Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

Analysis of Pressure Fluctuations During the Switching of Circulation Paths in Valve-type Continuous Circulation Drilling Systems

Jing Jun
Associate Professor of Southwest Petroleum University
School of Mechanical and Electrical Engineering
Chengdu, China

Dabin Tian
Postgraduate student of Southwest Petroleum University
School of Mechanical and Electrical Engineering
Chengdu, China

Xiaohua Zhu
Southwest Petroleum University
School of Mechanical and Electrical Engineering
Chengdu, China

Yueyang He
Postgraduate student of Southwest Petroleum University
School of Mechanical and Electrical Engineering
Chengdu, China

Xianbo Xue
Integration and New Energy Division of China Oilfield Services Limited
Tianjin, China

Lingxu Kong
The Northwest Sichuan Gas Mine of Southwest Oil & Gas Field Company of China National Petroleum Corporation
Mianyang, China

Funding Project: National Science and Techno- logy Major Project for New Oil and Gas Exploration and Development: Key Equipment for 10,000-Meter Ultra-Deep Drilling Including Intelligent Top Drive and Continuous Circulatio- n Systems (Grant No.: 2024ZD1401 8-002).

***Abstract*—This valve-type continuous circulat- ion drilling system achieves continuous circulation of drilling fluid during the process of making up or breaking out a single drill pipe joint by altering the drilling fluid circulation path, thereby avoiding safety issues such as drill-pipe sticking caused by cuttings deposition, heat accumulation in the wellbore, and imbalance of bottomhole pressure that can result from pump shutdown. However, when the surface control manifold of the system switches the circulation path, it can cause varying degrees of pressure fluctuations.To address this issue, a computational model for pressure fluctuations in the system was established based on a novel valve-type continuous circulation drilling system used on offshore platforms, and the model's accuracy was experimentally validated. Building on this model, an in-depth analysis was conducted on the mechanism of pressure fluctuations during the switching of drilling fluid circulation paths. The study investigated the pressure fluctuation patterns and influencing factors within the drilling fluid circulation path under three switching process conditions: "switching without fluid replenishment, switching with dual-circuit fluid replenishment, and switching with dedicated fluid replenishment lines." The research revealed that pressure fluctuations are significant during switching without fluid replenishment, reaching 2.44 MPa during main-to-side path switching in a case study well, accounting for 27% of the total circulating pressure. A faster valve opening speed intensifies the water hammer effect, leading to greater pressure fluctuations; when the valve fully opens in 13 seconds, the pressure fluctuation amplitude increases by approximately 16% compared to a 50-second opening time. During dual-circuit fluid replenishment, the throttle valve opening in the path to be switched has a pronounced impact; pressure fluctuations decrease from 1.98 MPa at an 80% opening to 0.68 MPa at a 35% opening, representing a 65.66% reduction, although the duration of pressure fluctuations extends from 35 seconds to 75 seconds. When using dedicated fluid replenishment lines, since the original path flow rate is not reduced, the closer the replenishment pressure is to the circulation path pressure, the smaller the pressure fluctuations during switching. However, the additional fluid replenishment equipment increases costs and exacerbates space constraints on the platform.**

***Keywords*—Continuous circulation drilling;Pr- essure fluctuation;Mud replenishment;Valve positi- on**

I. INTRODUCTION

During conventional drilling operations, it is often necessary to stop the pump to make or break connections. Once the pump is shut down, drilling fluid circulation ceases, which can easily lead to cuttings deposition in the annular space and even pipe sticking. Meanwhile, the stagnation of drilling fluid prevents bottomhole heat from being transported to the surface, resulting in heat accumulation and high- temperature failure of downhole tools. Additio- nally, pump shutdown and restart cause severe bottomhole pressure fluctuations, which can easily trigger kick or lost circulation incidents when drilling in narrow mud weight window formations[1-3]. Valve-based continuous circulati- on drilling technology utilizes a surface control manifold and a continuous circulation sub (CCS) at the wellhead to maintain uninterrupted drilling fluid flow. This system allows for making or breaking connections without stopping the pump, effectively avoiding a series of downhole complications caused by pump shutdown. It is particularly suitable for complex scenarios such as extended-reach drilling, formations with narrow mud weight windows, unstable formations, and lost circulation zones, significantly enhancing drilling safety [4-5]. However, when the surface control manifold switches the drilling fluid circulation path, the transient ingress of high-pressure fluid into empty or low-pressure pipelines can induce water hammer effects and pressure fluctuations in the original circulation loop, thereby posing risks to drilling safety. For example, in 2016 at the Panyu 11-5 oilfield in the eastern South China Sea, a transient severe pressure fluctuation occurred during the switching of the drilling fluid circulation path by the surface control manifold, which seriously interfered with signal transmission from downhole MWD (Measurem- ent While Drilling) and LWD (Logging While Drilling) tools [6]. The pressure fluctuation during the circulation path switching process in a continuous circulation drilling system is essentially a problem of drilling fluid flow pressure loss caused by the manifold path structure, valve throttling, and other factors within the manifold system.

Aiming at the issue of flow pressure loss in manifold systems, scholars worldwide have conducted extensive research. ENI integrated continuous circulation subs with Micro-Flux Control (MFC) technology to achieve precise pressure management during continuous circula- tion drilling operations [7]. Hu Zhijian et al. investigated the structural design and hydraulic characteristics of diversion manifolds in CCS systems[8]. Zhang Wunian et al. explored the industrial application of valve-based continuous circulation systems, summarizing practical cases of pressure fluctuations during flow diversion processes[9]. Sui Yue et al. established mathemat- ical-physical models to analyze pressure fluctua- tions during the pressurization phase of CCS systems[10]. Tian Zhixin et al. proposed adding a mud filling line to mitigate pressure fluctuations during flow diversion[11]. Wei Chenxing et al. developed simulation models for numerical analysis to study the impact of circulation path switching in continuous drilling manifolds on pressure dynamics[12].

Scholars worldwide have proposed imple- menting fluid replenishment processes to mitigate pressure fluctuations during circulation path switching. However, the mechanisms underlying pressure fluctuations in continuous circulation drilling systems under different switching methodologies, as well as the corresp- onding fluid replenishment techniques, require further in-depth investigation. To address this knowledge gap, this study utilizes a novel valve-based continuous circulation drilling system deployed on an offshore platform. By accounting for the comprehensive flow characte- ristics of drilling fluid throughout the entire circulation loop, we establish a computational model to analyze pressure fluctuations within the system. The research systematically investigates pressure fluctuation behaviors and their

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

influencing factors under various operational conditions, thereby providing a theoretical foundation for controlling pressure fluctuations during switching processes and developing automated pressure-stabilized switching control systems.

Ⅱ. ANALYSIS OF VALVE-BASED CONTINUOUS CIRCULATION DRILLING SYSTEM AND SWITCHING PRESSURE FLUCTUATIONS

A.Working Principle of Valve-Based Continuous Circulation Drilling System

The valve-based continuous circulation drill- ing system consists of a surface control manifold and a continuous circulation sub. The working principle of continuous circulation drilling oper- ation is illustrated in Figure 1.

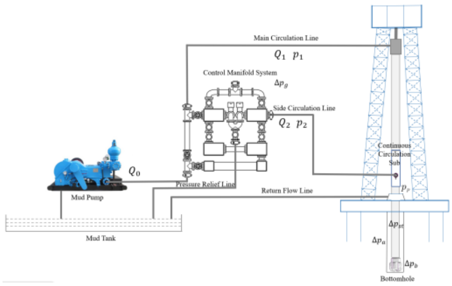


Figure 1. Schematic Diagram of Continuous Circulation Drilling Operation

The drilling fluid pumped by the mud pump flows into the surface control manifold, which contains two circulation paths: the main circulation path and the side circulation path. The main path is used during normal drilling operations, while the side path is activated during pipe connection and disconnection. During these operations, drilling fluid is diverted through the side flow line and the continuous circulation sub at the wellhead, entering the inner annulus of the drill string to maintain continuous circulation. After completing the pipe connection or disconnection, the flow is switched back to the main circulation path. Both the main and side paths in the surface control manifold are regulated by electrically controlled valve assemblies. Additionally, the manifold is equipped with a pressure relief path and a dedicated fluid replenishment path, allowing for fluid compensation in the standby path either through a dedicated replenishment pump or via a dual-circulation mode where fluid is diverted from the main and side paths.

The continuous circulation sub is directly connected to the drill pipe and is internally equipped with a main valve and a side valve. During drilling, drilling fluid flows through the main circulation path of the surface control manifold, the high-pressure rotary hose, and the top drive, then pushes open the main valve plate of the continuous circulation sub to flow toward the bottom of the well. At this time, the side valve plate achieves sealing under the pressure of the drilling fluid. When adding or removing a drill pipe single, the side circulation pipeline is connected to the side valve of the continuous circulation sub. The surface control manifold switches the drilling fluid circulation path to the side circulation path. The drilling fluid pushes open the side valve plate and automatically forces the main valve plate into a closed state. After passing through the side valve, the drilling fluid is conveyed to the bottom of the well. The surface control manifold and continuous circulation sub are illustrated in Figure 2.

Figure 2. Surface Control Manifold and Continuous Circulation Sub

B.Pressure Fluctuation During the Switching Process

Reasons for pressure fluctuations during flow path switching in a valve-based continuous circulation drilling system are:

The primary cause: The standby flow path to be switched into is initially empty of drilling fluid. Consequently, fluid from the active circulation path diverts into this standby path, causing a decrease in flow rate within the original active path and resulting in a pressure change.

The secondary cause: Structural and compos- itional differences exist between the main and side drilling fluid circulation paths. These differences lead to varying pressure losses for the same fluid flow rate, causing a pressure change once the flow path switching is completed.

For instance, in Well PY10-8-A3 (well depth 4942 m), the circulation pressure during side-path circulation was 21.1 MPa. During the switch from side to main circulation, the valve in the main circulation path was opened rapidly. This caused the pressure in the side circulation path to drop sharply to 4.2 MPa. After the main circulation was established, the pressure gradually recovered to 19.6 MPa. The pressure fluctuation during this flow path switching process reached 16.9 MPa (see Figure 3)[6], indicating a severe pressure surge.

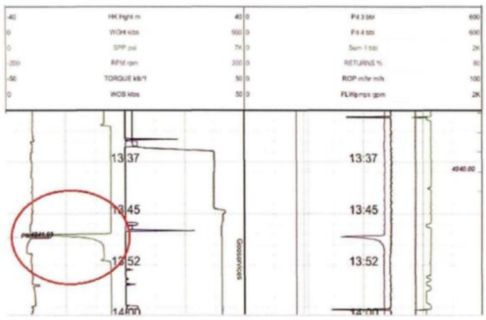


Figure 3. Composite Mud Log (CML)

III. ESTABLISHMENT AND VALIDATION OF A MATHEMATICAL MODEL FOR PRESSURE FLUCTUATIONS

As can be seen from the schematic diagram of continuous circulation drilling operations in Figure 1, the pressure transmission path of the main circulation circuit is: wellhead → annulus → bit → drill string → standpipe & rotary hose →

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

high-pressure hose → surface control manifold. The pressure transmission path of the side circulation circuit is: wellhead → annulus → bit → drill string → side valve port of the continuous circulation sub → high-pressure hose → surface control manifold.

In Figure 1:

Q_0: represents the drilling pump flow rate;

Q_1: represents the main circulation circuit flow rate;

Q_2: represents the side circulation circuit flow rate;

(Unit: L/s)

p_1: represents the internal pressure of the main circulation circuit;

p_2: represents the internal pressure of the side circulation circuit;

p_p: represents the wellbore outlet pressure.

$\triangle p_g$: represents the pressure loss across the surface control manifold;

$\triangle p_{st}$: represents the pressure loss in the drill string;

$\triangle p_b$: represents the pressure loss across the bit;

$\triangle p_a$: represents the pressure loss in the annu- lus.

(Unit: MPa)

A.Circulating Pressure Calculation Model

Analysis of the pressure transmission path reveals that the expression for pressure transfer, whether the drilling fluid flows through the main or side circulation loop, is:

$$p_1=p_p+\triangle p_a+\triangle p_b+\triangle p_{st}+\triangle p_{standpipe\ and\ rotary\ hose}+\triangle p_{hose}+\triangle p_g \quad (\text{main circulation}) \qquad (1)$$

$$p_2=p_p+\triangle p_a+\triangle p_b+\triangle p_{st}+\triangle p_{side\ valve\ port}+\triangle p_{hose}+\triangle p_{g} \quad (\text{side circulation}) \qquad (2)$$

Herein, downhole pressure losses are calculated using empirical formulas:

$$\begin{cases} \triangle p_s=7628\dfrac{\rho_d^{0.8}\mu_{pv}^{0.2}L_pQ_d^{1.8}}{d_{pi}^{4.8}} \\ \triangle p_b=554\dfrac{\rho_d Q_d^2}{A_0^2} \\ \triangle p_a=7628\dfrac{\rho_d^{0.8}\mu_{pv}^{0.2}L_aQ_d^{1.8}}{(D_a-D_{lo})^3(D_a+D_{lo})^{1.8}} \end{cases} \qquad (3)$$

a.Manifold Frictional Pressure Loss

The manifold frictional pressure loss encom- passes the pressure losses across the standpipe and rotary hose, the hose, and the straight pipes and bends within the surface control manifold. These are all calculated using the Darcy-Weisba- ch equation [13]:

$$\triangle p=f\cdot\frac{L}{D}\cdot\frac{\rho v^2}{2} \qquad (4)$$

Prior to calculating the friction factor, the Reynolds number (Re) is computed to determine the fluid flow regime. An Re of less than 2,000 indicates laminar flow; an Re between 2,000 and 4,000 indicates transitional flow; and an Re greater than 4,000 indicates turbulent flow. The calculation formula for the friction factor under laminar flow conditions is:

$$f=\frac{64}{Re} \qquad (5)$$

For the transitional flow regime, the friction factor is typically calculated as for the turbulent flow regime. Under turbulent conditions, the Chen friction factor formula is employed. The Chen formula is an explicit correlation, facilitat- ing straightforward computation while maintain- ing high accuracy[14-15]. The calculation formula is as follows:

$$f=\left[\frac{1}{-2lg\left(\frac{\varepsilon/d}{3.71}-\frac{5.05}{Re}\cdot lg\left(\frac{(\varepsilon/d)^{1.11}}{2.83}+\left(\frac{5.85}{Re}\right)^{0.90}\right)\right)}\right]^2 \qquad (6)$$

The calculation formula for the pressure loss at diameter change locations within the surface control manifold is given by[16]:

$$\triangle p=\zeta\cdot\frac{L}{D}\cdot\frac{\rho v^2}{2} \qquad (7)$$

In the formula, ξ is the local resistance coefficient. For a sudden contraction (reduction in diameter), $\xi=0.5(1-\frac{A_{min}}{A_{max}})$; for a sudden expansion (increase in diameter), $\xi=(1-\frac{A_{max}}{A_{min}})^2$.

When calculating the pressure loss for the rotary hose and high-pressure hose, the expansion effect under pressure must be considered. The pressure loss shall be calculated using the expanded diameter. The formula for calculating the increased internal radius of the hose due to expansion is given by [6]:

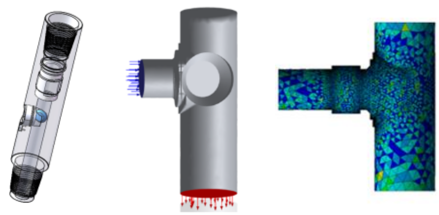
$$\triangle r=\frac{pr}{E}\left(\frac{r/R+1}{r/R-1}+\mu\right) \qquad (8)$$

In the formula:
Δr = increase in the hose's internal radius (unit: mm)
p = internal pressure of the hose (unit: MPa)
r = internal diameter of the hose (unit: mm)
R = external diameter of the hose (unit: mm)
E = elastic modulus of the hose material (unit: GPa)
μ= Poisson's ratio of the hose material (dimensionless)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

b.Pressure Loss Across the Side Valve Port of the Continuous Circulation Sub

When the main valve of the continuous circulation sub is open, its internal flow channel acts as a straight pipe with a constant diameter, allowing the pressure loss to be calculated using the standard formula for straight pipes. In contrast, the structure at the side valve port is complex. During side circulation, the side valve plate opens at a specific angle, as shown in Figure 4(1), making theoretical calculation of its pressure loss challenging. Therefore, computati- onal fluid dynamics (CFD) simulation methods are employed to analyze the effects of fluid flow rate and density on pressure loss. The flow of drilling fluid through the side valve port involves complex turbulent flow. Based on fluid dynamics simulation analysis software, a Realizable κ-ε turbulence model was adopted to establish a CFD simulation model for analyzing the pressure loss across the side valve port of the continuous circulation sub, as shown in Figure 4(2). The mesh configuration of the model is illustrated in Figure 4(3).



(1) (2) (3)

Figure 4. Flow and Pressure Loss Analysis Model for the Side Valve Port of the Continuous Circulation Sub

Through computational fluid dynamics (CFD) analysis, the pressure loss data across the side valve port were calculated for flow rates of 0.5 m³/min, 1.0 m³/min, 1.5 m³/min, 2.0 m³/min, 2.5 m³/min, and 3.0 m³/min, with fluid densities of 1.0 g/cm³, 1.2 g/cm³, 1.4 g/cm³, 1.6 g/cm³, and 1.8 g/cm³. The pressure loss data were subjected to nonlinear surface fitting (as shown in Figure 5) to derive an expression for the pressure loss across the continuous circulation sub's side valve port as a function of flow rate and density. The fitted formula achieved an R-squared value of 0.96, and its accuracy meets the computational requirements:

$$\triangle p=0.0221Q^2+0.02158\rho+0.08069Q\cdot\rho \quad (9)$$

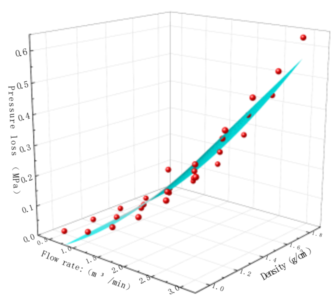


Figure 5. Nonlinear Surface Fitting

B. Pressure Calculation Model for the Fluid Replenishment Process

To mitigate pressure fluctuations during the switching process, a dual-circulation diversion and fluid replenishment device is employed to pre-charge the standby flow path. This process involves pressurizing and filling the sealed chamber of the standby flow path with fluid. Given the short duration of replenishment, the compression of the gas can be considered adiabatic (no heat exchange with the surroundi- ngs). Based on the gas state equation, the relationship between the pressure in the sealed chamber and the remaining gas volume can be derived as follows:

$$\begin{cases} P' = \frac{T'}{T_0}\frac{P_0V_0}{V'} = \alpha\frac{P_0V_0}{V'} \\ V' = V_0 - \int Q d_t \\ Q_1 = Q_0 - Q_2 \end{cases} \quad (10)$$

The inflow volume and rate of the replenis- hment drilling fluid are regulated by the opening degree and opening speed of the electro-control valve within the surface control manifold. The valve's inherent structure and its flow diameter are also critical factors affecting manifold pressure loss and pressure fluctuations. To address the issue of high pressure loss observed in the operation of a certain type of existing surface control manifold valve, an optimization for large flow diameter and drag reduction has been implemented. The optimized cylindrical choke valve and the matching relationship between the valve core and valve seat are shown in Figure 6.

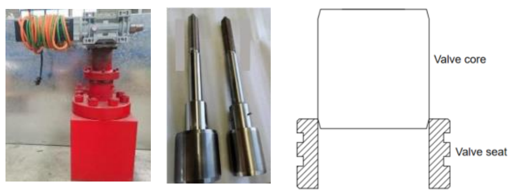


Figure 6. Physical Diagram of the Improved Electro-Control Choke Valve and Schematic of Valve Core-Valve Seat Matching

C. Flow Characteristics of the Cylindrical Choke Valve

The flow rate calculation formula for the choke valve is given by [17]:

$$Q = C_V \cdot A_r \cdot \sqrt{\frac{2\triangle p}{\rho}} \quad (11)$$

In the above formula, $\triangle p$ represents the pressure difference between the inlet and outlet of the choke valve, which can be determined through the pressure loss calculations described in the previous section. A_r denotes the throttling area, and C_v is the flow coefficient of the cylindrical choke valve. Calculating C_v requires knowledge of the choke valve's flow characteris- tics. When the valve core is opened to a certain stroke, the throttling area corresponds to the lateral surface area of the conical ring formed by the shortest distance between the valve core and the valve seat. Due to the tapered profile at the end of the valve core, the variation trend of this shortest distance is not consistent across the entire valve stroke but rather occurs in two distinct stages. Based on geometric

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

relationships, it can be deduced that Stage 1 corresponds to a stroke range of 0–7.49mm, and Stage 2 corresp- onds to a stroke range of 7.49–27mm. The calculation formula for the lateral surface area of the conical ring is as follows:

$$A = \pi \cdot (R + r) \cdot C \quad (12)$$

In the first stage, the opening state of the choke valve core is shown in Figure 7. The shortest distance between the valve core and the valve seat is segment ac, which represents the generatrix of the conical ring. Segment ac is perpendicular to segment dc, with angle d = 15°. Segment ad represents the valve stroke. Segme- nt bc is perpendicular to segment ad. The inner diameter of the valve seat is 40mm. The calculation formula for the relative throttling area of the choke valve is as follows:

$$\begin{cases} r = 40 - |ad| \cdot sin15° \cdot cos15° \\ C = |ac| = |ad| \cdot sin15° \\ f_1 = \frac{2160\pi sin15° l - 729\pi (sin15°)^2 cos15° l^2}{5026.55} \end{cases} \quad (13)$$

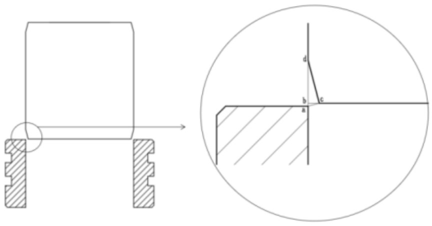


Figure 7. Schematic Diagram of the Choke Valve Core Opening State in Stage 1

In the second stage, the opening state of the choke valve is shown in Figure 8. The shortest distance between the valve core and the valve seat is segment ac, which represents the generatrix of the conical ring. The angle d = 15°. Segment ad corresponds to the valve stroke. Segment bc is perpendicular to segment ab. The inner diameter of the valve seat is 40mm, and the inner diameter of the lower end face of the valve core is 38.12mm. The calculation formula for the relative throttling area of the choke valve is as follows:

$$\begin{cases} C = |ac| = \sqrt{|1.87|^2 + (|ad| - 7)^2} \\ f_2 = \frac{78.12\pi\sqrt{1.88^2 + (27l - 7)^2}}{5026.55} \end{cases} \quad (14)$$

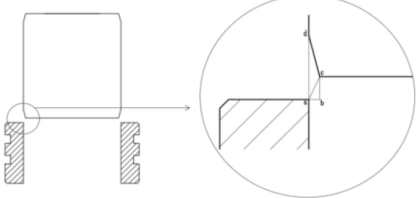


Figure 8. Schematic Diagram of the Choke Valve Core Opening State in Stage 2

The calculation formulas for the relative throttling area in both stages are plotted as curves and fitted, as shown in Figure 9. The fitted results indicate that the flow characteristics of the optimized cylindrical choke valve follow a parabolic pattern. The calculation formula [18] is given as follows:

$$C_V = C_{V100} \cdot \left(\frac{1}{R'}(1 + (\sqrt{R'} - 1) \cdot l)^2\right) \cdot \sqrt{\frac{1}{1 + (\frac{1}{s} - 1)(\frac{1}{R'}(1 + (\sqrt{R'} - 1) \cdot l)^2)^2}} \quad (15)$$

In the formula:

R and r are the upper and lower radii of the conical ring, respectively;

C is the generatrix length of the conical ring;

l is the relative opening degree of the valve core;

C_{V100} is the flow coefficient at full opening;

R' is the adjustable ratio;

s is the pressure drop ratio.

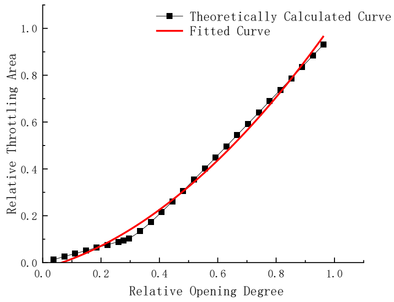


Figure 9. Relative Throttling Area and Fitting Curve of the Cylindrical Choke Valve

D. Model verification

Pressure Loss Test Experiment for the Valve-Based Continuous Circulation Drilling System: The power output was provided by a Model 190 diesel engine coupled with a Model CS-10-800 mud pump, with a theoretical maximum flow rate of 42 L/s. The test fluid was water with a dynamic viscosity of 0.001 Pa·s. During the experiment, the hose connected to the main circulation outlet was 8m long, the hose connected to the side circulation outlet was 10m long, and the return hose was 10m long. The test site is shown in Figure 10. The pressure loss test data from the main circulation circuit were used to validate the circulating pressure calculation model, while the data from the side circulation circuit were used to validate the computational fluid dynamics (CFD) simulation model for the side valve port of the continuous circulation sub.

Figure 10. Pressure Loss Test Experiment for the Valve-Based Continuous Circulation Drilling System

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

A comparison between the theoretically calculated pressure loss and the experimentally measured pressure loss for the main circulation circuit is shown in Figure 11. At a flow rate of 38 L/s, the maximum pressure loss error was 6.4% (0.016 MPa). A comparison between the computationally simulated pressure loss and the experimentally measured pressure loss for the side circulation circuit is shown in Figure 12. At a flow rate of 30 L/s, the maximum error was 7% (0.028 MPa). The comparisons demonstrate that the pressure fluctuation calculation model for the valve-based continuous circulation drilling system established in this study achieves high accuracy and can be reliably applied to subsequent research work.

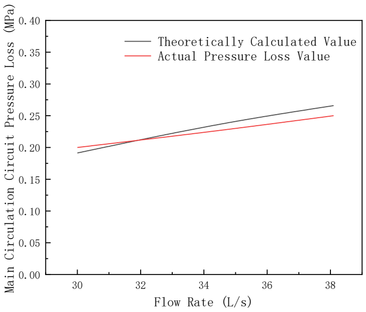


Figure 11. Comparison between Theoretically Calculated Values and Experimentally Measured Values

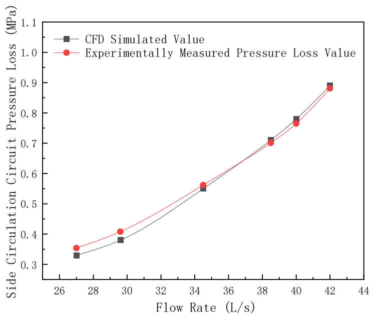


Figure 12. Comparison between Simulated Values and Experimentally Measured Values

IV. ANALYSIS OF PRESSURE FLUCTUATION PATTERNS AND INFLUENCING FACTORS

For the case study well JZ25, with a well depth of 2,156m, a pump flow rate of 2.5m³/min, a drilling fluid density of 1.2g/cm³, a plastic viscosity of 23mPa·s, a dynamic viscosity of 0.03Pa·s, a drill pipe inner diameter of 107mm, a drill pipe outer diameter of 127mm, a casing inner diameter of 216mm, a bit nozzle cross-sectional area of 1,442.93mm², a pipe absolute roughness of 0.086mm, a rotary hose and standpipe length of 60m, a newly connected drill pipe length of 30m, a side circulation high-pressure hose length of 10m, a main circulation circuit cavity volume of 0.6208m³, and a side circulation circuit cavity volume of 0.0726m³. Based on the established mathematic- al model of pressure fluctuations, the mechanism of pressure fluctuations during the switching process was analyzed, along with the patterns and influencing factors of pressure fluctuations under three switching process conditions: "no fluid replenishment, dual-circulation fluid replenishment, and replenishment line fluid replenishment". According to the pressure fluctuation mathematical model and the case well conditions, the calculated circulation pressure for the main circulation circuit was 8.95MPa, and for the side circulation circuit was 8.92MPa.

No Fluid Replenishment Process: This invol- ves performing pathway switching without any pre-replenishment of the standby pathway, by fully opening the choke valve to execute the switch.

Dual-Circulation Replenishment Process: This method controls the opening degree of the choke valve to partially divert drilling fluid from the active circulation pathway into the standby pathway until it is filled, after which the pathway switch is implemented.

Replenishment Line Replenishment Process: This utilizes an additional replenishment device to fill the standby pathway with fluid before executing the pathway switch.

A.Pressure Fluctuation Patterns During Switching with the No Fluid Replenishment Process

When the choke valve of the standby flow path was fully opened within 13s, 20s, 30s, 40s, and 50s, pressure fluctuation curves of the circulation flow path under different valve opening speeds were obtained, as shown in Figures 13 and 14. As can be seen from Figure 13, the total pressure of the main circulation circuit was approximately 8.95MPa. During switching using the no fluid replenishment process, significant pressure fluctuations occurred in the circulation flow path. When switching from the main to the side circulation path with the choke valve fully opened in 13s, the pressure fluctuation in the circulation flow path reached 2.44MPa, representing 27% of the total circulation pressure. Even when fully opened in the 50s, the pressure fluctuation still reached 2.10MPa, accounting for 23% of the total circulation pressure.

The opening speed of the choke valve in the standby flow path has a significant impact on pressure fluctuations during the switching process. The faster the valve opening speed, the more pronounced the flow diversion effect in the original flow path, resulting in a rapid decrease in flow rate and more evident water hammer effects, leading to greater pressure fluctuations. Compared to the pressure fluctuation value when the choke valve was fully opened in 50 s, the value when fully opened in 13 s increased by approximately 16% to 2.44 MPa.

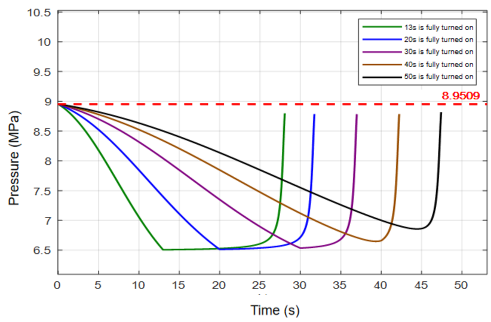


Figure 13. Pressure Fluctuation During Switching from Main Circulation to Side Circulation

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

As can be seen from Figure 14, the total pressure of the side circulation circuit is approximately 8.92MPa. During the switch from side to main circulation, since the main circulation circuit includes the rotary hose, standpipe, and newly connected drill pipe, its cavity volume is 8 times that of the side circulation circuit. Consequently, the pressure fluctuation duration during the side-to-main switching process is longer. When the choke valve is fully opened at the fastest speed of 13s, the pressure fluctuation in the circulation circuit is 2.44MPa, and it takes approximately 3minutes for the circulation pressure to stabilize. The opening speed of the choke valve in the standby flow path has minimal impact on the pressure fluctuation value during the side-to-main switch- ing process. The pressure fluctuation value when the choke valve is fully opened in 13s increases by only about 0.08% compared to when it is fully opened in 50s.

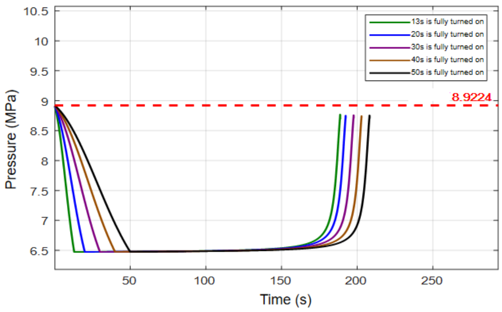


Figure 14. Pressure Fluctuation During Switching from Side Circulation to Main Circulation

B.Analysis of Pressure Fluctuation Patterns and Influencing Factors During Dual-Circulation Replenishment

a. Under Different Choke Valve Opening Degrees

When the opening degree of the choke valve in the standby flow path was set at 35%, 50%, 65%, and 80%, pressure fluctuation curves of the circulation flow path during both main-to-side and side-to-main switching processes under different choke valve opening degrees were obtained, as shown in Figures 15 and 16. During dual-circulation replenishment switching, the choke valve opening degree is a critical factor affecting pressure fluctuations. A smaller valve opening degree results in less drilling fluid diverted to the standby flow path, weaker flow diversion effects on the original circulation circuit, and consequently smaller pressure fluctuation amplitudes. However, a smaller opening degree also means a lower flow rate of drilling fluid entering the standby flow path per unit time, requiring a longer duration to reach the rated pressure. As can be seen from Figure 15, when the choke valve opening degree was 35%, compared to 80%, the pressure fluctuation in the main circulation circuit decreased from 1.98MPa to 0.68MPa, a reduction of 65.66%, while the pressure fluctuation duration increased from 35s to 75s.

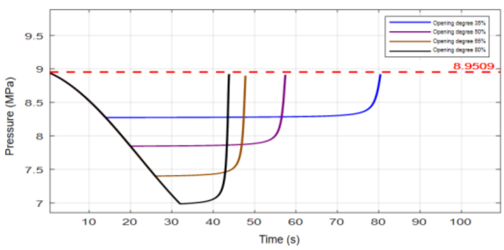


Figure 15. Pressure Fluctuation During Switching from Main Circulation to Side Circulation

As can be seen from Figure 16, the influence of the choke valve opening degree on the pressure fluctuation value during side-to-main switching is generally consistent with that during main-to-side switching. However, due to the larger cavity volume requiring replenishment, the impact of the choke valve opening degree on the pressure fluctuation duration is more pronounced. The smaller the opening degree, the longer the replenishment time. The pressure fluctuation duration at an 80% opening degree is 235s, while at a 35% opening degree it extends to 632s, representing an increase of 168.94%.

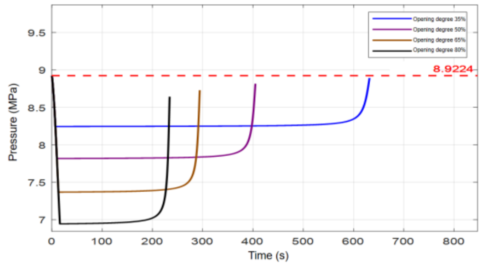
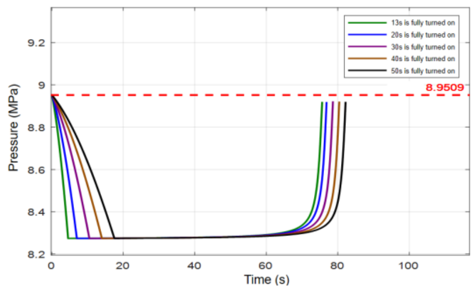


Figure 16. Pressure Fluctuation During Switching from Side Circulation to Main Circulation

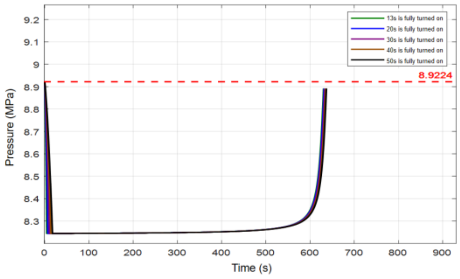
b.Different Opening Speeds of the Choke Valve

Under the precondition of implementing minor pressure fluctuation control with a choke valve opening degree of 35%, the pressure fluctuation curves of the circulation flow path during both main-to-side and side-to-main switching processes were analyzed when the choke valve was opened to 35% in 13s, 20s, 30s, 40s, and 50s, as shown in Figure 17. As can be seen from Figure 17(1), during main-to-side switching, comparing the pressure fluctuations at the two opening speeds of fully opening in 13s and fully opening in 50s, the pressure fluctuation value decreased by 0.08%, while the pressure fluctuation duration increased by 7.89%. As can be seen from Figure 17(2), during side-to-main switching, due to the large volume of the main circulation line requiring replenishment, the replenishment time was as long as 620s. Compared to fully opening in 13s, the fluctuation value when fully opening in 50s decreased by only 0.02%, and the pressure fluctuation duration increased by only 1.11%. Therefore, during dual-circulation replenishment switching, under the same valve opening degree condition, the opening speed of the choke valve has minimal impact on both the pressure fluctuation amplitude and duration, and this is particularly evident during the side-to-main switching process.



(1)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

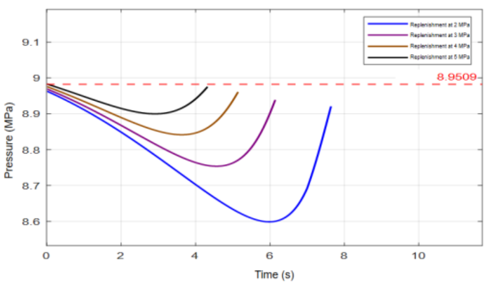


(2)

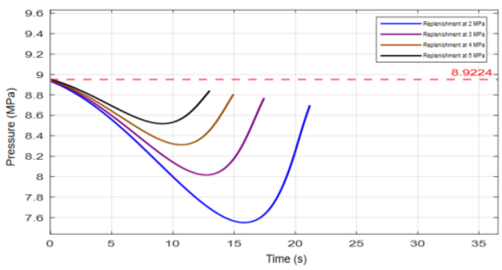
Figure 17. Influence of Valve Opening Speed on Pressure Fluctuations at 35% Opening

C. Degree During Dual-Circulation; Pressure Fluctuation Patterns During Replenishment Line Fluid Replenishment

Using a certain type of replenishment equipment (3DP110 plunger pump, dimensions approximately 1.6×1.1×1.8 m) for fluid repleni- shment operations, pressure fluctuation curves of the circulation flow path were obtained at different replenishment pressures (2, 3, 4, and 5MPa) for the standby flow path, as shown in Figure 18. As can be seen from Figure 18(1), at a replenishment pressure of 5MPa during the main-to-side switching process, the pressure fluctuation value was 0.05MPa, and the circulat- ion pressure stabilized within approximately 5s. Compared to replenishment at 2 MPa, the press- ure fluctuation value decreased by 85.49%, and the pressure fluctuation duration was reduced by 37.50%. As can be seen from Figure 18(2), at a replenishment pressure of 5MPa during the side-to-main switching process, the pressure fluctuation value was 0.40MPa, and the circulation pressure stabilized within approxima- tely 13s. Compared to replenishment at 2MPa, the pressure fluctuation value decreased by 70.58%, and the pressure fluctuation duration was reduced by 38.10%. Therefore, during switching using a separate replenishment line, the closer the replenishment pressure of the standby flow path is to the pressure of the circulation flow path, the smaller the amplitude and shorter the duration of pressure fluctuations during the switching process.



(1)



(2)

Figure 18. Influence of Replenishment Pressure on Pressure Fluctuations During Replenishment Line Fluid Replenishment

V. CONCLUSIONS

During switching using the no fluid replenis- hment process, significant pressure fluctuations occur in the circulation flow path. In the main-to-side switching process, the opening speed of the choke valve in the standby flow path has a pronounced impact on pressure fluctuations during switching. The faster the valve opening speed, the more significant the flow diversion effect in the original flow path, resulting in a rapid decrease in flow rate, more evident water hammer effects, and consequently greater pressure fluctuations. In the side-to-main switching process, the cavity volume of the main circulation circuit is much larger than that of the side circulation circuit, leading to a longer duration of pressure fluctuations during side-to-main switching. However, the opening speed has minimal impact on the pressure fluctuation values during the side-to-main process.

During dual-circulation replenishment switc- hing, a smaller choke valve opening degree results in less drilling fluid being diverted to the standby flow path, leading to a weaker flow diversion effect on the original circulation circuit. Consequently, the amplitude of pressure fluctuations is reduced. However, a smaller opening degree also means a lower flow rate of drilling fluid entering the flow path requiring replenishment per unit time, thus requiring a longer duration to reach the rated pressure. During side-to-main switching, when the cavity volume requiring replenishment is large, the influence of the choke valve opening degree on the pressure fluctuation duration becomes more significant.

The standalone replenishment line method demonstrates superior performance compared to the dual-circulation replenishment method. When the replenishment pressure approaches the circulation circuit pressure, both the amplitude and duration of pressure fluctuations during the switching process are significantly reduced. However, the additional replenishment pump required for this method will lead to increased costs and exacerbate space occupancy on the platform.

REFERENCES

[1] JENNER J W,ELKINS H L,SPRINGETT F,et al.The continuous circulation system: An advance inconstant pressure drilling [C].SPE 90702 -MS,2004. doi:10. 21 18/98947- MS.

[2] Ayling L J,Jenner J W,Elkins H.Continuous circulation drilling[R].OTC 14269,2 002.

[3] Ayling L J.Continuous circulation drilling Meth- od:US,6315051B1[P].2001-11-13.

[4] Yue J X,Liu Y C,Wang G D. Design and simulation St- udy on continuous circulation valve drilling system ［J］.IOP ConferenceSeries：Earth and Environmental Science,201 9,242(3):032036.

[5] Vogel R. Continuous circulation system debuts with co- mmercial successes offshore Egypt,Norway[J].Drilling Cont- ractor,2006,62(6):50-52.

[6] Wang Zhiwei;. Research on the Mechanism of Pressure Fluctuation During the Diversion Process of Continuous Circulation Valve Drilling System [D]. Chengdu: Southwest Petroleum University, 2018.

[7] Angelo Calderoni , Giorgio Girola, Michele Maestrami,etc.Micro-flux control, E-CD continuous circulation valves allow operator to reach HPHT reservoirs[J].OFFSHORE DRILLING,2009, 7:58-62.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

[8] Hu Zhijian; Ma Qingfang; Wang Aiguo;. Structural De- sign and Hydraulic Characteristics of the Diversion Manifold in Continuous Circulation System [J]. China Petroleum Machinery, 2011, v.39; No.394(12).

[9] Zhang Wunian; Jia Yinge; Zhang Jing; Luan Bo;. Disc- ussion on the Industrial Application of Valve-Type Continuous Circulation Drilling System [J]. Oil Drilling & Production Technology, 2014, v36; No.216(06).

[10] Sui Yue; Ma Qingfang; Hu Zhijian;. Mechanism of Pr- essure Fluctuation During the Diversion and Pressure Boosting Process in Continuous Circulation Drilling System [J]. China Petroleum Machinery, 2015, v.43; No.438(08).

[11] Tian Zhixin; Li Wenjin; Zhang Wunian; Jia Yinge. Application of Valve-Based Continuous Circulation Drilling Techno- logy in Extended-Reach Wells of Panyu Oilfield[J]. Oil Drilling & Production Technology, 2017, v.39; No.232(04).

[12] Wei Chenxing; Zeng Junwen; Zhu Xuewei; Xu Xueyan; Cao Jinchao; Kong Weiying. Study on the Influence of Flow Path Switching in Continuous Circulation Drilling Manifold on Pressure[J]. China Science and Technology Information, 2021, v.31; No.798(12).

[13] Xin Lei;. Research on Water Pressure Loss in Long-Distance Water Supply Firefighting Systems [D]. Beijing Forestry University, 2014.

[14] Niazkar M, Talebbeydokhti N. Comparison of Explicit Relations forCalculating Colebrook Friction Factor in Pipe Network Analysis Usingh-based Methods[J]. Iranian Journal of Science and Technology-Transactionsof Civil Engineering, 2020, 44(1): 231-249.

[15] HAALAND S E. Simple and explicit formulas for the frictionfactor in turbulent pipe flow[J]. Journal of Fluids Engineering,1983, 105(1): 89-90.

[16] Liu Jubao; Yao Liming; Li Xingyue; et al. Experimen- tal and Numerical Simulation of Pressure Loss for Sand-Laden Fracturing Fluid in Converging-Diverg- ing Pipes [J]. Acta Petrolei Sinica, 2019, 40(1): 86-98.

[17] Shi Wenzhuo. Research on Key Technologi- es and Applications of Ultra-High Press- ure Large Flow Proportional Relief Valves and Throttle Valves [D]. Zhejiang University, 2019.·

[18] Wang Xiujuan, Qiu Xuanzhen, Wang Weiguo. Theory and Practice of Engineering Design Estimation for Control Valves [C]. Proceedings of the 6th Industrial Instrumentation and Automation Confere- nce, Shanghai: Chinese Association of Automation, 2005.