Fractured Reservoir Protection Technology of H-block in Jilin Oilfield

Jingyuan Zhao, yuxue Sun, fulei Zhao

Northeast Petroleum University, Daqing, Heilongjiang, 163318, China

Abstract

Some reservoir fractures in Haituo Area are developed, and most of them are high angle fractures and vertical fractures, with the fracture width of about 0. 3 mm. The opening distribution range of the fractures in the formation is extensive, and it is very difficult to carry out the reservoir protection by the general temporary shielding technology. For this purpose, the fiber blocking agent and composite blocking agent are optimized, to form the bridging in the pore throat with greater influence on the permeability. The drilling fluid composition of temporary shielding is determined, accompanied by the filling particles and deformable particles in suitable particle size, to further block and finally form the dense temporary blocking zone. The experiment of effect evaluation on the temporary blocking strength and blockage removal by reverse flow proves that, the technology has good protective effect on the fractured reservoir in Haituo Area.

Keywords

Haituo Area, fractured reservoir, reservoir protection, temporary shielding

1. Research on Fractured Reservoir Protection Technology

1.1 Optimization of fiber blocking agent

The fiber blocking agent has the definite length and flexibility, and shows the chain shape or curl shape in the drilling fluid, which can form the bridging in the fracture end face and joint surface, pack closely, block various kinds of fractures effectively, decrease the flowing space of the fracture and high permeability pore, enable smaller particles and fibers of the proximate grade to bridging continuously till blocking completely, and form the mud cake with extremely low permeability [1-4]. The Rise – 3002 type particle image analyzer is used to make the particle size analysis on multiple fiber blocking agents in different specifications, and the fiber blocking agent with the fiber particle size distribution range of 2~625 μm is finally selected. See Fig. 1 for detailed particle size distribution situation.

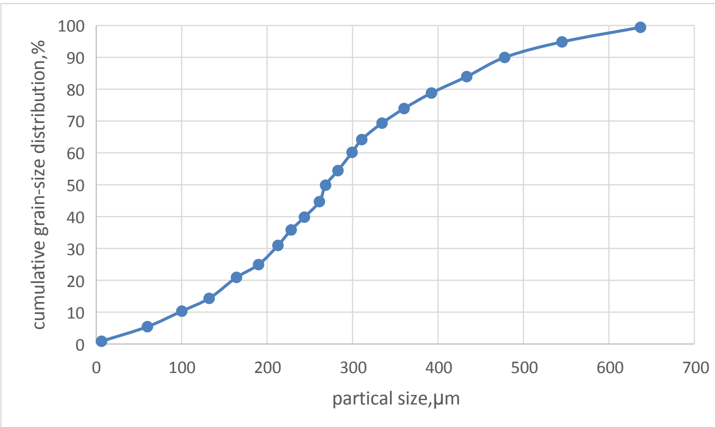

Fig. 1 Particle Size Distribution Situation of Fiber Blocking Agent

The median size is about 270 μm, which can effectively cover the fracture with the width of 100~500 μm and meet the demands of blocking fracture in Haituo Area. The fibrous particles are cross-linked mutually by tens of or dozens of particles to form a flocculation pellet, rather than distributing in the drilling fluid by the single particle. The flocculation pellet is easier to be deposited on the fracture surface than the solid particles of the same size. Once depositing on the fracture, the contact between the flocculation pellet and the fracture surface is tens of or dozens of points, rather than one point. Therefore, it is not easy to be washed away by the liquid flow, and accordingly the stable bridging is formed. Due to the low strength of the flocculation pellet, it is easily deformed under the effect of differential pressure, and can fill in the fractures of any shapes, and meanwhile it can form the effective blockage at the entrance of the fracture under the combined action of other particles in the drilling fluid.

1.2 Optimization of composite blocking agent

The composite blocking agent is composed of the bridging filling materials and softening deformation particles. The softening deformation particles can have the slight softening deformation under the downhole temperature, and can be squeezed into various fractures and pores, and also will not be melted and decomposed at high temperature, with higher stability and blocking ability [5].

The bridging filling materials are mainly composed of the hard calcium carbonate of different proportions. The size distribution of the hard calcium carbonate particles influences the effect of the fracture bridging largely. This paper mainly introduces the application of the blocking fracture of hard rigid particles. See Table 1 for the product size and specification of the hard calcium carbonate particles.

Table 1 Size Distribution of Hard Calcium Carbonate Particles

Materials	D_{10} / μm	D_{50} / μm	D_{90} / μm
$CaCO_3$- 20	15. 30	350. 00	716
$CaCO_3$- 30	6. 07	152. 00	492
$CaCO_3$- 35	5. 00	125. 00	404
$CaCO_3$- 40	4. 32	108. 00	350
$CaCO_3$- 45	3. 50	80. 00	260
$CaCO_3$- 50	2. 35	58. 64	190
$CaCO_3$- 60	1. 98	49. 38	160
$CaCO_3$- 70	1. 85	46. 23	150
$CaCO_3$- 140	0. 84	29. 90	68

Notes: D is the particle diameter, μm

D_{90} theory is the most advanced theory of determining the temporary blocking agent formula at present. According to the filling theory, the ratio of the corresponding hard calcium carbonate particle of the fractures in different widths can be gained by applying the data in Table 1, i.e. the ratio of the corresponding composite temporary blocking agent bridging particle of the fractures in different widths. See Table 2 for details.

Table 2 Blocking Formula of Fractures of Different Widths

Fracture size / μm	Formula		D_{10} / μm	D_{50} / μm	D_{90} / μm
100	$CaCO_3$—140:$CaCO_3$—50:$CaCO_3$—45 =	60:20:20	1. 23	35. 6	108
200	$CaCO_3$—140:$CaCO_3$—50:$CaCO_3$—40 =	20:50:30	2.80	65.0	206
300	$CaCO_3$— 70:$CaCO_3$— 45:$CaCO_3$—35 =	15:40:45	16.00	293.0	304
400	$CaCO_3$— 60:$CaCO_3$— 35:$CaCO_3$—30 =	15:40:45	5.50	128.0	405
500	$CaCO_3$— 45:$CaCO_3$— 40:$CaCO_3$—20 =	30:50:20	7.00	159.0	509

1.3 Determination of formula of fracture temporary shielding drilling fluid

Add different kinds of treating agents with different doses respectively in the drilling fluid base mud. The laboratory tests the basic performance of various drilling fluid systems in different proportions, including viscosity, shearing force, water loss, and pH value. By contrast, the fracture temporary shielding drilling fluid is optimized, and the formula is (4%~5%) bentonite + 0.5% sodium carbonate + (0.15%~0.30%) KPA + (1.0%~1.5%) ammonium salt + (0.5%~1.0%) KCl + 1% anti-salt filtrate reducer + 1% HQ - 1 + 1% fiber blocking agent + (2%~3%) composite temporary blocking agent (hard calcium carbonate particles and softening particles in different proportions).

1.4 Performance of fracture temporary shielding drilling fluid

Test the general performance of the fracture temporary shielding drilling fluid, and compare with the KCl polymer drilling fluid system. See Table 3 for the results. From Table 3, compared with the second section drilling fluid, the fracture temporary shielding drilling fluid system has little change in the general performance, slight increase in the viscosity and decrease in the water loss, indicating that the optimized fiber blocking agent and composite temporary blocking agent have small influence on the performance of the drilling fluid [6-9].

Table 3 Formula and Performance of Drilling Fluid

Drilling fluid system	Apparent viscosity /mPa s	Plastic viscosity /mPa s	Dynamic shearing force /Pa	Initial shear / End shear / (Pa /Pa)	pH	API water loss /mL
KCl polymer drilling fluid	39	28	11	2. 5 /6. 0	9	3. 0
Fracture temporary shielding drilling fluid	41	29	12	3. 0 /7. 5	9	2. 0

2. Blockage Effect of Fracture Temporary Shielding Drilling Fluid

Adopt the natural core in Haituo Area, and use the fracture temporary shielding drilling fluid to make the pollution assessment experiment on the core in different fracture widths by the manual fracture forming treatment. The pollution experiment conditions are the differential pressure of 3.5 MPa, temperature of 80 ℃, shearing rate of 100 s^{-1}, and pollution time of 60 min. While measuring the permeability before and after pollution, the pressure is constant. See Table 4 for the result.

Table 4 Result of Blocking Effect Assessment Experiment

Fracture width / μm	Permeability before pollution / 10^{-3} $μm^2$	Blocking ratio / %	Shearing length of pollution end / mm	Permeability recovery value / %
104. 3	115. 84	99. 15	6. 6	97. 44
198. 5	245. 69	97. 64	7. 4	96. 36
301. 6	336. 52	97. 88	7. 8	96. 69
399. 8	486. 15	96. 44	8. 2	95. 43
502. 3	607. 65	98. 13	8. 6	96. 75

From Table 4, the blocking ratio of the fracture temporary shielding drilling fluid for the core in Haituo Area in different fracture widths is more than 96%, i.e. resulting in the severe blockage for the pollution end, and accordingly avoiding the drilling fluid filtrate and solid phase from further intruding into the internal hydrocarbon reservoir.

3. Assessment Experiment of Temporary Blocking Strength

The greater the strength of the temporary blocking zone is, the more the surge pressure is impacted, and the better the temporary blocking effect is. On the contrary, the lower the strength of the temporary blocking zone, the easier the breakthrough of the temporary blocking zone is under the impact of the surge pressure. Accordingly, the new pollution is produced, and the purpose of protecting the oil reservoir can not be reached. Take the artificial core in different fracture widths, use the fracture temporary shielding drilling fluid for pollution, and assess the temporary blocking strength by measuring the permeability under different displacement pressure. See Table 5 for details.

From Table 5, with the increase of the displacement pressure, the permeability of the core is reduced gradually. When the displacement pressure is up to 11 MPa, the permeability of the core is close to or equal to zero, i.e. when the pressure is 11 MPa, the sudden increase of the permeability is not seen, indicating that the temporary blocking zone is not destroyed, and the temporary blocking zone formed on the core with different permeability can at least bear the pressure of 11 MPa.

Table 5 Assessment Experiment Result of Temporary Blocking Strength

Fracture width	Permeability before pollution	Permeability under different displacement pressure / 10^{-3} μm^2				
/ μm	/ 10^{-3} μm^2	3. 5 MPa	5. 0 MPa	7. 0 MPa	9. 0 MPa	11. 0 MPa
101. 5	109. 65	0. 081	0. 008	0. 006	0. 003	0. 000
202. 4	213. 48	0. 074	0. 007	0. 006	0. 002	0. 000
298. 3	298. 56	0. 105	0. 008	0. 007	0. 002	0. 000
406. 6	428. 66	0. 118	0. 007	0. 005	0. 003	0. 001
500. 4	533. 15	0. 126	0. 009	0. 007	0. 005	0. 000

4. Effect Assessment Experiment of Blockage Removal by Reverse Flow

Measure the kerosene forward permeability of the core sample by the core holder on the core flow laboratory instrument. Connect the core holder to the high temperature and high pressure dynamic comprehensive tester of drilling fluid, and reversely damage the rock sample by the fracture temporary shielding drilling fluid. Take down the core holder, connect the core flow laboratory instrument, carry out the forward displacement (reverse flow) by the kerosene, measure the forward kerosene permeability under differential pressure, and then calculate the permeability recovery rate under different conditions. See Table 6.

Table 6 Experiment Result of Blockage Removal by Reverse Flow

Fracture width	Permeability before pollution	Permeability recovery value of core under different reverse flow pressure / %				
/ μm	/ 10^{-3} μm^2	0. 1 MPa	0. 5 MPa	1. 0 MPa	1. 5 MPa	2. 0 MPa
100	109. 65	31. 25	48. 44	73. 68	85. 63	95. 65
200	213. 48	35. 67	52. 12	67. 91	83. 56	96. 31
300	298. 56	33. 29	49. 33	72. 39	84. 36	97. 13
400	428. 66	34. 08	51. 74	78. 65	86. 44	96. 82
500	533. 15	32. 30	47. 65	79. 60	84. 28	95. 66

From Table 6, with the increase of the reverse flow pressure, the permeability recovery rate of the fractured core is increased. Moreover, when the reverse flow pressure is up to 2.0 MPa, the permeability recovery value of the rock sample is more than 95%, indicating that the reverse flow is successful and the shielding ring blockage is removed.

5. Conclusion

(1) The fiber blocking agent and composite fracture blocking agent are selected, accompanied by the filling particles and deformable particles in suitable particle size, to further block and finally form the dense temporary blocking zone. The technology has the effective reservoir protective effect on the fractured reservoir in Haituo Area.

(2) The optimized formula of the temporary shielding drilling fluid is (4%~5%) bentonite + 0.5% sodium carbonate + (0.15%~0.30%) KPA + (1.0%~1.5%) ammonium salt + (0.5%~1.0%) KCl + 1% anti-salt filtrate reducer + 1% HQ - 1 + 1% fiber blocking agent + (2%~3%) composite temporary blocking agent (hard calcium carbonate particles and softening particles in different proportions).

(3) In the assessment experiment of temporary blocking strength, the temporary blocking zone formed on the core with different permeability can at least bear the pressure of 11 MPa. In the effect assessment experiment of blockage removal by reverse flow, with the increase of the reverse flow pressure, the permeability recovery rate of the fractured core is increased. Moreover, when the reverse flow pressure is up to 2.0 MPa, the permeability recovery value of the rock sample is more than 95%, indicating that the reverse flow is successful.

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