

Research and application of plugging technology for fractured formation in Yihuang block

Yan Sun

Drilling & Production Engineering Technology Institute, CNPC Chuanqing Drilling Engineering Company Ltd., Xi'an, Shaanxi, 710018, China

Abstract: The formation drilling in Yihuang block is prone to loss and difficult to plug. Through field practice and mechanism analysis, it is concluded that the leakage in this block is mainly caused by the propagation of micro-fractures and the connection of natural fractures. In view of the leakage characteristics of the block, the indoor study is carried out, and all the plugging materials in the plugging zone are cemented and solidified with gel materials, forming a plugging working liquid called Dust-1. The working fluid works at well temperature of 50~60°C, curing strength of 24 hours is 28MPa, good fluidity, strong pressure bearing capacity and can be cured. In the field test of 7 Wells in Yihuang block, the drilling cost is reduced by 15%, and the pressure bearing capacity of leakage layer is increased from 1.19g/cm³ to 1.25g/cm³, indicating that this technology can meet the plugging needs of differential pressure induced fracture loss in Yihuang block.

Keywords: Yihuang block; crack leakage; plugging; cementing.

1. Introduction

Yihuang block is the key area of gas exploration in Changqing Oilfield in recent years. During the drilling process, many Wells have leakage, which leads to high drilling cost, delay drilling operation time, prolong the whole drilling cycle, and may damage oil and gas layers and interfere with geological logging. In Yihuang block, the vertical depth of wellbore is shallow, the same well section has many leakage points, and the length of single-layer leakage section is up to 60m. Therefore, it is necessary to rush drilling for plugging for many times, resulting in low plugging efficiency and great downhole risk. With the fluctuation of downhole pressure, the plugging agent can not enter the leaking layer or seal the door. When circulating drilling or increasing density, the cracks open and plugging failure. The main well loss formations are Liujiagou formation and Shiqianfeng Formation, and most of them are recurrent well losses. In view of the problem of formation leakage in this block, the leakage mechanism was analyzed, and a high-strength, curable leak plugging treatment agent was developed and applied in the field, and good results were obtained.

2. Leakage characteristics and mechanism analysis

Natural fractures exist in various layers of Yihuang block, such as Yanchang Formation, Liujiagou Formation, Shiqianfeng Formation, Shihezi Formation and Shanxi

Formation. According to the field practice, the loss type of yihuang block is mainly induced by pressure difference, and the main reason is the poor bearing capacity of the formation. The obvious characteristic is that the loss will increase with the increase of the specific gravity, viscosity and shear force of drilling fluid, and will change with the different bearing capacity of the formation. The loss rate is determined by the size of the crack. The slow loss rate can maintain the circulation, and the loss of return phenomenon occurs when the loss rate is larger [1-3].

The key leakage zones in this block are Liujiagou and Shiqianfeng. The characteristics of the loss are as follows: (1) The large loss is mainly concentrated in liujiagou and Shiqianfeng strata; (2) the same open hole section of multiple layer leakage (3-8 leakage layer), the same leakage layer continuous long vertical cracks, vertical cracks and leakage of a single continuous long 10 to 60 m), the leakage hole drilling leakage lack of speed control technology, lead to leakage layer is required for a continuous period of drilling section plugging for many times, need many times to rob drilling plugging, sand card risk big, the plugging efficiency is low; (3) The double stone layer is easy to collapse, and when the density increases, the well leakage recrudeses, and it is difficult to determine the specific recurrence layer; (4) the crack is greatly affected by pressure excitement and sand settling, and it is lost when drilling, and the crack is "pseudo closed" when plugging, and the plugging material can not effectively enter the leaking layer.

Scanning electron microscopy (SEM) analysis of shiqianfeng and Shihezi strata in Yihuang block shows that The Shiqianfeng Formation is a fractured formation, while the Shihezi Formation is a fractured formation with dissolution pores, intergranular pores and fractures. See Figure 1 and 2.

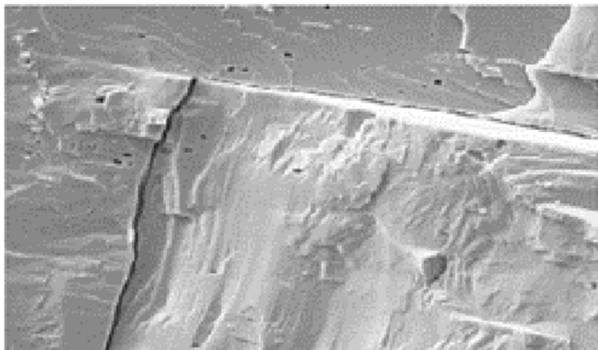


Fig. 1 Sem of shiqianfeng Formation Core

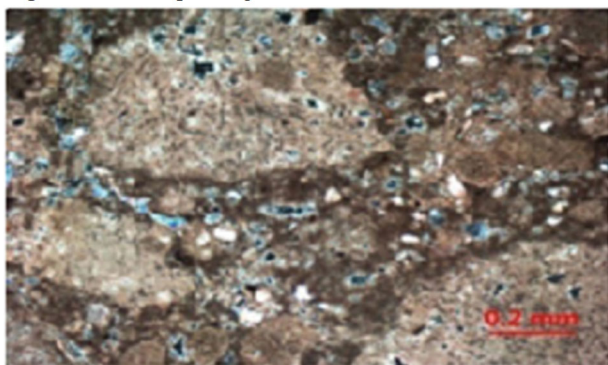


Fig. 2 SEM of Stone Box Formation core
 Many researchers have shown that[4-6], combined with on-site plugging analysis and based on a large number of experimental studies, put forward a new concept of fracture leakage plugging evaluation: namely, conventional bridging plugging material has four states for plugging cracks: door sealing state; throat sealing state; waist sealing state; tail sealing state.
 It is found that the distribution and development of fractures in the prolonging section of core are very uneven and random. Most are tensile cracks, static closed or reduced, plugging agent can not enter the leak layer, circulation drilling open, leakage recurrence; The success rate of plugging is low and the recurrence rate is high. In Liujiagou formation, pressure differential leakage and fracture leakage coexist, and it is difficult to accurately match the size of plugging agent with the porosity of leaking layer, resulting in "door sealing" phenomenon. A layer of multi-point leakage (2-4 leakage points), the same leakage point vertical fracture continuous length (10-60m); The crack is greatly affected by the pressure and sand settling, and it is lost when drilling, and the crack is "pseudo closed" when plugging, and the plugging material can not effectively enter the leaking layer. The stone box is vertical crack, and the crack of the lower shaft wall is filled in by drilling cuttings/plugging agent, forming a false sealing door. When the upper shaft wall is crowded, the plugging slurry is entered. After the squeezing is stopped, the plugging slurry is returned to the

wellbore due to gravity, and the plugging effect is poor. See Figure 3 for the distribution of leakage layer in this block.

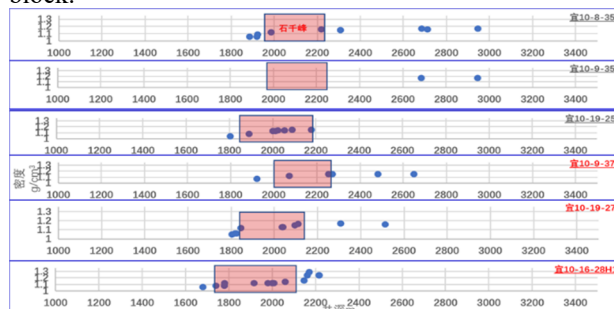


Fig. 3 Leakage distribution map of Yihuang block
 The block formation pressure differential leakage and fracture leakage cause of formation pressure is low, therefore, to prevent leakage, solve the leakage occurred in the process of drilling well, using multistage particles mixed plugging material primarily, by the effective collocation and combination of differential pressure leakage effectively plugging and natural through crack leakage, to prevent further invasion of drilling fluid.

3. Study on the formulation of anti-leak plugging agent

Research ideas and optimization of treating agent
 Accurate matching of plugging agent size and leak layer pore is the premise of effective plugging of leakage channel. According to the characteristics of leakage velocity and the prediction of leakage channel size, the formula design of plugging agent in Yihuang block is as follows: after plugging material enters large cracks, the initial structure is carried out by structuring grains; To multidimensional particles with high strength and rigidity to fill cracks in medium, after by three-dimensional fiber material to block, block with the tiny gap seal belt with gelling materials finally all plugging material in the mesh cementation solidification, form the high strength seal wall, to meet the requirements of a wide range of crack and higher bearing capacity. On the basis of previous studies and analysis of research ideas, the indoor preferred plugging material is shown in Table 1, so as to form the plugging slurry formula and conduct performance evaluation.

Table 1 Multicomponent rigid gel plugging material table

Plugging agent	type	particle size, mm
Crystalline materials	deformable	<0.5
Composite plugging agent	bridge material	0.3-2.0
Stereofiber fiber binding material	fiber	<0.5
	Gel	<0.5

Study on the formulation of plugging agent
 Crystal structuring agent and its additive optimization
 The grain size and its addition have an important effect on the effective adhesion of multi-dimensional particles and curing properties of plugging fluid. In order to determine

the optimal ratio of different types of plugging agents, 5% bentonite slurry was used as the base slurry to select the structure-crystal material.

Table 2 Comparison of curing time and compressive strength of crystallizer

Item	Cure time of 70°C,min	compressive strength of 70°C、24h,MPa	compressive strength of 70°C、72h,MPa
GJJ-I	90	28	62.5
GJJ-II	45	35	54.5
GJJ-III	24	40.5	42.3

It can be seen from Table 2 that GJJ - iii has the fastest curing speed and the early strength increases rapidly. This is because the internal crystal of GJJ - iii has large pores and a relatively loose structure, resulting in a relatively large internal specific surface area. At the same time, according to the plugging process requirements, convenient for on-site slurry and pumping requirements, plugging working liquid can not cure too fast. Therefore, GJJ - i type was selected as the main crystal structuring agent.

To facilitate observation and description, the static evaluation method of gel strength was referred to [7-9]. According to the different forms of the curing process of plugging slurry, the curing process can be divided into four grades from weak to strong: A, B, C and D. The order is:A, good liquidity; B. Loose packing with large consistency; C, plasticine shape, has been cured; (not pumpable)D. Solidified body with integrity.

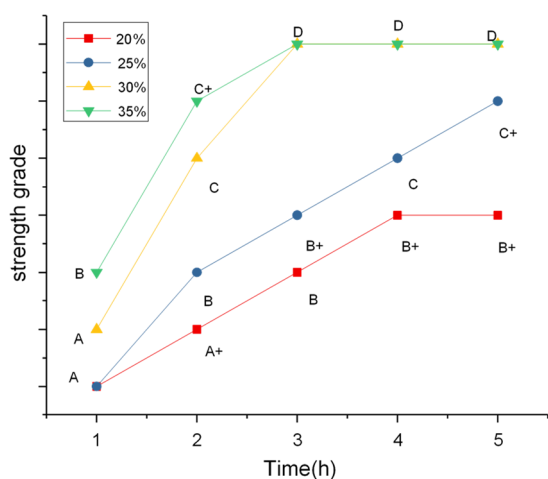


Fig. 4 Influence of addition of crystal agent at 80°C on curing strength of working liquid

It can be seen from Figure 6 that when the amount of structurizer is 35%, the curing speed of plugging slurry is too fast, which affects the safe pumping of construction. When the dosage is 20%, the curing strength of plugging slurry is low, which affects the plugging effect. Therefore, the suitable dosage range of structuralist solidified material in plugging slurry is 25%-30%.

Determination of organic cementitious materials and analysis of flow pattern characteristics

By the structure of polymer gel network , make the crystal solidification of each crystal link closely, at the same time can reduce the amount of crystal agent, and finally form a curing body with elastic structure. According to a certain ratio, the organic crosslinking adhesive was added into the working liquid of crystal curing plugging, and the curing condition of the working liquid was observed. See Table 3.

Table 3 Ratio of crosslinked adhesive and crystalline curing

Crystalline curing material, (CS)%	Crosslinking adhesion, (CA)%	Curing conditions
30	5	60°C, 30min whole curing, elastic solid 60°C,
25	5	50minwhole curing, elastic solid 60°C,
20	5	70minwhole curing, elastic solid 60°C,
20	3	90mincuring, low intensity 60°C,
20	7	50mincuring, high intensity 60°C,
20	10	20mincuring, high intensity

Curing effect of plugging working fluid is shown in Figure 7.



Fig. 5 Curing effect of crosslinked bonding and crystalline curing compound working fluid

As can be seen from Figure 7, a complete cured body can be formed under the combined action of crosslinked adhesion and crystalline solidification, which has viscoelastic properties. When a certain amount of crosslinking adhesive is added, the cured body has good toughness and is not easy to break under the action of external forces. The plugging working fluid at 60°C, curing time in 20~90min (The higher the content of crosslinking adhesive, the faster the curing time). Therefore, the plugging working liquid system is suitable for the leakage layer of 50~60°C well temperature, the plugging working liquid flow performance is good, the ratio of 20%~30% crystalline solidified material +5% crosslinking agent is more appropriate.

Compound plugging agent, three-dimensional fiber size determination

At present, compound plugging agent has gradually replaced single inert bridge plugging agent and become the main plugging agent for well loss treatment in oilfield. According to the fracture width of Yi Huang block, rigid particles with particle sizes of 0.3-0.5mm, 0.5-1.0mm and 1.0-2.0mm were selected as composite plugging agents to fill medium cracks in the formation. At the same time, stereoscopic fibers with a length of 0.5-2.0cm were selected to block micro-cracks in the formation.

The dosage of compound plugging agent was determined by pressure test of QD-2 plugging material tester. QD-2 plugging material tester simulates the pressure intensity of plugging agent in the formation by air pressure, and simulates the width of cracks in the formation by different seam plate widths. By applying pressure to plugging fluid, the loss of plugging slurry in different widths of joint plate is investigated, and then the retention and plugging ability are judged. Test results of filtration loss of seam plate (5mm) and working fluid load are shown in Table 4 under the premise that the working fluid is pumped normally in pipes before plugging fluid is solidified.

Table 4 The effect of the amount of plugging material on the performance of the working fluid

dosage,%	fluidity,cm	experimental results
5	21	A total of 550mL leakage to 3.5mpa process, pressure to 5MPa all leakage
10	19	In the process of 3.5mpa, a total of 200mL leakage, pressurized to 5MPa, a total of 500mL leakage
15	18	In the process of 3.5mpa, a total of 180ml leakage, pressure to 5MPa stable 30min without leakage
20	15	A total of 130ml leakage occurred during the process of reaching 3.5mpa, and no leakage occurred after 30min of stabilization after pressurizing to 5MPa
25	12	A total of 80ml leakage during the process to 3.5mpa, and no leakage after 30min after pressurization to 5MPa

It can be seen from Table 4 that when the addition of compound plugging agent is 15%~20%, the retention effect of plugging working fluid at the crack is better, and the flow performance meets the requirements of pumping. Therefore, the suitable dosage of plugging agent is set at 15%~20%.

The gel strength tester was used to evaluate the working fluid adding three-dimensional fiber, and the material was mixed and cured to make a molding test block (φ 5×3). The compressive strength of the molding test block was tested, and the measured value was the maximum pressure (g/cm² or kg/cm²) that the unit force area could bear.

Table 5 Comparison of main parameters of crystal solidified bridge plug plugging working fluid before and after solidification

	Fluidity, cm	Density, g/cm ³	Curing time, min	Curing strength
No fiber plugging fluid	26	1.23	120	Integral solidification, micro indentation, 0.8kg/cm ²
fiber plugging fluid	17	1.63	135	Hardening and consolidation, no indentation, 4.3kg/cm ²

It can be seen through the appropriate size of the intervention of bridge plug, not just to improve its working liquid filtration, effective retention in the gap between, the binder and the each other between different aggregate function can effectively prevent or remedy may be produced by rapid solidification block, subsidence volume, ensure good integrity at the same time, with better bearing capacity.

Through the above experiments, the optimal plugging formula is determined as follows: 8% base slurry +25%~30% crystal structure agent +15%~20% compound plugging agent +5% Three-dimensional fiber +5% organic binder, forming a plugging working liquid dust-1, the curing time and curing strength of the working liquid are in line with the field plugging conditions.

4. Field application

By the self-innovated plugging fluid, 7 Wells were completed in Yihuang, the cost of drilling fluid was reduced by 15%, and the effect of preventing and treating leakage gradually appeared which significantly effective. Taking well Y10-16-28 H1 as an example, the paper introduces the effect of leak-plugging working fluid DLY-1. The designed well depth of Y10-16-28 H1 is 4101 meters, and the designed horizontal section length is 1500 meters. According to the data of adjacent Wells, the block is in the low-pressure shallow leak-prone area, and multiple leak-points coexist in the same well section with leakage frequency, which is prone to recurrence. It is

difficult to accurately judge the leak-points, and the on-site plugging construction is difficult. In the process of drilling, it is found that the vertical depth of the well, many leakage points, easy to relapse; Liujiagou and double stone layer easy leakage, shiqian Feng the most serious; Compared with conventional Wells, the second opening section of the horizontal well has higher construction density and more times of well loss, so it can be judged that the well may be a large-scale fracture-cave type of malignant loss. The fractures are mainly vertical and the fracture opening is large. There are large penetrating fractures from top to bottom of the stratum, which makes the formation bearing capacity of the well low. When the well was drilled to 1680 meters, the Liujiagou group used the leak prevention formula in advance. After drilling to 1779 meters, the second time of plugging while drilling failed with a leakage rate of 12-16 m³/h. The self-developed plugging working fluid for the formation with large penetrating fractures was used for plugging operation. The well has a total of 15 leaking layers, with 7 times of squeezing and sealing, 1 time of pure cement, and 9 times of self-developed dust-1 working fluid.

Table 6 Leakage point of Well Yi 10-16-28H₁

Well depth, m	Leakage situation	Plugging measures	Effects
1680	4-5m ³ /h	plugging while drilling	Down to 2-3 square feet per hour
779	12-16m ³ /h	plugging while drilling, DLY-1	successful
1780	Well head loss to return	plugging leakage accompanied with pressure	Squeeze into 16 square, unstable pressure, reduce drilling parameters while drilling plugging
1916	Well head loss to return	plugging leakage accompanied with pressure	Squeeze in 16.4 m ³ plugging slurry, reduce parameters to resume drilling
1980	12m ³ /h	plugging while drilling	Down to 1-2 square feet per hour
2008	Well head loss to return	plugging while drilling, DLY-1	successful
2147	Well head loss to return	plugging leakage accompanied with pressure, DLY-1	successful
2162	Well head loss to return	Static plugging; Pressure plugging; cement plugging, DLY-1	successful
2171	31m ³ /h	plugging leakage accompanied with pressure, DLY-1	successful
2168.88	Well head loss to return	plugging leakage accompanied with pressure	successful
2216	20-40	plugging leakage accompanied with pressure	successful
2217	8-15	DLY-1	successful

After the failure of other plugging technologies, the well adopts leak plugging working fluid DLY-1 for 9 times successfully. The loss time is 499h, and the formation bearing capacity increases from 1.19g/cm³ to 1.25g/cm³, ensuring the smooth entry of the deviant section into the window.

At the same time, Yi 10-7-35 well was constructed by the outsourcing team. The drilling cycle of the first well was over 90 days due to technical difficulties, and the drilling team was forced to withdraw due to difficulties in breaking through the technical bottleneck. Changqing drilling construction team continued the construction, using this technology to continuously operate two Wells within 24 days of drilling cycle control, loss reduction by 60%.

5. Conclusion

The analysis of well loss data and the study of rock characteristics show that the formation in Yihuang block has poor bearing capacity, and the well loss is mainly caused by pressure difference and fracture. And when plugging the crack "false closure", plugging material can not effectively enter the leaking layer. According to the characteristics of formation leakage in Yihuang block, a working fluid DLY-1 for plugging has been developed. The working fluid works at 50-60 °C and has a curing strength of 28MPa in 24 hours. It has good fluidity, strong bearing capacity and can be cured. Nine field plugging experiments have been carried out with leak-plugging working fluid Dust-1, all of which have achieved a success. The construction period is shortened, and the formation bearing capacity is increased from 1.19g/cm³ to 1.25g/cm³, which provides a guarantee for smoothly entering the window of the deviated well section and supports the smooth drilling operation of the block.

Reference

1. Cao Cheng, Pu Xiaolin, Wang Gui, et al. Research on the sealing performance of sealing agents for water-based drilling fluids. Applied Chemical Industry. 2015 (02) 247-249.
2. Ehsan Sabooniha, Mohammad-Reza Rokhforouz, Shahab Ayatollahi. Pore-scale investigation of selective plugging mechanism in immiscible two-phase flow using phase-field method. 2019, 74.
3. Bao Dan, Qiu Zhengsong, Zhao Xin. et al. Outlook on the Research on Intelligent LCM with Temperature Sensitive Shape Memory Property. Drilling Fluid & Completion Fluid. 2019 (03) 265-272.
4. Zhu Huaijiang, Tan Zhongliang, Sheng Deqiang, et al. A Study on Evaluation of Relative Strength for Different Polymer Gels Used at Oil Fields. Oilfield Chemistry. 2001 (03) 255-259.
5. Sun Huan, ZHU Mingming, Wang Weiliang et al. Prevention and plugging technology of ultra-long horizontal section in HuaH90-3 well, Changqing

- Shale oil horizontal well. *Petroleum Drilling Technology*.2022(01).
6. XU Chengyuan, YAN Xiaopeng, KANG Yili, et al. Mechanism and strengthening method of sealing layer structure instability in deep fractured reservoirs. *Petroleum Exploration and Development*. 2020(02).
 7. Chen Jiayu. Experimental study on high-efficiency Fiber leakage prevention and plugging technology. China University of Petroleum (East China) 2019.
 8. Zhao Zhengguo. Theoretical and experimental study on prevention and plugging of drilling fluid for strengthening wellbore Southwest Petroleum University.2016.6:23-34.
 9. Yang H J, QIAO A X, Wei S B, et al. Study on properties of composite polyacrylamide gel. *Journal of Xinjiang Petroleum Institute*. 2000(03).
 10. Liu Guo-bao, Sun Ming-ze. Preparation and performance evaluation of heat resistant gel system. *Oilfield Chemistry*. 2019(04).