# Application of flexible colloid-fiber compound plugging technology in oil and gas wells with large differential pressure in the East China Sea

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**Abstract.** In order to solve the contradiction between the safety requirements of well control in the upper reservoir and the loss of kill fluid in the lower reservoir, the idea of "compound plugging technology" was proposed to solve the abnormal pressure inversion phenomenon of "the co-existence of blowout and lost circulation" with large interlayer pressure difference. Flexible colloidal particle-fiber composite temporary plugging fluid was developed. The plugging layer formed by the temporary plugging fluid of flexible rubber fiber can withstand the positive pressure difference of more than 40 MPa, and there is no overflow and leakage. The advantages of compound temporary plugging fluid under large differential pressure are verified and it has a good application prospect.
**Keywords:** Flexible colloidal particles; Compound temporary plugging; Large differential pressure; Reservoir protection.

## 1 Introduction

With the exploration of oil and gas field, large differential pressure reservoirs are becoming more common. The solid-free temporary plugging kill fluid is generally used to balance HTHP formation pressure[1-2]. It can be divided into foam type, viscous type and water absorption resin type. Among them, foam kill fluid and viscosified kill fluid have relatively small temporary plugging capacity due to structural reasons. The strength range of temporary plugging layer formed by this material is very wide. Aiming at the problem of loss of kill fluid in HTHP wells, Jia et al. (2010)[3] pointed out that the solidified water system could be reduced to clear water or salt water by destroying the chemical bond during flowback, thus achieving the purpose of "no residue". Lai et al. (2014)[4] prepared a temporary plugging agent for fracturing using starch, acrylic acid, acrylamide, initiator and crosslinking agent as raw materials.

The existing temporary plugging and killing technologies can not meet the demand of temporary plugging and loss control for large differential pressure oil and gas wells. The ultra-high-temperature resistant flexible colloid workover fluid developed by the research group provided technical guidance for the safe and efficient workover operation of

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high-temperature oil and gas wells in Shunbei Oilfield of China[5]. Combined with the complex environment characteristics of large differential pressure strata in the East China Sea, this paper puts forward the idea of flexible cement-fiber compound plugging technology for the dual purpose of successfully plugging low-pressure strata and squeezing high-pressure strata. This technology not only provides safe wellbore conditions, but also enhances plugging capability.

## 2 Experimental section

### 2.1 Experimental materials and equipment

The experimental materials include flexible colloidal particles (KA01, mainly composed of resin particles), stabilizers (mainly composed of polyethylene imine), fibers and regular cores. The experimental equipment mainly includes oil and gas well working fluid leakage prevention and plugging experimental device (laboratory fabrication), gas permeability measurement experimental device.

### 2.2 Compound temporary plugging fluid performance

The core was first treated by cutting along the center and milling out grooves in the section to simulate reservoir fractures as shown in **Fig. 1**. Core pressure test was carried out with compound temporary plugging fluid and filtration loss of working fluid under different pressures was recorded. The plugging performance is evaluated by filtration loss.

**Fig. 1.** Compound temporary plugging fluid in fracture core plugging morphology.

### 2.3 Evaluation of reservoir protection performance

The reservoir protection performance of composite temporary plugging fluid is evaluated by measuring the permeability recovery rate of core before and after the pressure test. Before the pressure bearing experiment, the permeability $K_f$ of each core was measured by gas measurement.

## 3 Results and Discussions

### 3.1 System preparation

The configuration method of flexible colloidal temporary plugging liquid is: slowly add a certain amount of flexible colloidal particles into clean water, stir for 5 minutes, and then swell up after absorbing water to prepare temporary plugging fluid. The system was formulated with a combination of 100 mL water, 1% flexible colloidal particles.

When the fiber material is added to the abovefluid, it evenly aggregates into flocculents with a diameter of about 10 mm, as shown in **Fig. 2 (a)**. The color of the system is brown-red,

as shown in **Fig. 2 (b)**, the flexible colloid-fiber compound plugging liquid system is prepared.

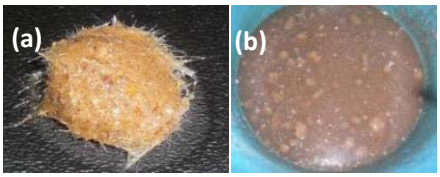


**Fig. 2.** Fibrous tubular-like structure and flexible colloid-fiber compound plugging liquid system. (a) Flocculent structure. (b) Flexible colloidal and fiber compound plugging system.

### 3.2 Compound plugging mechanism

The compound temporary plugging fluid was used as the working fluid. The relation of filtration loss with time is shown in **Fig. 3**. It can be found that the time interval for filtration loss stabilization after pressurization is gradually shortened, which may be due to the fact that the temporary plugging fluid gradually forms a dense colloidal layer on the fracture surface at 120℃, which further controls the filtration loss of working fluid. It is proved that the temporary plugging system can effectively plug the leakage of wide crevices and further broaden the application field of the temporary plugging fluid.

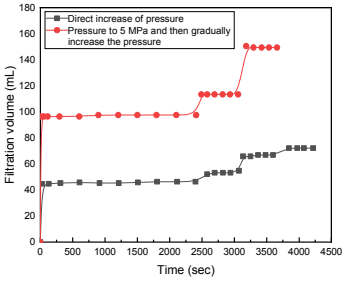


**Fig. 3.** Filtration curve of 1 mm crack core at 120℃.

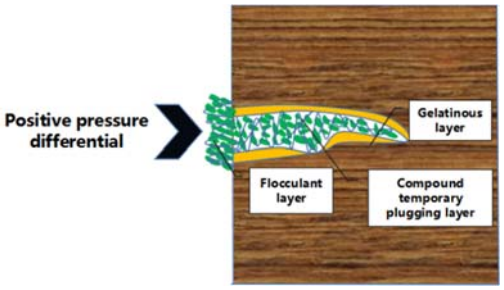


**Fig. 4.** Plugging mechanism of system.

The plugging mechanism is shown in **Fig. 4**. The outer flocculant for large diameter ball layer, flexible colloidal particles formed by filament winding, sealing mouth to reduce cracks blocking leakage of working liquid permeability. The intermediate layer is composed of free fibers entangled with flexible colloidal particles inside the crack, which can further reduce the filtration loss. The inner layer is carbonized colloidal layer with fiber material as the skeleton, and the dense colloidal layer is tightly attached to the fracture wall, which can effectively block the working fluid lost from the outer and middle layers.

### 3.3 Evaluation of reservoir protection performance

The reservoir protection performance of flexible colloid-fiber composite temporary plugging fluid was evaluated by using core with initial permeability of 17.70 mD and 52.82 mD, respectively. The experimental results are shown in **Table 1**. From low permeability core to high permeability core (Granite group), the regained permeability recovery rate is 72.25% and 86.5%, respectively, proving that the system has little damage to the reservoir and good reservoir protection ability.

**Table 1.** Evaluation of core permeability recovery effect.

| Core number | $K_f$ (mD) | $K_w$ (mD) | Regained permeability recovery (%) |
|---|---|---|---|
| H5-3 | 17.70 | 12.21 | 72.25 |
| H5-8 | 52.82 | 45.15 | 86.5 |

## 4 Field application

The drilling depth of Well X was 4,670 m, and the drilling horizon was sand formation. The well hole's permeability in A-a layer of high pressure condensate gas reservoir, A-b for high middle low permeability condensate gas reservoir, formation pressure coefficient is 1.49, and layer b for atmospheric pressure high condensate content in low permeability reservoirs of middle bottom water condensate gas reservoir. In order to ensure well control safety, it is decided to use compound fluid containing 0.1% fiber as temporary plugging agent to plug reservoir B, consider optimizing construction technology, and use the same system of flexible colloid temporary plugging agent to temporarily plug reservoir A.

It has been verified by practice that the flexible colloid-fiber compound temporary plugging fluid can withstand the pressure difference of at least 44 MPa in the well killing operation of Well X, with no overflow and no leakage and a successful well killing.

## 5 Conclusion

(1) The pressure bearing capacity of flexible colloidal temporary plugging fluid to low and medium permeability core and high permeability core can reach 20 MPa and 11 MPa respectively. (2) Composite temporary plugging fluid can control the working liquid filtration in 1 to 2 mm. (3) The permeability recovery rate of flexible colloidal and fiber composite temporary plugging fluid for low and medium permeability core is 72.25% and 86.5%, indicating good reservoir protection performance and excellent pressure bearing capacity.

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