Study on fracturing fluid suitable for sand fracturing in underground coal mines

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Abstract: Along with the coal mine development extends to the deep, the ground stress gradually increases, conventional water hydraulic fracturing usually occurs fracture re-closure after fracturing. In order to improve the gas extraction effect, using hydraulic fracturing and sand adding technology, optimizing clean fracturing fluid suitable for sand fracturing in underground coal mine, evaluating the ability of suspending sand, carrying sand, anti-swelling. The damage rate of the fracturing fluid system to the coal core is 15.62%, proppant does not settle in fracturing fluids, it shows excellent properties of high suspended sand, high carrying sand and low damage, it is suitable for hydraulic fracturing and sand adding construction of underground coal mine with low displacement and high sand ratio.

1. Introduction

Most coal reservoirs in China are characterized by high gas and low permeability. The adoption of hydraulic fracturing technology can effectively improve the permeability of coal seams and enhance the extraction efficiency of gas. At present, a single fracturing pump set is generally used for water fracturing in underground coal mines. After fracturing, the cracks formed are inevitably closed again. In order to solve this problem, sand can be added to support the fracture, improve the fracture flow conductivity, and improve the gas drainage effect after pressure. Sand fracturing make coal seam produce fracture system by subsequent proppant pack effectively, establish a large number of interconnected cracks and channels, greatly improving the effective permeability of reservoir, the diversion conditions have markedly improved, provides a high-speed channel for gas extraction, faster to reduce the gas content of coal seam, reduce coal mine coalbed methane development time cost[1-3].

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 0.6m^3/min, and the displacement of double pump parallel construction can reach 1.2m^3/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[4-5]. Therefore, the new MEC clean fracturing fluid system is optimized.

3. Performance evaluation of fracturing fluid system

3.1 Suspended sand performance

Under normal temperature and pressure, 40-70 mesh quartz sand and 1.25g/cm^3 volume density

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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.

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

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, %.H_2-expansion volume of coal core in clean water, mL.H_1-expansion volume of coal core in anti-swelling agent solution, mL.H_0-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 K_2% KCl to the coal core reaches 75%, and the anti-swelling ratio of P_3 % 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 mm^2/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

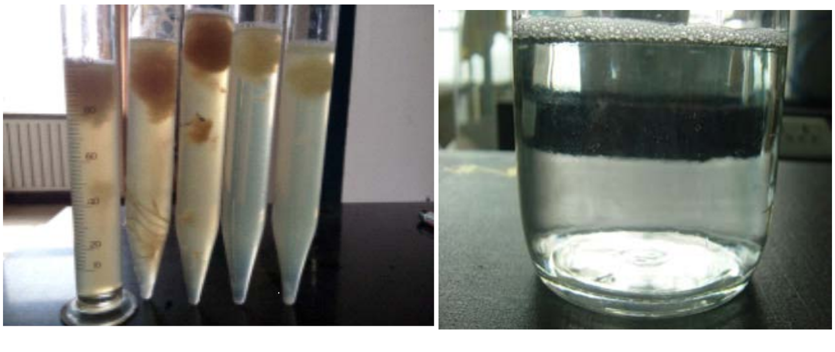


Fig.1 Comparison between fracturing fluid guanidine gel and gel breaking liquid

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 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 K_1 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:

$$\eta_{\mathrm{d}} = \frac{K_1 - K_2}{K_1} \times 100\%$$

Where η_{d} -Permeability damage rate of coal core matrix,%.K_1-Coal core matrix permeability,$\times 10^{-3}\mu m^2$.K_2-Coal core permeability after fracturing fluid damage,$\times 10^{-3}\mu m^2$.

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

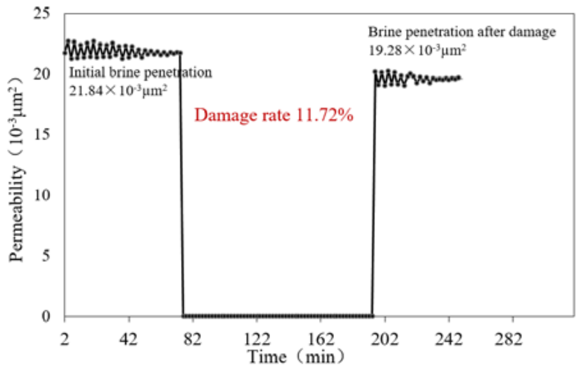
Table 5 Fracturing fluid system for coal core damage

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

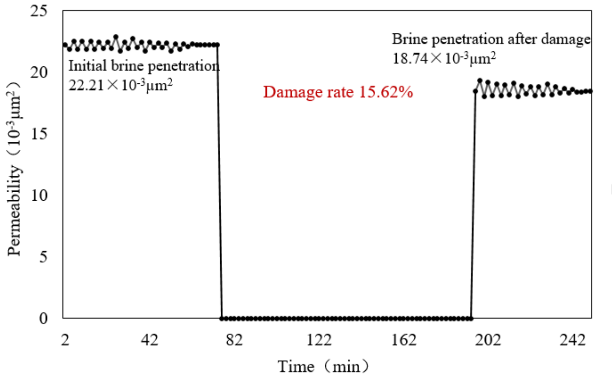
Table 6 Guanidine gum and active water damage data comparison

Fracturing fluid	Permeability/$\times 10^{-3}\mu m^2$		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)

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

4. Conclusion

(1) Studies have shown that the fracturing fluid formula for sand fracturing in underground coal mines can be as follows: X_3% thickener+K_2% KCl+P_3% anti-swelling agent+CNK-1 low-temperature activator.

(2) The clean fracturing fluid has excellent sand suspension performance, high anti-swelling, low-temperature glue breaking performance and low damage, and can be used for low-displacement sand fracturing in underground coal mines.

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