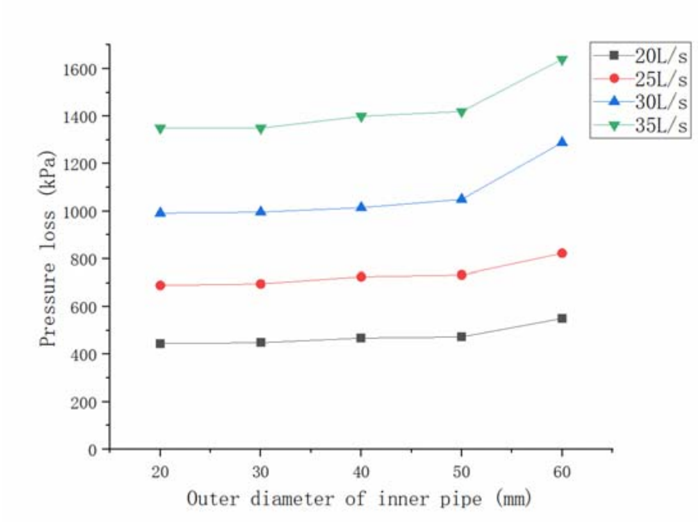
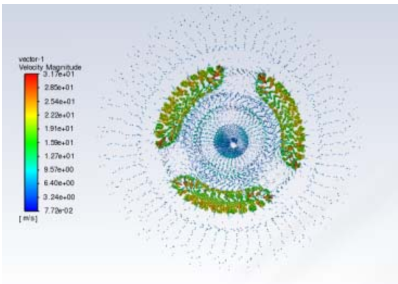
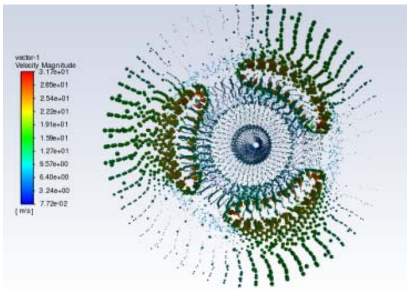


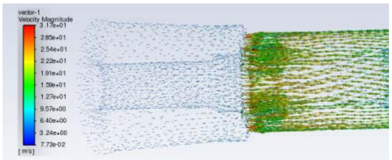
Figure 4. Influence of different outer diameter of inner pipe on pressure loss



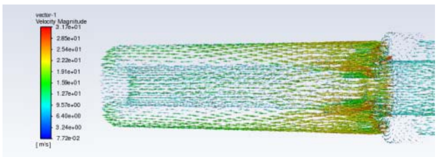
(a)Inlet view velocity vector



(b)Exit overlooking vector diagram



(c)Entrance face vector view



(d)The outlet faces the vector image

Figure 5. Watershed velocity vector diagram of inlet and outlet drilling fluid

As can be seen from Fig.4, as the outer diameter of the inner pipe keeps increasing, the pressure loss also increases. However, due to the limited internal space of the drill pipe, the size of the inner pipe is constrained to a certain extent, and the pressure loss is always maintained at a high state within the proper size of the inner pipe. Given the pressure loss of a single double drill pipe, it would be difficult to establish a circulation channel for drilling fluid if the double drill pipe was used in the actual depth section. As can be seen from Fig.5, the flow rate of drilling fluid increases dramatically at the positioning ring, so the cross-sectional area has a great impact on the pressure loss. Therefore, the main pressure loss point of annular injection drilling fluid is the annular positioning device.

3.2.2. Analysis of drilling fluid injection with inner pipe

When drilling fluid flows into the inner pipe of modular double-decker drillpipe, there is no positioning device in the inner pipe, but it is also necessary to carry out pressure loss analysis with drilling fluid flowing into the inner pipe in different inner diameter ranges. During the analysis, the research object is limited to single pipe pressure loss. 3D modeling software UG was used to establish the models with inner pipe outer diameter of 50mm, 55mm, 60mm, 65mm and 70mm respectively, and imported them into FLUENT for analysis. The setting during analysis was the same as the above annular drilling fluid injection method. The dot plot of the influence of different outer diameter of inner pipe on pressure consumption is shown in Fig.6.

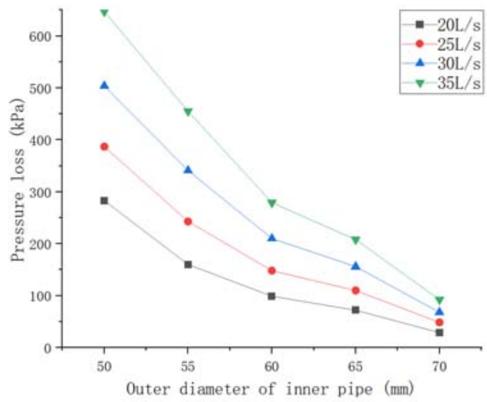
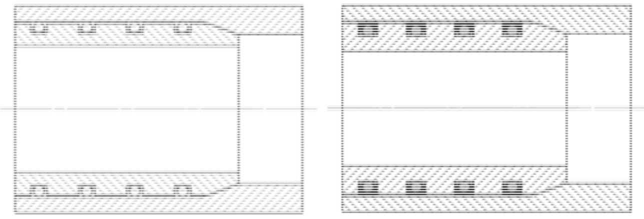


Figure 6. Influence of different inner diameter on pressure loss

As can be seen from Fig.6, the pressure loss tends to decrease obviously when the inner diameter of the inner pipe keeps increasing, and the larger the outer diameter of the inner pipe, the smaller the impact on the drilling fluid displacement. Therefore, reserving enough compressed air passage and increasing the diameter of the inner pipe as much as possible can effectively reduce the pressure loss and improve the flow capacity of the drilling fluid.

3.3. Sealing analysis of inner pipe joints

The tightness of the inner pipe of the double drill pipe is the key to the reliability of the double drill pipe. On the basis of the above analysis, using the inner pipe to inject drilling fluid and the annulus to inject compressed gas is more in line with the needs of the gas lift positive circulation drilling process. The medium in the inner pipe passage is 35Mpa drilling fluid, so it has high requirements for sealing. If the inner pipe is connected by thread, it is difficult to ensure the synchronous connection in the process of modular double drill pipe connecting a single root, so in order to ensure the connection of the double drill pipe is reliable, prevent the overall structure with the vibration of the drill string axial or circumferential displacement, because the drill pipe is affected by the load channel movement of its strength, the outer joint design for high pressure plug structure, Allow the existence of channeling while ensuring its sealing performance. Based on the existing double drill pipe O-ring seal, this paper proposes a C-shaped combined seal for the sealing of the inner pipe joint, and its schematic diagram is shown in Fig.7.



(a) O-ring seal (b) C combination seal ring

Figure 7. Schematic diagram of sealing of pipe joint in drill pipe of double drill pipe

3.3.1. Mathematical model

In this paper, the ANSYS software is used to analyze the performance of O-ring and C-ring combined seal under static and dynamic seal conditions, and it is concluded that the two kinds of seal rings have certain reference significance when used in modular double drill pipe. The main difference between O-ring and C-ring is that C-ring is a combination of O-ring and polytetrafluoroethylene (PTFE) C-ring containing added materials. The geometric characteristics, constraints, and external load of these two kinds of rings are symmetric about the central axis, and all the stress, strain and displacement are symmetric in the central axis. Therefore, the two sealing rings can be simplified into a plane axisymmetric model. The equilibrium differential equation of axisymmetric problems is as follows [16].

$$\begin{cases} \frac{\partial \sigma_\rho}{\partial \rho} + \frac{\partial \tau_{z\rho}}{\partial z} + \frac{\sigma_\rho - \sigma_\varphi}{\rho} + f_\rho = 0 \\ \frac{\partial \sigma_z}{\partial z} + \frac{\partial \tau_{\rho z}}{\partial \rho} + \frac{\tau_{\rho z}}{\rho} + f_z = 0 \end{cases} \tag{6}$$

Where, ρ, z is the direction of the coordinate axis of the cylindrical coordinate system; σ_ρ is radial normal stress; σ_φ is the circumferential normal stress; σ_z is the axial normal stress; $\tau_{\rho z}$ is the shear stress along the z axis, and $\tau_{\rho z} = \tau_{z\rho}$, f_ρ is the radial force; f_z is the axial force.

3.3.2. Material definition

The inner pipe male joint is made of steel, which has higher stiffness than the two sealing ring materials. In order to reduce the amount of simulation calculation, the hydraulic cylinder wall and sealing groove are set as discrete rigid body. The elastic modulus of C-shaped polytetrafluoroethylene ring is 1000MPa and Poisson's ratio is 0.4[17]. The O-ring is mostly rubber material. Rubber has nonlinear characteristics, and has the elastic properties of metal and the viscous properties of fluid. It does not have the linear properties as metal materials, and does not conform to Hooke's law, so it can not be solved only by basic parameters. In the finite element simulation, the following assumptions are made: ①The rubber material has certain Young's modulus and Poisson's ratio; ② Isotropic rubber material; ③ The volume of rubber is unchanged when it is extruded; ④The contact boundary between rubber and other parts cannot be crossed.

Aiming at the special properties of rubber materials, the Mooney-Rivlin model of continuum representation is widely used to calculate the mechanical problems of hyperelastic materials under large deformation. The two-parameter strain energy density function is expressed as follows.

$$W = C_1(I_1 - 3) + C_2(I_2 - 3) \tag{7}$$

Where: W is strain energy density; C_1, C_2 is the material constant of the Mooney-Rivlin model; I_1, I_2 is the first and second tensor invariants. In this paper, 1.87MPa and 0.47MPa are adopted [18].

3.3.3. Establishment of analysis model

The analysis model adopts the sealing groove form of inner pipe joint in radial seal, and simplifies the axisymmetric sealing ring into a two-dimensional cross-section analysis model, which can significantly improve the calculation efficiency. The model size view is shown in Fig.8. Through the universal friction and wear testing machine, the friction coefficient between the five groups of O-rings and the inner wall of the joint and the sealing groove is about 0.2, and the friction coefficient between the C-ring and the inner wall of the joint and the sealing groove is about 0.03[19]. The O-ring and C-O-ring combined seal meshes were divided respectively, the contact surface was refined, and the finite element model was established. The radial dimension of the inner pipe sealing groove is 50mm. The downward displacement is applied to the inner wall of the joint, and the upward displacement is applied to the sealing groove to simulate the process of the sealing ring being compressed during assembly. After compression, a certain sealing pressure is applied to one side of the sealing ring.

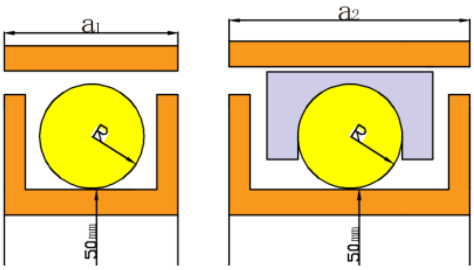


Figure 8. Model size view

3.3.4. Sealing performance analysis

In this paper, the sealing performance of O-ring and C-ring is analyzed on the seals by applying different pressures. Whether the sealing is sealed or not is determined by the maximum contact pressure σmax (MPa) of the sealing surface and the working pressure. If the maximum contact pressure of the sealing surface is greater than the working pressure, the sealing is realized. The maximum contact pressure and seal pressure rule of different sealing rings are shown in Fig.9.

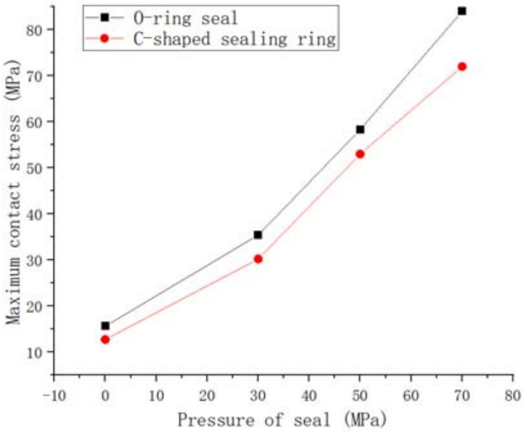


Figure 9. Maximum contact pressure at different seal pressures

As shown in Fig.9, the sealing performance of the two kinds of sealing rings is that the maximum contact stress increases with the increase of sealing pressure, and the maximum contact stress is greater than the sealing pressure, which can achieve the purpose of sealing. Compared with the two kinds of sealing rings, the C-type combined sealing ring has a smaller maximum contact pressure than the O-type sealing ring, and the sealing parts are not easy to deformation. In the process of using the double-layer drill pipe, it is more suitable for the complex and varied downhole environment, and has higher reliability.

4. Conclusion

(1) Double-decker drill pipe is an important supporting equipment of gas-lift positive circulation drilling technology. The modular double-decker drill pipe has the characteristics of reliable positioning, simple assembly, good applicability and easy maintenance.

(2) The modular double drill pipe needs to strengthen the joint, which can effectively improve its reliability; Using the inner pipe to inject drilling fluid can significantly reduce the pressure loss through the fluid.

(3) Modular double drill pipe has reliable tensile and torsional performance of drill pipe, and the inner pipe size can be adjusted flexibly; The drilling fluid with large inner tube has lower pressure loss; The C-shaped sealing performance of the inner pipe joint is better than the O-shaped sealing structure of the existing double drill pipe.

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