Erosion Characteristics Analysis of Bypass Valve of Positive Displacement Motor based on CFD

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Abstract

Bypass valve is one of the main parts of positive displacement motor, the advantages and disadvantages of its using performance has a certain impact on the service life of positive displacement motor. Aim at bypass valve often appear thorn leakage phenomenon in use process, and cause the using efficiency of positive displacement motor decline problem, the erosion performance of bypass valve of φ172mm positive displacement motor is analyzed by using Fluent software. The simulation results show that the most serious erosive wear occur in the valve core is full open position. The erosion wear rate of bypass valve cause by drilling fluid, is approximate linear relationship between drilling fluid flow rate and sediment content. In the process of drilling, the most serious erosion wear occur in reducing diameter of valve core. Reasonable excessive taper should adopt in the reducing diameter of valve core and material resistance to erosion wear should use for valve core. The research results have a guiding significance to improve the erosion wear resistance of bypass valve.

Keywords

Positive Displacement Motor; Bypass Valve; CFD; Erosion Resistance.

1. Introduction

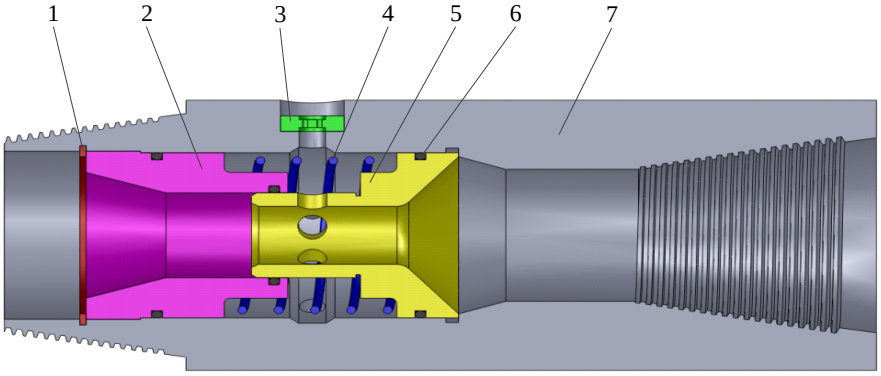
Screw drill tool is currently the most widely used a kind of downhole drilling tools. Bypass valve is a major part screw drilling tools, by-pass valve quality, directly affects the stability and reliability of screw drilling tools work. At the scene of the drilling operation, drilling fluid often contain more sediment, by-pass valve body, valve cover and the inside of the valve core excessive erosion, increase wearing parts replacement frequency, at the same time, shorten the service life of screw drilling tools [1]. Bypass valve of the excessive erosion, and often the sting of valve core leakage phenomenon, screw drill motors flow cannot meet the use requirement, impact on the performance of screw drill tool [2]. Therefore, research on drilling fluid erosion wear condition of by-pass valve is analyzed, has the vital significance.

Qiang Zhang [3], etc., to Φ 244 mm wall thickness, such as screw drill by-pass valve opening and closing process of the circulation flow control, analyzed the by-pass valve under different flow pressure drop and flow coefficient. Mingliang Li [4] uses ansys fluent software to analyze the water-based drilling fluid flow characteristics in the bypass valve and the by-pass valve valve core drilling fluid pressure distribution and velocity distribution and so on carries on the detailed analysis. Baolei Shan [5] of single screw drill tool analyzes the common faults of by-pass valve, single screw drill tool bypass valve structure improvement scheme, to bypass valve structure design provides a theoretical basis.

Currently, using CFD to screw drill tool bypass valve less erosion wear and research. Therefore, the author at 172 mm screw drill tool Φ bypass valve as an example, the analysis of water-based drilling fluid in different by-pass valve opening and drilling fluid flow and sediment concentration conditions, such as bypass valve of erosion wear. Research results to optimize the structure of the bypass valve and improve the use of screw drill tool performance has positive significance

2. The structure and working principle of screw drill tool bypass valve.

Is the main purpose of bypass valve in tripping and hole in the drill string, realizes the space inside the drill string and wellbore annular space communication, avoid the screw drill in the drilling fluid overflow pollution, rig affect normal drilling work [6]. Screw drill tool bypass valve structure diagram as shown in figure 1, it mainly consists of the valve body, valve cover, valve core, a spring, sieve plate and elastic ring, sealing ring structure. Drill hole or the mud pump output flow rate is small, on both ends of the valve core drilling fluid pressure can be seen as equal. Valve core by spring force should be greater than the pressure of drilling fluid, in the spring force under the action of by-pass valve core in the fully open position. At this point, the screw drill tool space inside the drill string and wellbore annular space between, through the bypass valve is in a state of interlinked, drilling fluid can be through the internal bypass valve into the drill pipe. When the screw drill in drilling work, mud pump output flow rate is larger, drilling formation pressure difference on both ends of the valve core. At this point, the by-pass valve valve core under the action of the pressure of drilling fluid, to overcome the spring force to close the bypass valve side opening channels, to provide enough power for the motor. Drilling mud pump stop pump, the pressure difference on both sides of the valve core drilling fluid disappears, under the action of the spring, make the by-pass valve valve core is open, and the drill pipe in the drilling fluid flowing in the wellbore annular space.



1-Elastic ring, 2-Valve sleeve, 3-Sieve plate, 4-The spring, 5-Vvalve core, 6-Seal, 7-The body
Fig.1 The structural schematic of bypass valve for positive displacement motor

In order to prevent larger particles in the mud, side holes through the bypass valve into the inside the drill string, usually in the bypass valve side hole filter with the function of sieve plate. However, itself contains impurities in the drilling fluid is more, at the same time, the drilling process of impurity also easy side holes from the bypass valve to the interior by-pass valve, by-pass valve of erosion damage, even cause the failure of by-pass valve spring components, by-pass valve core card lag phenomenon.

3. Bypass valve erosion analysis

With the rapid development of computational fluid dynamics (CFD) technology, especially the multiphase flow analysis technology in the application of CFD software, erosion wear for analysis of complicated structure, provides a simple and effective analysis method. Therefore, the author uses the Fluent software in a discrete phase model (DPM), and analyze the erosion characteristics of the by-pass valve.

3.1 Erosion wear rate

Erosion wear rate on the surface of the structure is to point to in unit time, structure surface by fluid erosion in per unit area caused by mass loss. Factors influencing the structure of erosion wear rate mainly include: the Angle between the structural surface and the incident particle trajectory, the speed of the incident particles, structure characteristics and structure of the material properties of the incident particles, etc. [7]. Erosion wear is a very complicated process, using semi-empirical model [8]. Is currently the most widely used Alhert [9] erosion model is put forward, the model of erosion wear rate can be expressed as [10].

$$R = 1559B^{-0.59}F_S v^{1.73} f(\alpha)$$

Among them, R - structure on the surface of the erosion wear rate, $kg \cdot s^{-1} \cdot m^{-2}$.

B - structure surface material brinell hardness, HB.

FS - the shape coefficient of incident particles, sharp particles take 1, sleek particles take 0.2.

V - the speed of the incident particles, m/s.

α- incident Angle on the surface of the particle trajectory and structure, rad.

f(α)- A function of incident Angle of particles, brittle plastic abrasion wear and has different expression [11].

Based on the type of impact structure element of erosion wear rate for setting up reasonable parameters in the simulation model, for screw drilling tools bypass valve analysis of erosion wear.

3.2 Sediment particle motion equation

In the study of drilling fluid sediment erosion abrasion on the surface of structure, the key is to analyze the operation of the sediment particle trajectory [12]. In the discrete phase model of Fluent software, between discrete and continuous items to exchange of momentum, and energy. At the same time, the sediment particle trajectory following equations of motion of the reference coordinate system (elm), considering the inertia of sediment particles and force equilibrium, the equation of motion can be represented as [13] [14].

$$\frac{du_p}{dt} = F_D\left(u - u_p\right) + \frac{g\left(\rho_p + \rho\right)}{\rho_p} + F \tag{1}$$

Among them, Up-discrete item of sediment particle velocity, m/s.

U- continuous phase of water flow, m/s.

P- continuous phase of water density, kg/m – 3.

ρ_p - discrete density of sediment particles, kg/m – 3.

g- acceleration of gravity, m/s^2.

F - additional force on the sediment particle unit mass, N/kg.

FD - discrete items of the quality of the resistance coefficient of sediment particle units, can be calculated by the type,

$$F_D = \frac{18\mu}{\rho_P D_P^2} \times \frac{C_D R_e}{24} \tag{2}$$

Among them, μ- continuous dynamic viscosity, Pa, s.

Dp - discrete particle diameter, m.

CD - drag coefficient and dimensionless.

Re - the relative Reynolds number, nondimensional.

The basic assumption is that the discrete model of a discrete item of particle volume fraction should be smaller (less than 10%). Without considering the interaction between clay particles, sediment effects on drilling fluid continuous study.

4. he establishment of the by-pass valve simulation model

According to Φ 172 mm screw drill tool samples of by-pass valve, by-pass valve in Solidworks 3 d model, then derived for the IGS format file, in order to read in the ANSYS software, the 3 d simulation model diagram is shown in figure 2. In ANSYS ICEM CFD, complete the by-pass valve 3 d model boundary and the definition of grid, and to export the processed files into Fluent input file format.

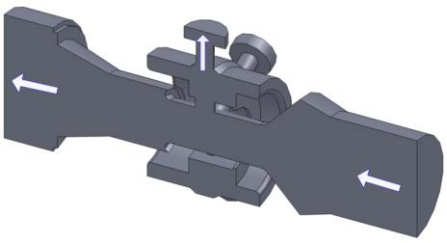


Fig.2 The simulation model of bypass valve

In the ANSYS Fluent software, in order to track the movement of sediment particles in drilling fluid analysis, simulation analysis was made on the discrete phase model. Combined with the working condition of the bypass valve, in front of the Fluent software processor set the following parameters.

Bypass valve internal fluid flow is relatively complex, belong to the three dimensional unsteady, incompressible turbulent flow. Select standard k - epsilon equation in the Fluent software, as the control equations of turbulence model. At the same time in the model considering the influence of gravity.

Selecting water as the continuous phase, the density of 1000 kg/m3, dynamic viscosity of 1.003 x 10-3 pa, s. Sediment particles for discrete phase, the particle diameter of 0.4 mm, density of 3300 kg/m3. Depending on the simulation of the sediment particles velocity. Drilling fluid is calculated according to the volume ratio of sediment particle content. Valve core material of 40 cr, density of 7850 kg/m3.

Drilling, screw drill motor pressure drop is less than 0.8 MPa, so set the by-pass valve outlet pressure is 0.8 MPa, by-pass valve side hole outlet pressure to zero. Bypass valve inlet flow according to the simulation of concrete operating mode Settings. The bypass valve closing flow rate about 7.58 L/s, when the opening of the by-pass valve different simulation, traffic should be higher than this value.

Computing discrete items of pressure speed coupled with SIMPLE algorithm, the momentum of discrete format USES first-order wind, turbulence, turbulence kinetic energy dissipation rate of discrete format adopts second order wind, to solve the discrete equations.

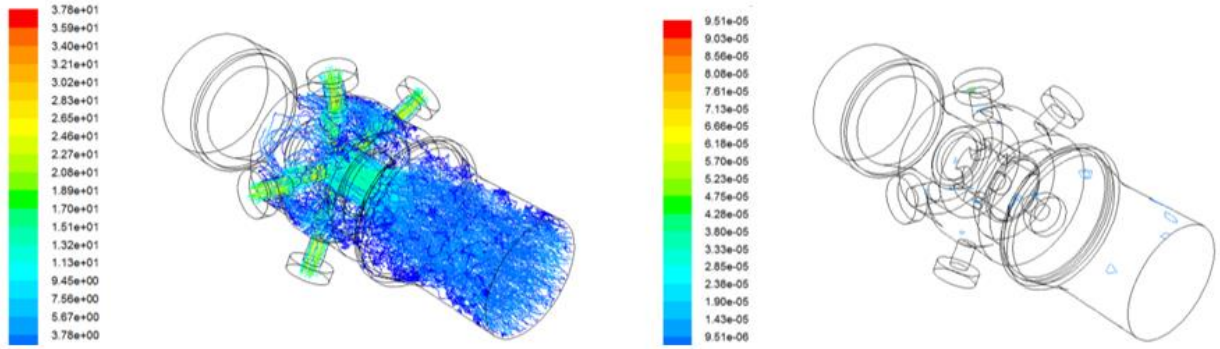
5. he results of simulation analysis

Bypass valve from open to close fully, in the process definition side valve core hole is valve cover to cover, the by-pass valve opening is 100%; Lateral valve core hole is defined just completely covered by valve sleeve, the by-pass valve opening is 0%; The rest of the side hole opening is in accordance with the valve core has been covering stroke accounted for the percentage of the whole trip to define the process.

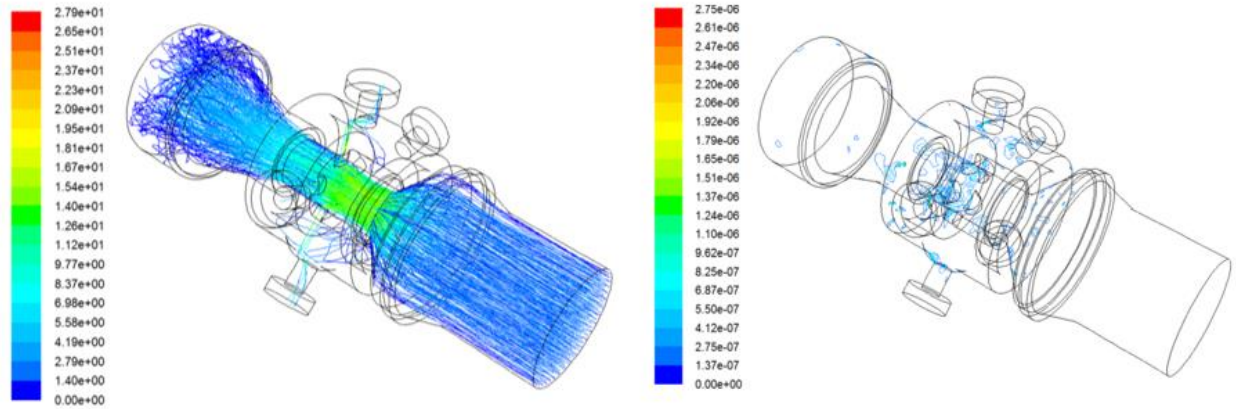
5.1 Bypass valve under different opening of erosion analysis

Under different opening degree of bypass valve erosion analysis, its significance lies in the analysis of by-pass valve opening and closing process, the drilling fluid to bypass valve cause analysis of the erosion wear. At the same time, the drilling fluid flow is not enough to make the by-pass valve fully open, also can make the by-pass valve can in different degrees. Therefore, the analysis of the different opening bypass valve erosion wear by drilling fluid, has important practical significance.

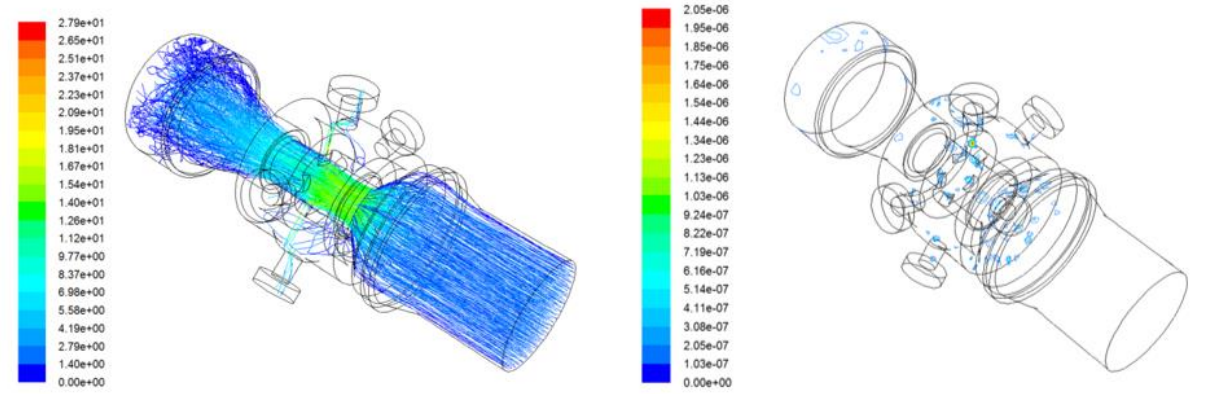
This paper conducted under different opening of by-pass valve by erosion and wear simulation analysis, to flow for 15 l/s, sediment concentration of 1% of the drilling fluid, on the basis of analysis of the valve core of the opening of the side of the opening of the hole in the 75%, 75%, 25% opening three state, the bypass valve by erosion. The three opening of simulation results is shown in figure 3.



(a) The opening of the 75% of sediment particle trajectory (b)The opening of the 75% of erosion wear rate



(c) The opening of the 50% of sediment particle trajectory (d) The opening of the 50% of erosion wear rate



(e) The opening of the 25% of sediment particle trajectory (f) the opening of the 25% of erosion wear rate

Fig.3 The erosion wear of bypass valve under different opening

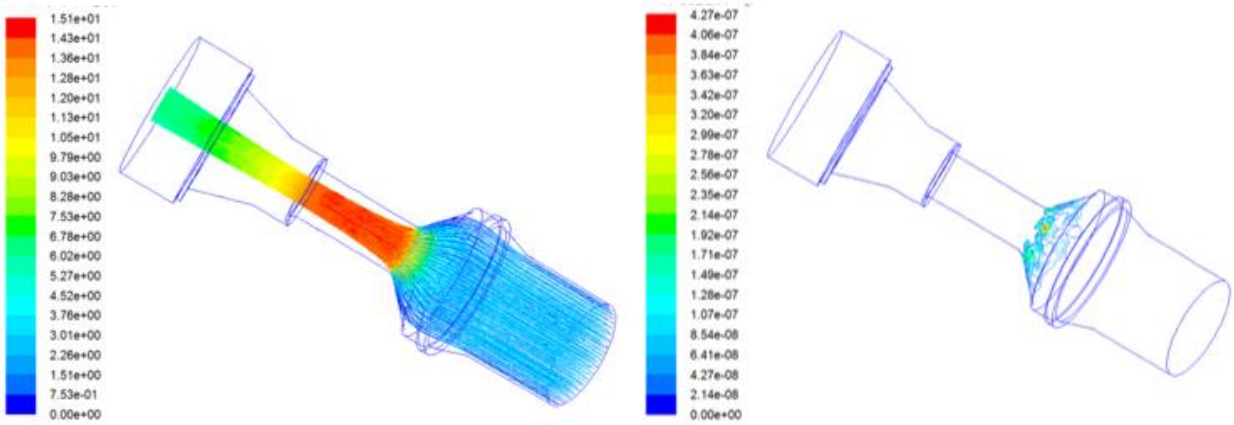
From sediment particle trajectory simulation results it can be seen that as the opening of the by-pass valve, by-pass valve internal drilling fluid turbulent situation improved, sediment particles from the chaotic movement gradually became more regular, at the same time, the velocity of sediment particles decreases. From the bypass valve of erosion wear rate of the simulation results can be seen, by-pass valve side hole and the valve core diameter changes, such as the location of the site is the most serious erosion wear. At the same time, the valve core is the bypass valve parts by erosion wear is the most serious. With the drop of the by-pass valve opening from the bypass valve side hole outflow sediment particle number, reduced sediment particle velocity at the same time, reduces the erosion wear inside the by-pass valve. Therefore, in the process of using screw drilling tools, we will strictly control the mud pump output flow, make the bypass valve will shut off quickly. If the mud pump output flow instability or output flow within the scope of the by-pass valve closed flow, will

cause the by-pass valve cannot be completely shut down, makes the by-pass valve have serious wear and tear. At the same time, to avoid bypass valve valve core card lag phenomenon.

5.2 Bypass valve fully closed condition analysis of the erosion

Of by-pass valve fully closed condition analysis of erosion wear, reflects the screw drilling tools in the process of drilling, drilling fluid erosion wear of by-pass valve. Screw drill tool in the process of drilling, bypass valve has been closed. So in the case of by-pass valve fully closed, the analysis of the erosion wear, it is of great significance.

In order to grasp the by-pass valve fully closed cases, by-pass valve interior flow field distribution of the drilling fluid and erosion wear situation of bypass valve, in the first place in the simulation model, the flow of 15 l/s, sediment concentration of 1% of the drilling fluid of erosion wear situation analysis, the simulation results are shown in figure 4.



(a) The direction of movement of sediment particles (b) The rate of esion

Fig.4 Erosion analysis of 1% sediment concentration of drilling fluid to bypass valve(flow rate is 15L/s)

By figure 5 (a) it can be seen that seated state, the bypass valve valve core sediment particles within the by-pass valve movement more regularly. Its trajectory is only on the surface of valve core variable diameter by rebound, the remaining parts of the sediment particles trajectory can render good straight lines. As a result, the valve core diameter changes under the surface of the most serious erosion wear. You can see from figure 5 (b) in the valve core variable diameter, the diameter of the smallest position is the most serious erosion wear. Because of the simulation accuracy, the wear of the most serious areas should be circular [15] [16].

6. Conclusion

(1) the screw drill tool bypass valve in the process of opening or closing, as the by-pass valve opening gradually reduce, drilling fluid to bypass valve erosion wear rate gradually decreases. Therefore, in the drilling process, screw drill tool should be able to close the bypass valve quickly, avoid card lag phenomenon, causing serious wear and tear of by-pass valve.

(2) In the process of drilling, the by-pass valve valve core diameter variable diameter location is the most serious erosion wear, should design reasonable excessive slope, the sediment particle erosion Angle in a reasonable range, in order to reduce the sediment erosion and wear of valve core. At the same time, the valve core and erosion resistance of materials should be adopted.

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