Wellbore Stabilization Technology for Fractured Formation in Shunbei No.5 Fault

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Abstract. Basic geological background, drilling fluid formulation optimization and field application were carried out aiming at the technical problems of multiple blocks in Shunbei Oilfield when collapsing strata and collapsing and blocking frequently. The lithology of the fracture zone is non-clay minerals. After the drilling fluid or filtrate is eroded, the self-developed pore network is easily pressurized and connected, which reduces the adhesion of the bedding interface, which in turn induces large-scale spalling and slump stuck. Based on the mechanism of the instability of the borehole wall, a submicron-micron (0.1-100μm) comprehensive and effective plugging is proposed to prevent drilling fluid or filtrate from invading the formation pores and fractures around the well, and at the same time ensure that the drilling fluid has an efficient rock-carrying solution. The technical achievements carried out on-site tests at Shunbei No. 5, based on the original Sikai high-temperature polysulfonate drilling fluid, optimized the indoor formulation, and developed a wellbore stable drilling fluid suitable for broken formations. During the application process, there were no drilling accidents such as block blockage, which was the shortest record of drilling time in the reservoir section of the block.

1. Geological Background of Broken Strata
Shunbei oilfield is composed of a series of carbonate fault solution marine oil and gas reservoirs distributed along the fault zone with a buried depth of more than 7000m. It has the characteristics of oil-bearing and uneven enrichment along the fault zone as a whole. The geological prediction of Shunbei y well deployed in this block is that in 7830-7920 m drilling, the fracture surface is encountered, the formation is broken and the stress is concentrated, and there is a huge risk of collapse and block falling in the process of directional drilling. The other is the key to the stability of the wellbore[1-3]. The mechanism of drilling fluid stabilizing the sidewall is analyzed. The wellbore stabilizing drilling fluid suitable for fractured formation drilling is developed. The drilling is carried out in the well Y formation in the north of the well, which helps to overcome the difficulty of collapsing and collapsing of the broken strata.

Through the physical property analysis of 7468-7486m interval core of the same Ordovician Jianfang formation, which belongs to the adjacent well of No.5 fault zone, the lithology of Shunbei y well is analyzed by reference. The total coring length is 18m, which is divided into 27 layers according to the core lithology and oil-gas situation. See Table 1 for the lithology, fracture and structure characteristics of some representative cores of the Ordovician Yijianfang Formation in the adjacent well.

As shown in Table 1, the coring location of the 8-layer core is 7470.12-7486.90m long, and the recovery rate is 100%; the lithology composition is gray micrite limestone, hard and brittle, which is micrite structure and sand debris micrite structure. It is mainly composed of argillaceous calcite, with a small amount of black asphaltene and yellow pyrite aggregates, all of which are non-clay minerals.
and have anhydrous swelling effect; the overall cracks and holes are relatively developed, with 2 flat seams, 14 sutures, 3 corrosion pores and some surface reticulated sutures; the cracks and holes are mostly collected by black asphaltene, gray white semi idiomorphic calcite and yellow pyrite Half filling - full filling.

**Table 1.** Stratigraphic properties of the Ordovician Yijianfang Formation in Well Y, Shunbei

| Well depth / m | Lithology | Lithology characteristics | Matrix /% | Fractures and structural features |
|----------------|-----------|--------------------------|-----------|----------------------------------|
| 7470.12 ~ 7472.20 | Grey micrite limestone; hard and brittle, dense; micrite calcite | Mud crystal structure | 100 | 1 flat suture and 5 sutures are developed, and 3 corrosion pores are developed along the suture |
| 7472.59 ~ 7474.10 | Mud crystal structure | 100 | 3 sutures and seamless holes developed |
| 7474.36-7476.00 | Mud crystal structure | 100 | 3 sutures, 2 dissolution pores and seamless pores are developed |
| 7474.36 ~ 7476.00 | Mud crystal structure | 100 | Development of surface mesh suture and seamless hole |
| 7476.63 ~ 7477.80 | Sand crystal structure, 30% | 70 | Development of surface mesh suture and seamless hole |
| 7478.58 ~ 7479.66 | Sand crystal structure, 30% | 55 | 1 flat seam developed |
| 7479.66 ~ 7480.81 | Grit structure of grit, 15% grit, 30% asphaltene | 55 | 3 sutures and seamless holes developed |
| 484.00 ~ 7486.90 | Sand crystal structure, 30% | 85 | Development of surface mesh suture and seamless hole |

### 2. Optimization of Drilling Fluid

#### 2.1. Evaluation of High Temperature Resistant Polysulfonate Drilling Fluid

Before the fourth spud in, the field drilling fluid was transformed into a high temperature resistant polysulfonate drilling fluid system, which is basically composed of bentonite + sodium carbonate + caustic soda + high temperature and salt resistant fluid loss reducer + asphalt anti sloughing agent + ultra-fine calcium carbonate + unidirectional pressure shielding agent + barite + crude oil. After the completion of the transformation, the drilling fluid was evaluated indoor and analyzed to find out the reason why it is difficult to maintain the stability of the broken formation wall, and lay the foundation for the subsequent performance optimization design.

Sikang high temperature resistant polysulfonate drilling fluid lacks solid particles with a particle size of 10-100 μm, and the particle size distribution is too centralized. In view of the characteristics of the development of bedding pores and fractures in the fractured formation, the field drilling fluid can not achieve the reasonable particle size distribution among small, medium and large particles, and can not quickly form the mud cake with permeability close to zero and thin and tough, so it is difficult to fundamentally inhibit the drilling fluid filtration, curb the hydraulic wedge and improve the pressure bearing capacity of the high layer.
2.2. Optimization of Drilling Fluid Indoor Formula

The indoor evaluation and analysis show that the drilling fluid with high temperature and polysulphonate resistance in the fourth spud has the characteristics of low dynamic plastic ratio, large high temperature and high pressure filtration and too concentrated solid particle size distribution, which fails to meet the requirements of drilling fluid optimization design index and can not guarantee the well wall stability during drilling in the broken formation in the fourth spud. In view of this, select the types of filtrate reducer, optimize the dosage of five customized high-efficiency plugging and anti sloughing agents, and optimize the drilling fluid formula.

1) Optimization of filtrate reducer. The performance test results of four different formulations of drilling fluid show that pac-lv has the best effect compared with tsh-ii and lv-cmc, which can inhibit the high temperature and high pressure filtration, enhance the compactness of mud cake and meet the optimization design index. In view of this, pac-lv is selected as the core filtrate reducer.

2) Optimization of dosage of high efficiency plugging and anti collapse agent. Combined with the field application experience and laboratory small-scale experiment, it can effectively enhance the plugging performance of drilling fluid to determine the optimal dosage, reasonably grade rigid particles and plastic particles, and supplement solid particles with particle sizes of 0.1-1 μm and 10-100 μm. The results show that the low adhesion between the rigid plugging material in the pore throat and the fracture wall and the easy sliding are the important reasons for the poor plugging effect. The rigid plugging material with different particle size, supplemented by the plastic plugging material with suitable softening point, can realize the comprehensive plugging with the particle size of 0.1-100 μm, at the same time, the adhesion between the rigid and plastic materials under the high temperature and high pressure at the bottom of the well can be used to improve the hole fracture The wall friction enhances the sealing effect at the crack entrance near the shaft wall.

2.3. Borehole Stability Drilling Fluid Indoor Evaluation

Based on the indoor evaluation and optimization of the drilling fluid with high temperature resistant polysulphonate in the fourth spud, the formula of the drilling fluid with high temperature resistant polysulphonate + 0.5%PAC-IV + 1.5% QHFD-I+ 1.5% QHFD-II + 2% LQFT -I+ 2% LQFT -II+ 1.5% WNFT-II was designed to meet the drilling requirements of fractured formation. The performance evaluation and particle size test of wellbore stabilized drilling fluid were carried out. The dynamic plastic ratio of the wellbore stable drilling fluid at 90 ℃ is 0.5pa/mpa · s, the initial filtrate loss at high temperature and high pressure is 1.0ml, and the total filtrate loss at high temperature and high pressure is 9.0ml. Compared with the original four opening high temperature resistant polysulphonate drilling fluid, the performance of the drilling fluid is significantly improved by adding the filtrate reducer pac-lv and five high-efficiency plugging agents, which meets the requirements of the optimized design index of the drilling fluid performance.

The wellbore stabilization drilling fluid has excellent hole purification efficiency, which can effectively carry the wellbore micro block falling under complex conditions, so as to prevent the formation of cuttings deposition in the build-up and horizontal sections from causing stuck drilling; the high-temperature and high-pressure filtration performance is excellent, which can completely seal the microporous joints, form dense and tough inner and outer mud cakes, and prevent the wall from peeling off. The solid-phase particles with the diameter of 0.1-1 μm, 1-10 μm, 10-30 μm and 10-100 μm are 13.2%, 23.5%, 21.1% and 42.2%, respectively. Compared with the original Si Kai high temperature resistant polysulphonate drilling fluid, the ideal distribution of small, medium and large particles in the range of 0.1-100 μm has been achieved by adding pac-lv and 5 kinds of high efficiency plugging agents. The well wall stable drilling fluid has reasonable rigid and plastic solid particle size distribution, which can quickly form mud cake with permeability close to zero and thin and tough, fundamentally restrain the drilling fluid filtration, restrain the hydraulic wedge, improve the formation pressure bearing capacity, and realize the plugging and collapse prevention of broken formation.
3. Wellbore Stable Drilling Fluid Technology

For deep well high density drilling fluid, its composition is generally bentonite, inorganic salt, treating agent and barite. Among them, the particle sizes of bentonite and barite are about 1 μm and 45-75 μm respectively, while the majority of inorganic salts and treatment agents are easily soluble in water, resulting in the absence of solid particles with a particle size of 2-44 μm in the drilling fluid, unable to form an ideal distribution of small, medium and large particles with uniform and excellent proportion. However, the quality of particle size distribution and the content of submicron solid particles determine the permeability and density of mud cake, and determine whether a stable and tough isolation layer "artificial well wall" can be established[4-6].

On the basis of no clay minerals in the target horizon, but concentrated stress and broken formation, it is the key for the drilling fluid to stabilize the well wall when drilling in broken formation to achieve effective sealing in submicron micron level (0.1-100 μm), to prevent the drilling fluid or filtrate from intruding into the formation fractures of the well wall, and to ensure the efficient carrying of the drilling fluid. If the sub micron to micron level comprehensive and effective plugging can not be achieved, the invasion of drilling fluid or filtrate into the formation can not be effectively prevented, so as to prevent the well wall from collapsing and falling. At this time, the increase of drilling fluid density will lead to the increase of wellbore pressure difference, induce the invasion of drilling fluid and the action of hydraulic wedge, and make the wellbore instability more serious.

3.1. Drilling Fluid Optimization Design

1) Ensure efficient rock carrying. The efficiency of wellbore purification and the degree of flow profile flattening are related to the dynamic plastic ratio of the drilling fluid. Adjusting the dynamic plastic ratio of the drilling fluid to 0.5pa/mpa · s, increasing the flow core size of the drilling fluid, making it change from the peak type laminar flow to the plate type laminar flow [10], can ensure that the deep well with large displacement deviated well section has high effective rock carrying capacity. In view of the huge risk of collapse and block fall of broken formation, to ensure the excellent rock carrying capacity of drilling fluid under high temperature and pressure environment can effectively reduce the risk of sticking caused by the lack of rock carrying capacity or rock carrying efficiency. In order to simulate the actual situation at the bottom of the well, raise the drilling fluid temperature to 90 °C to measure the dynamic plastic ratio.

2) Strictly control the high temperature and high pressure filtration. The treatment agent material should be sealed at the crack entrance near the shaft wall, and the closer the shaft wall is, the better the sealing effect is. In order to achieve rapid and comprehensive sealing and plugging at the moment of drilling, it is required that the initial filtrate loss of drilling fluid at high temperature and pressure shall not be more than 1ml, so as to fundamentally contain the hydraulic wedge and establish a stable and tough protective layer. In order to prevent the wall from peeling and falling off during drilling, it is necessary to ensure that the total filtrate loss of HTHP is no more than 10ml on the basis of instantaneous plugging.

3.2. Supporting Engineering Measures

During drilling, strictly control the tripping and pumping speed, avoid strong swabbing caused by excessive downhole pressure excitation, and prevent well collapse and instability caused by excessive impact of downhole BHA on well wall[7-8]. Combined with the real-time data of geological logging, the key indexes such as drilling time, torque, WOB and liquid level height are mainly detected to ensure the normal operation of liquid level alarm device and manual measurement detection. In case of abnormal drilling conditions, analyze and make corresponding adjustment quickly to ensure that the drilling fluid performance is better than the drilling design requirements. For the seriously stuck well section, the borehole shall be lifted and repaired in time for every 1 m drilling, and it shall be circulated for 5 min under the condition of turning on the rotary table and increasing the displacement, and then the original displacement with pump shall be reversed and lifted to ensure the borehole is clean and unobstructed.
3.3. Field Application

Based on the in-depth analysis of wellbore instability mechanism in broken formation, the theoretical analysis of wellbore stability mechanism of drilling fluid is carried out, and the indoor optimization design of drilling fluid is studied. The reason why the original four opening high temperature resistant polysulfonate drilling fluid can not achieve wellbore stability is determined. The optimization design obtains the drilling fluid formula suitable for the Ordovician broken formation in Shunbei Y well. The application in the fourth spud shows that the drilling fluid with stable borehole wall has excellent performance and successfully avoids the complex accidents such as borehole wall collapse and instability in the broken formation. The drilling depth is 8014m safely and efficiently, and the shortest drilling time is 23.2d in the reservoir section of this block.

4. Conclusion

1. According to the geological research, the broken stratum of Yijianfang Formation of Ordovician is mainly composed of argillaceous calcite and a small amount of black asphaltene and yellow pyrite. It is hard and brittle, with argillaceous structure and sand debris argillaceous structure. The fractures and holes are relatively developed.

2. The mechanism of wellbore instability shows that under the action of drilling fluid erosion, the self-developed pore network will be rapidly pressurized and connected, which makes the interface adhesion between the layers sharply reduced and the units become loose. When the downhole pressure is excited too much or the BHA collides with the borehole wall mechanically, it is very easy to cause large-scale peeling off and block, collapse and stuck drilling and other borehole wall instability accidents.

3. The research of drilling fluid countermeasures shows that on the basis of no clay mineral in lithologic composition but concentrated stress and broken formation, it is the key for drilling fluid to stabilize the well wall when drilling in broken formation to completely and effectively block the drilling fluid or filtrate from intruding into the formation fractures of the well wall and ensure the drilling fluid to carry the rock efficiently.

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