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Optimization Research on Fracturing Fluid for Low Displacement Sand Fracturing in Coal Reservoir

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Abstract

In order to solve the easy closure and "water lock" effect of the fractures after the clean water fracturing of the coal seams in the coal mine, it was proposed to use sand adding technology during the fracturing process, and the clean fracturing fluid suitable for sand fracturing in coal mine was optimized. Its sand carrying, anti swelling, gel breaking and injurious abilities were evaluated. The research results show that the fracturing fluid formula suitable for sand fracturing in coal mine is 0.2~0.25% thickener+0.2% cross-linking agent+0.3% anti swelling agent+0.1% ammonium persulfate+0.1% low-temperature activator. The anti expansion rate of the clean fracturing fluid reaches 81.3%, the average residue content of gel breaking fluid is 28mg/L, and the damage rate is 15.62%. It is an excellent fracturing fluid that can be used for low displacement sand fracturing in coal mines.

Keywords

Coal Mine Gas; Antireflection; Hydraulic Fracturing; Sand Fracturing; Fracturing Fluid.

1. Introduction

The vast majority of coal mines in China are mine mining, and there are many high gas mines and outburst mines. Among them, coal and gas outburst is a powerful natural disaster in coal mine production, which seriously threatens the safety of coal mine production and is extremely destructive. It is characterized by high gas content, high gas pressure, high risk of coal and gas outburst, low permeability, small coal seam thickness, large dip angle, and complex geological structure, all of which bring great challenges to gas control [1-3]. In order to avoid gas accidents in coal mines, it is necessary to extract gas. The use of hydraulic fracturing technology can effectively improve the permeability of coal seams and the extraction efficiency of gas. Gas is a mineral resource mainly stored in coal and rock in the form of adsorption, which is separated from coal and rock by depressurization and desorption [4-5]. Most coal reservoirs in China are characterized by high gas and low permeability. Hydraulic fracturing is required to increase the permeability of coal seams and accelerate the desorption of coalbed methane. At present, the fractures formed by the single clean water fracturing in the coal mine are inevitably re closed. Domestic and foreign scholars began to optimize the fracturing fluid to improve the fracturing effect. Zhang Ye et al. [6] optimized a set of nitrogen foam fracturing fluid system with excellent performance. Fan Yao[7] designed the pre acid formula of hydrochloric acid system and hydrochloric acid+hydrofluoric acid system, and the fracturing fluid formula of active hydraulic fracturing fluid and biological enzyme gel breaking guar gum fracturing fluid. Xu Yaobo et al. [8] chose to add KCL solution of certain concentration and anionic surfactant YZ-1 solution as anti

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swelling agent and cleanup agent to meet the compatibility with coal reservoir and reduce the damage to coal reservoir. Wang Ning et al. [9] proposed to improve the traditional hydraulic fracturing technology of coal seams by using the corrosive coal body technology of surfactant and acid fluid.

In recent years, in order to solve the problem of easy closure of fractures after fracturing of coal seams in coal mines, scholars [10-13] proposed to support fractures by adding sand, improve fracture conductivity and improve gas drainage effect after fracturing. Sand fracturing makes the fracture system generated by the coal seam filled by the subsequent proppant, which is effectively supported. A large number of interconnected fracture channels have been established. The effective permeability of the reservoir has been greatly improved, the seepage and diversion conditions of the reservoir have been significantly improved, providing a high-speed channel for gas drainage, reducing the coal seam gas content faster, and reducing the time cost of coal mine development. Based on this, the author studied a fracturing fluid suitable for low displacement sand fracturing of coal reservoir on the basis of previous research, so as to improve the fracturing effect.

2. Fracturing Fluid System is Optimized

According to the construction experience of clean water fracturing in underground coal mine, the displacement of single pump construction can reach 0.6m3/min, and the displacement of double pump parallel construction can reach 1.2m3/min. Underground fracturing equipment and construction conditions of coal mine are limited by space, only this technical condition can be achieved. Therefore, it is necessary to use the fracturing fluid with certain viscosity to improve the ability of the carrying sand capacity and formation fracture capacity, and to realize the sand fracturing in coal mine with the condition of lower construction displacement. In 2002, Cong Lianzhu studied the damage experiment of active water, linear glue, gel fracturing fluid and clean fracturing fluid to coal seam by pulverized coal filling model, it shows that the damage rate of clean fracturing fluid to coal core is the same as that of active water, and it has excellent sand suspension performance[14-16]. Therefore, the new MEC clean fracturing fluid system is optimized.

3. Performance Evaluation of Fracturing Fluid System

3.1. Suspended Sand Performance

Table 1. Static suspension performance comparison

Liquid type	Liquid viscosity	Liquid column height mm	Low density ceramsite sand		Quartz sand	
			Settling time/s	Settling velocity/(mm/s)	Settling time/s	Settling velocity/(mm/s)
X_1% Base fluid	12.0	210	75	2.8	40	5.25
X_2% Base fluid	18.0	210	170	1.24	80	2.63
X_3% Base fluid	24.0	210	420	0.5	190	1.11
Clear water		260	5	52	4	65

Under normal temperature and pressure, 40-70 mesh quartz sand and 1.25g/cm3 volume density low-density ceramsite sand were put into measuring cylinder containing clear water, fracturing fluid base fluid and glue liquid with 0.2% crosslinking agent respectively, and the time of settling quartz sand and ceramsite sand to the bottom of measuring cylinder was recorded. According to the experiment, the sedimentation rate of low-density ceramsite sand in fracturing fluid base fluid is less than half that of quartz sand, and less than 1/100 in clean water. In the fracturing fluid gel mixed with 30% sand ratio and 40-70 mesh quartz sand and low density ceramsite sand, format sand suspension fluid, stand 24h, quartz sand suspension fluid appears 5% sand desilting, low density ceramsite sand no desilting phenomenon occurred, it is indicate that the fracturing fluid gel has a good ability to suspend sand, and the fracturing fluid combined with low-density ceramsite sand has a better ability to suspend sand.

3.2. Anti-swelling Performance

Linear expansion method was used to analyze the anti-swelling property of fracturing fluid system. Take 70-100 mesh pulverized from coal mine, put it in a centrifugal pipe, and add different KCl solution respectively and different clay anti-swelling agent solution, kerosene, deionized water and other reagents to the coal sample and mix well, and let it sit for 2h. The anti-swelling ratio is calculated as follows:

$$B=\frac{H_2\text{-}H_1}{H_2\text{-}H_0}\times 100\%$$

Where B-anti-swelling ratio, %.H2-expansion volume of coal core in clean water, mL.H1-expansion volume of coal core in anti-swelling agent solution, mL.H0-expansion volume of coal core in kerosene solution, mL.

The experimental results of coal core expansion are shown in Table 2 and Table 3.

Table 2. Anti-swelling of pulverized coal in KCl solution date

KCl Concentration/%	Expansion volume/mL		Anti-expansion rate/%	
	Industrial grade	Analytical purity	Industrial grade	Analytical purity
K_1	0.90		0	
K_2	**0.75**	**0.60**	**6.3**	**25.0**
K_3	0.55	0.50	31.3	37.5
K_4	0.45	0.40	43.8	50.0
K_5	0.20	0.15	75.0	81.3
K_6	0.15	0.15	81.3	81.3
K_7	0.15	0.15	81.3	81.3
kerosene	0		100	

Table 3. Pulverized coal anti-swelling of clay anti-swelling agent solution date

Clay anti-swelling agent concentration/%	Expansion volume/mL	Anti-expansion rate/%
P_1	0.50	37.5
P_2	0.30	62.5
P_3	**0.15**	**81.3**
P_4	0.10	87.5
P_5	0.10	87.5
P_6	0.10	87.5

The experimental results show that the anti-swelling ratio of K2% KCl to the coal core reaches 75%, and the anti-swelling ratio of P3 % clay anti-swelling agent solution to the coal core reaches 81.3%. This indicates that clay anti-swelling agent has a good performance of inhibiting clay expansion, thus reducing reservoir damage caused by clay expansion in a certain extent, and clay anti-swelling agent is more convenient for underground fracturing with sand.

3.3. Gel Breaking Performance

For the low temperature environment of coal seam, by optimizing the combination of gel breaker and low temperature gel breaking activator, realizes gel breaking of fracturing fluid system under the condition of 20℃. Using 0.1% ammonium persulfate and 0.1% compound amine salt low temperature activator agent SDP-1 to break gel 4h under the condition of 20℃, measured viscosity was 1.24 mm2/s. After fracturing fluid is broken, residues are generated due to water insoluble substances contained in thickener and water insoluble substances produced after breaking glue. Residues content has a great impact on fracture flow conductivity after fracturing, so the less residues content in fracturing liquid system, the better. Set of three groups to test fracturing fluid residue content, with reference to the determination standard of residue content in the SY/T5107-2016 water-based fracturing fluid performance evaluation method, adding the low temperature gel breaker combination in the fracturing fluid, put in 20℃ water bath, determine the glue residue content after gel broken completely. The test results are shown in Table 4, the average residue content of the broken gel solution is 28mg/L.

Table 4. Residue content test result

Serial number	Linear gel volume/mL	Filter/mg	Filter + residue/mg	Residue content/ (mg/L)
1	500	87	101	28
2	500	88	99	22
3	500	88	105	34
Average				28

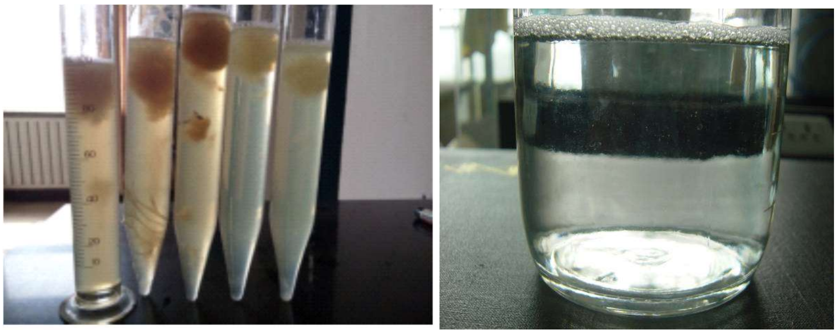

Figure 1. Comparison between fracturing fluid guanidine gel and gel breaking liquid

Compared with the conventional guanidine gum fracturing fluid residue content between 300 mg/L and 600mg/L, this fracturing fluid belongs to the extremely low residue fracturing fluid system, which greatly reduces the damage of glue breaking liquid residue to reservoir fracture plugging after fracturing.

3.4. Damage Performance

The coal blocks in the reservoir were crushed and screened through 60 mesh screens to make pulverized coal. The pulverized coal was poured into the rock sample model and pressurized by a press for 15MPa forming. Then saturate with salt water and set aside. The prepared core was loaded into the coal core holder and connected to the process. Standard saline was used to squeeze into the coal core from the reverse end of the core holder for displacement. The flow

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velocity of the flow medium was lower than the critical flow velocity. Until the flow rate and pressure difference are stable, the stabilization time shall not be less than 60min. Measure coal core permeability K1 before damage. The fracturing fluid is pressurized through a pressure source and pushed into the coal core from the positive end entrance of the core holder. When the fracturing fluid begins to flow out, the timing is started, and the displacement time is 36min. After extrusion, close the two valves of the clamping device, and keep the fracturing fluid in the coal core for 2h. Then standard brine was used as the medium to measure the permeability K2 of the damaged coal core.

The permeability damage rate of coal core matrix is calculated as follows:

$$\eta_d = \frac{K_1 - K_2}{K_1} \times 100\%$$

Where η_d -Permeability damage rate of coal core matrix,%.K1-Coal core matrix permeability,×10-3μm2.K2-Coal core permeability after fracturing fluid damage,×10-3μm2.

In the experiment, the two fracturing fluid formulations are shown in the Table5 and Table6.

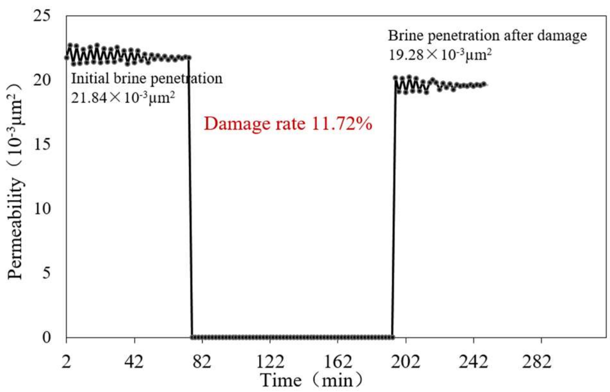
Table 5. Fracturing fluid system for coal core damage

Fracturing fluid type	Fracturing fluid formula	Gel viscosity/ mPa.s
Active water	KCl	1.02
Fracturing fluid	X_3% thickener +K_2% KCl+P_3% anti-swelling agent + CNK-1 low-temperature activator	2.06

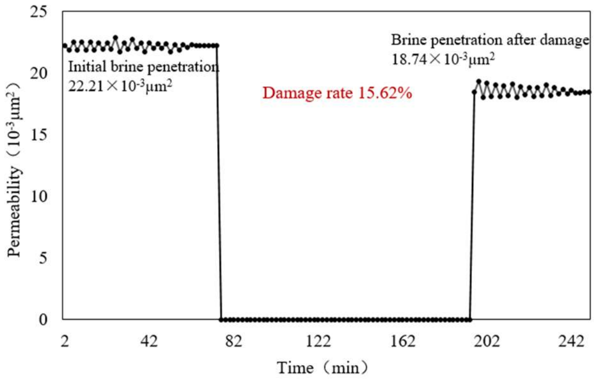
Table 6. Guanidine gum and active water damage data comparison

Fracturing fluid	Permeability/×10^{-3}μm^2		Damage rate/%
	Permeability before damage K_1	Permeability after damage K_2	
KCl Active water	21.84	19.28	11.72
Fracturing fluid	22.21	18.74	15.62

Through KCl active water and clean fracturing fluid system of coal core damage comparison experiment, it can be seen that the damage rate of KCl active water is 11.72%. The damage rate of clean fracturing fluid system is 15.62%, which is the same as that of KCl active water, reflecting the excellent low-damage performance of clean fracturing fluid.



(a)



(b)

Figure 2. KCl active water and Clean fracturing fluid system damage to coal core

4. Conclusion

(1) The fracturing fluid formula applicable to sand fracturing in coal mine is: 0.2~0.25% thickener+0.2% cross-linking agent+0.3% anti swelling agent+0.1% ammonium persulfate+0.1% low-temperature activator.

(2) The clean fracturing fluid has an anti expansion rate of 81.3%, an average gel breaking fluid residue content of 28mg/L, and a damage rate of 15.62%. It has excellent suspended sand performance, high anti expansion, low temperature gel breaking performance, and low damage, and can be used for low displacement sand fracturing in coal mines.

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