Applying Selected Lost Circulation Materials to Study Lost Circulation of Azkand Formation in Khabaz Oil Field

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Abstract. Managing lost circulation during drilling is a great challenge issue in naturally fractured or vugy formations. This situation becomes further complicated if there are gas or oil returns at the same formation or at a formation above it. The lost circulation problem happens in some of the northern Iraqi oil fields such as Khabaz oil field. Particulate lost circulation materials (LCM) have been used for many years to control lost circulation. However, these traditional LCMs are not efficiently applicable to cure severe to total losses, such as highly fractured formations and formation with large vugs. In this work, an experimental attempt was done to solve such problem in Khabaz oil field. The experiments were carried out using a closed loop circulation system that simulates the drilling fluid loss into formations. Five core plugs from Azkand formation of Khabaz oil field from different depths were used. The experiments were grouped into three, the first was done with the fresh-water-based drilling fluid to measure the severity of losses. The second, fresh-water-based drilling fluid was treated with traditional LCM (cotton seeds) to investigate how the severity of losses is affected by these materials. Adding polymer lost circulation material were the last sets to modify the drilling fluid rheological properties which prepare a medium within the lost circulation zone that increases the friction inside the losses paths to increase the LCMs (the polymer itself) sealing efficiency.

1. Introduction
Lost circulation can be defined as the reduced or total absence of drilling fluids flow up the annulus when drilling fluids are pumped through the drill string. Or it can be defined as a lack of mud returning to the surface after being pumped down a well [1]. Lost circulation occurs when the drill bit encounters natural fissures, fractures or caverns, and mud flows into the newly available space. Also, it may be caused by applying more mud pressure (that is, drilling overbalanced) on the formation than it is strong enough to withstand, thereby opening up a fracture into which mudflows [2]. Even though lost circulation is a well-known problem for years, lost circulation still considered one of the main providers to non-productive time (NPT) [3].

During drilling mud circulate back to the surface, the fluid comes into contact directly with the wellbore inner walls. In traditional drilling practices, the wellbore pressure exceeds that of the formation to allow drilling to be continued without allowing the formation fluids from entering the wellbore. As
was mentioned previously, in order for a fluid to be lost from the wellbore into the formation, the wellbore pressure has to exceed the formation pore pressure. In one method of fluid loss from the wellbore into the permeable rock, a filtration process takes place, whereby the solid particulates and the emulsion droplets accumulate on the wellbore wall and form a filter cake after the liquid components have left them and moved into the rock. The low permeability of this cake works as a barrier to keep the volume of the fluid lost by leak-off relatively low. Knowing that this is not considered a lost circulation event. But when the rock is fractured, vugular, highly porous or induced fractures when the wellbore pressure is higher than the rock’s tensile strength, lost circulation occurs with large volumes of drilling fluid into the thief zone [4].

According to [4] a comprehensive lost circulation management program consists of four tiers. The bottom three tiers focus on lost circulation prevention measurements, while the top one represents remediation measures by using lost circulation materials where LCMs can be pumped with the drilling mud and can start curing losses directly as soon as they have reached the thief zone [5]. [3] had found that when a system controls a certain severity level it will always control the less severe conditions, and vice versa, when it fails to control a certain severity level it will never control more severe conditions.

The best method to govern lost circulation is to make an evaluation of the severity of a loss section (seeping, partial, severe or complete) and match the remedial material and technique to it in terms of both the size of the material and its purpose [6]. In general, when classifying LCMs into sizes, three classes may appear and they are [7]:

1. Fine materials: for most cases, they will pass through the shaker screens and remain in the system.
2. Medium size materials: where they lean towards screening out of the flowing system, but in most cases will not plug the jets or MWD tools.
3. Course materials: they can plug off most tools except open-ended drill pipe.

Moreover, there are LCMs that are chemically reactive such as using an internally activated silicate solution which permits to gain a solid free Newtonian solution with a very low early viscosity. After a certain period, which depends on the fluid temperature and design, the viscosity of the solution rises rapidly to form a gel. This gel is strong, coherent, and does not develop free water with time. The very low initial viscosity of this solid free fluid permits it to be pumped right through the bottom hole drilling assembly, therefore saving time and provides deep penetration of the final gel [8].

Conventional LCM was used instead of cement or hydratable LCM pill to seal relatively large fractures. Their results showed that using LCMs that have irregularity in particles shapes and degree of deformability can seal the wide fracture when used individually or in combination with other LCM.

Some researchers concluded that using large multi-model particle size distribution (PSD) and acid–soluble solution can allow for curing severe –to-total loss circulation in naturally fractured reservoir formation [10].

Using environmentally friendly LCM was the study of [11]. They used two new eco-friendly LCMs, one of them was from a special type of grass while the other was made from a flowering plant. They concluded that the performance of these new additives was superior to widely used LCM.

The aim of this study includes using traditional lost circulation material LCM as cotton seeds and comparing it to new LCM which is a cross-linked copolymer. These results were conducted using a laboratory model test.

2. Data Gathering

Five Dolomite core plugs were used in this study. These core plugs were collected from Khabaz oil field, Azkand formation well KZ-35. Core plugs 2, 4 and 6 are got from C1 sub-formation, while plugs 1 and 3 from the sub-formation C2 that is located below C1. All the core plugs characteristics are shown in Table 1. While the drilling mud data, depths of drilled formations and used LCMs were gathered from wells KZ-30 and KZ-35.

The Khabaz oil field represents a small subsurface asymmetrical anticline, and its northeast limb dipper than the southwest limb. The Khabaz structure is located between Jambur and Bai Hassan oil
fields. This oil field located 23 km to northwest of Kirkuk city northeast Iraq as shown in Figure 1 [12].

![Figure 1](image_url)

**Figure 1.** Major petroleum fields of Iraq shows the location of the study area, modified from[12].

3. Experimental Work

3.1 Materials

This study compares the efficiency of the reference mud and the effect of the addition of two different types of lost circulation materials (LCM) to it. The reference mud system is composed of 60 gm bentonite, 5gm XC polymer, 5gm starch, and 1gm soda ash where all these materials mixed in one litter of fresh water. The cotton seeds and Cross-Linked Copolymer of Acrylamide and Potassium Acrylate (FLOSORB CE 300 S) were used as LCMs'. The materials are shown in Table 2. And the mud system rheological properties are shown in Table 3.

3.2 Rheological and filtration properties

The rheological and filtration properties were measured for the reference mud and the five types of mud systems with LCMs as shown in Table 2. These properties are very important due to their high impact
on their performance in sealing the pores, vugs, and fractures as well as controlling the volume of mud losses.

Adding 100 gm of cotton seeds lead to a decrease in all properties. The large size of the seeds (5 to 8 mm) leads to separating the bentonite plates apart that cause a decrease in yield point, plastic viscosity, and gel strength. While a decrease in the volume of filtration is observed due to the existence of cotton seeds which close the pores of mud cake. The wide range of mud cake thickness can be directed to the irregular gathering of cotton seeds.

When Flosorb CE 300 S in four concentrations (0.2, 0.5, 2, and 5 gm/l) were added to the reference mud leads to an increase in yield point and plastic viscosity this is due to the flocculation of the bentonite plates. An improvement in filtration properties is obtained due to the effect of polymer addition.

**Table 1. Core plugs characteristics**

| Core No | Depth (ft) | L (cm) | D (cm) | K (md) | Appearance |
|---------|------------|--------|--------|--------|------------|
| 2       | 7226.5     | 4.37   | 3.77   | 30.92  |            |
| 4       | 7236.4     | 4.38   | 3.79   | 59.28  |            |
| 6       | 7246.2     | 4.4    | 3.77   | 39.44  |            |
| 1       | 7251.1     | 4.37   | 3.79   | 319.93 |            |
| 3       | 7261       | 4.37   | 3.79   | 14.43  |            |
### Table 2. Specifications of the Materials in Mud System

| Materials                        | Concentration (gm/litre) | Primary Function                      | Solubility in Water |
|----------------------------------|--------------------------|---------------------------------------|---------------------|
| Bentonite                        | 60                       | Viscosity and fluid-loss control      | Insoluble           |
| Soda Ash, Sodium Carbonate, Na₂CO₃ | 1                        | pH controller                         | Soluble             |
| XC Polymer                       | 5                        | Viscosity and fluid-loss control      | Soluble             |
| Starch                           | 5                        | Fluid-loss control and viscosity      | Insoluble           |
| Flosorb CE 300 S                 | 2 or 5                   | LCM                                   | Insoluble           |
| Cotton Seeds (5-8 mm size)       | 100                      | LCM                                   | Insoluble           |

### Table 3. Rheological filtration properties of drilling mud with different concentrations of LCMs

| Properties                        | Rf. Mud | Rf. Mud+100 gm/l Cottonseed | Rf. Mud+0.25 gm/l FLOSORB CE 300S | Rf. Mud+0.5 gm/l FLOSORB CE 300S | Rf. Mud+2.0 gm/l FLOSORB CE 300S | Rf. Mud+5.0 gm/l FLOSORB CE 300S |
|-----------------------------------|---------|----------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| SP.GR                             | 1.02    | 0.97                       | 1.01                              | 1                                 | 1.02                              | 0.995                             |
| 10 sec gel, lb/100 ft²            | 78      | 67                         | 72                                | 85                                | 132                               | 124                               |
| 10 min gel, lb/100 ft²            | 117     | 88                         | 110                               | 119                               | 154                               | 125                               |
| Filter Volume, ml                 | 7.4     | 6.6                        | 7.4                               | 7.8                               | 5.8                               | 5.6                               |
| Mud Cake Thickness, mm            | 1.1     | 7                          | 0.9                               | 0.9                               | 1                                 | 0.8                               |
| pH                                | 10.66   | 10.66                      | 10.4                              | 10.3                              | 10.3                              | 10.25                             |
| YP, lb/100 ft²                   | 116     | 117                        | 108                               | 116                               | 178                               | 165                               |
| PV, cP                            | 13      | 1.4                        | 15.6                              | 16.7                              | 59                                | 34                                |

*depends on whether there is a cotton seed or not

### 3.3 Closed loop Circulation System

A closed loop circulation system was constructed to simulate the event of lost circulation into a formation. Figure 2 shows the closed loop circulation system and its schematic is demonstrated in Figure 3. The details for the preparation and developing of the model are described in the following sections.
3.4 Dynamic Mud Loss Cell

The dynamic mud loss cell is a core holder similar to standard Hassler type core holder. It is made of stainless steel that can house a core plug of 4.4 cm diameter.

The core plug was positioned inside a rubber sleeve and the two sealed together by applied overburden pressure by an air compressor. The pressure was applied to prevent bypassing the injected fluids to the annulus between the rubber sleeve and the core samples, as shown in Figure 4.

![Figure 2](image1)

**Figure 2.** Main components of the closed loop circulation system.

![Figure 3](image2)

**Figure 3.** Schematic Closed Loop Circulating System. Where 1-8 isolation valves, 9- mud tank, 10- pump, 11- flow rate indicator transmitter, 12- pressure indicator transmitter, and 13- core holder.
3.5 Test Procedure
Prior to starting the test, eight to ten litres of mud were prepared. The procedure of the test is explained as follows, where the core plugs are fixed inside the rubber sleeve of the core holder and valve 4 is opened, as shown in Figure 3. After applying the desired pressure by an air compressor, valve 4 is closed. The test starts with opening valves 1 and 2, as shown in Figure 3. The mud is circulated by the pump, while the mud temperature is observed until it reaches 60 °C. After that, valves 3, 6 and 7 is opened and valve 2 is closed, as shown in Figure 3. The pressure is controlled by closing valve 7 gradually until the pressure reaches 120 psi. Start recording lost mud through the core plug with time until the test is finished. After the test is finished, valve 7 is opened to reduce the pressure before the pump is shut down.

4. Results and Discussion
The performance of the materials added to the reference mud as LCMs is presented in the Figures 5 to 8 and demonstrate how efficient each additive preformed in other words how much mud is lost in a unit time.

The cotton seeds and the fibre attached to them gathered on the core plug face to reducing lost circulation. Cotton seeds have reduced the volume of lost mud when it was added at a concentration of 100 g/l about 7.7 % - 20.7 % of lost volume of the reference mud for core plugs 6 and 5 respectively. The same previously mentioned figures also demonstrate the effect of FLOSORB CE 300 S that have reduced the mud losses to 37.5 % - 60 % for the core plugs 1C2 and 6 respectively when they were add at 0.25 g/l to the reference mud. This reduction in drilling mud losses was improved with increasing FLOSORB CE 300S concentration to 0.5 g/l where the efficiency of curing the losses reached 80% with core plug 3 where the crossed-liked polymer involved participate on the plug face to bridge and seal permeable formations.
**Figure 5.** Effect of cotton seeds and polymer LCM on lost volume for core No 2.

**Figure 6.** Effect of cotton seeds and polymer LCM on lost volume for core No 4.
**Figure 7.** Effect of cotton seeds and polymer LCM on lost volume for core No 6.

**Figure 8.** Effect of cotton seeds and polymer LCM on lost volume for core No 1.
Adding 5gm/l FLOSORB CE 300S leads to 70% reduction in lost volume for core No. 1 and 90% for core No.2 and core No.3 that have 30.92 and 14.43 md permeability respectively. Cores No.4 and No.6 with 59.28 and 39.44 md permeability have 80% and 20% reduction in lost volume respectively. As the permeability increases it becomes more challenging to cure the losses especially when fractures are presented in the core plug, and this is illustrated in Figure 8. Where core No.1 has 319.93 md permeability and it is clear that the plugging efficiency of the cotton seeds is poor in comparison with the FLOSORB CE 300S. This is due to the wide range of sizes that FLOSORB CE 300S provide after it absorbs water giving the crossed-link polymer the ability to bridge and block the permeable sections. Adding relatively high concentrations of FLOSORB CE 300S such as 2 or 5 gm/l will increase the plugging and the loss control capability to 95%, but it will affect the rheological properties dramatically.

5. Conclusion
1. Drilling mud loss into fracture are more severe than that into a vuggy formation.
2. For all of the cases, FLOSORB CE 300S acted better than the cotton seeds where it managed to cure the losses in plugs 2 and 3 of the lower permeability.
3. For the core plugs, 4, 6, and 1, FLOSORB CE 300S did not cure the losses 100% but it gave a better result.
4. Adding only (0.2, 0.5, 2, to 5 gm/L) of FLOSORB CE 300S gave better results than adding 100 gm/L of cotton seeds, which gives a great advantage when it comes to the needed storage area.
5. Adding (2 to 5 gm/L) of FLOSORB CE 300S dose give better sealing properties but it increases the rheological properties too much.
6. FLOSORB CE 300S can be pumped through the relatively small bit nozzles.
7. The LCMs used in the presented study for the purpose of reducing or preventing lost circulation have to be applied on other formations suffering lost circulation in the adjacent wells and presumably in other fields.

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