

High Fluid Loss Squeeze Lost Circulation Material Efficiently Seals Simulated Fractures up to 10 mm

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Abstract

The control of severe to total lost circulation in naturally fractured, vugular, and unconsolidated formations can present major challenges. Conventional lost circulation materials (LCM), such as ground marble, graphite, nutshells, or any of these combinations may not work. As a next resort, fibrous LCMs are often used; as a last resort option, gunks, reverse-gunks, or cement are considered. One approach in the industry is to apply combinations of smaller particulate materials that depend on a very high fluid loss to quickly build a sufficiently high concentration of particles to preclude further fracture propagation. These applications are generally referred to as a high fluid loss squeeze (HFLS). This approach is somewhat successful for moderate losses, but may not mitigate severe to total losses. This paper provides a different approach in material selection and HFLA application. Data from a laboratory investigation of a HFLS LCM that plugs large and varied size slotted disks on a permeability plugging apparatus (PPA) test is discussed.

The proposed HFLS LCM is a combination of particulates and unique reticulated foam LCM, which contributes to both the rapid de-watering effect and initial fracture plugging. The reticulated foam is the unique component that forms a plug/bridge at the face/mouth of large fractures; this is followed by the particulates of the composition plugging the foam, eventually forming a thick cake.

The HFLS LCM on its own was able to seal slotted disks up to 3,000 μm . By supplementing HFLS LCM with additional reticulated foam (medium), slotted disks of up to 8,000 μm were plugged efficiently. For plugging slotted disks greater than 8,000 μm and up to 10,000 μm , the HFLS LCM was supplemented with both medium- and coarse-sized reticulated foam. This type of plugging data is the first of its kind, and the results provide confidence in considering the HFLS LCM as a potential option for severe-to-total loss situations.

Introduction

Particulate-based lost circulation materials (LCMs) that are often used for managing losses may have limitations in the application of severe to total losses. Particle size is a factor in the arrest of losses up to a certain level of loss rates. At high

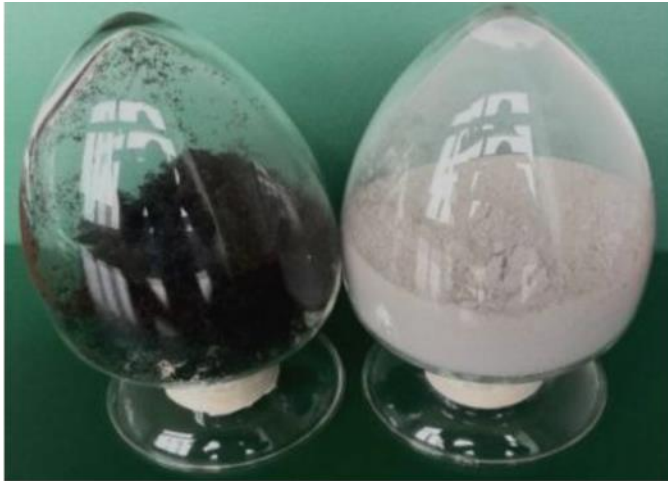
loss rates (typically greater than 100 bbl/hr), both increasing the concentration of particulate-based LCMs and particle size distribution (PSD) may be required. This combination then becomes of concern in terms of pumping it through a bottomhole assembly (BHA) with limited clearances. This process can require tripping out of the hole or using a treating (circulating) sub in the drillstring. Depending on the loss rate and on whether or not particulate-based LCMs are working, operators resort to the use of solutions, such as cement. The use of cement for curing losses, however, is not trivial; it usually involves tripping out, going open ended, pumping cement, waiting on cement, and then tripping in to continue drilling. In many cases, multiple cement plugs may be required. This paper presents a high fluid loss squeeze (HFLS) LCM that is a likely candidate in such high loss scenarios before resorting to cement. The concept is not new and has been discussed or presented previously,^{1, 2} but the material combinations are both new and unique.

High Fluid Loss Squeeze LCM

The HFLS LCM is based on the ability to de-fluidize rapidly to form an efficient plug across the loss zone and does not depend on the particle size distribution. The benefit of the HFLS is obtained by mixing materials, such as a fine-grind, soft, siliceous sedimentary material and other particles that yield smaller/finer particle size distribution¹. The powdered siliceous materials behave similarly to diatoms and supposedly look like skeletal objects at a microscopic level, contributing to a low packing efficiency which, in turn, yields to high fluid loss nature. Filtration control agents are not recommended to be added to the HFLS LCM pills. Polymer-based viscosifiers (e.g., xanthan) and filtration control agents severely inhibit the high fluid loss nature and reduce the effectiveness of the pill. Suspension agents are also part of the HFLS LCM package, but are based on clays with minimal fluid loss control (as opposed to any polymers for the same reason as previously described).

Fig. 1 shows the HFLS LCM described in this paper. Contrary to other similar HFLS LCMs, the unique feature of the technology described in this paper is the presence of a “fine reticulated foam component” and “multi-modal particulates”³.

The mechanism by which a typical HFLS LCM works is well known. The powdered siliceous material that is part of the multi-modal particulates serves as a source of silica and reacts with water to form siliceous acid. The siliceous acid, in turn, reacts with a calcium source (which is also part of the multi-modal particulates) to form a hard/aggregated mass. Typical HFLS LCMs tend to form this reaction very well in water; consequently, it is recommended to mix these HFLS LCMs in water for best performance.



Fine foam component Multi-modal particulates

Fig. 1—High fluid loss squeeze LCM.

Reticulated Foam LCM

As previously described, the unique feature of HFLS LCM is the fine component reticulated foam LCM (**Fig. 2**). The foam LCM is perceived to play a critical role in the plugging of large fractures.



Fine Medium Large

Fig. 2—Reticulated foam LCM.

The HFLS LCM is efficient when used alone (because already it contains the fine foam component) for up to certain loss rates and fracture widths. When it does not work on its

own, this may indicate the fracture widths are larger than the fine foam component. In such situations, the HFLS LCM can be supplemented with the medium or large foam components. The reticulated foam LCM is not soluble in acid, and it has good temperature stability (up to 350° F). The low concentrations at which these materials are added to the HFLS LCM pill are in the range of 0.25 to 1 ppb.

The HFLS LCM is not entirely acid soluble; it is approximately one-third soluble in 15% HCl. Consequently, it is not recommended for use in applications in which complete acid solubility is needed. Other operational aspects of mixing and pumping HFLS LCM and reticulated foam LCM is discussed in subsequent sections of this paper.

Objective of Present Work

As previously stated, the primary objective of this paper is to present the HFLS LCM (**Fig. 1**) and its combination with reticulated foam LCM as a potential option for managing severe to total losses. Because this HFLS LCM is different from similar products, this option may be an efficient and effective application before resorting to more complex gunks or cement plugs.

Statements such as ‘an LCM solution can work for managing severe to total losses’ are often considered to be subjective; consequently, application examples or case studies are sought whenever such LCMs are presented as potential options that could work at high loss rates. Often, obtaining case studies for new LCMs can be very difficult without having prior experience. In such cases, laboratory-based evaluations may provide useful data for assessing the ability of any solution for its intended applications. A similar approach was used to evaluate the HFLS LCM and reticulated foam LCM. An industry-accepted, laboratory-based permeability plugging apparatus (PPA) was used, with some modifications. Lost circulation materials are often tested in PPA equipment to determine their ability to seal aloxite discs/slotted discs. Aloxite discs are used as test media for assessing the capability of LCM to plug permeable pores, and slotted discs are used when LCMs are tested for plugging fractures (natural/induced). In the present work, the objective was to use a PPA setup and slotted discs (which can have openings ranging from 3000 to 9800 microns) to evaluate the HFLS LCM and its combinations with reticulated foam LCM for their maximum sealing capability. The details of the laboratory procedure, tools, and results is presented in the following section, followed by a brief discussion of the results. Operational considerations are presented to provide guidance for mixing, pumping, and applying such HFLS LCMs.

Laboratory-Based PPA Test Procedure and Tools

This section discusses tools and laboratory procedures used to test HFLS LCMs. As previously mentioned, some of the tools for a standard PPA test were used, including the PPA cell, hydraulic pump, and retaining ring. The custom slot (**Fig. 3**) consisted of two sliding pieces on a plate that had a large cutout equivalent to the diameter of the cell. The two sliding

pieces were fastened by screws to be adjustable and create various opening sizes, ranging from 3000 to 9800 microns. The top fixture on the PPA cell was modified (Fig. 3) to enable the passage of heavily solid-laden fluid and that would not plug before the slot. A simple cell cap piece was created that fit into the cell with an opening of approximately 30 mm. This piece was then fastened into the cell with a retainer ring. A receiver body (Fig. 4) was created with the same inner diameter as the cell cap, with a volume retention of approximately 250 ml. Finally, a top cap (Fig. 4) was created for the receiver body with a small outlet.

Because the LCM is a high fluid loss squeeze material, the laboratory method also must mimic a squeeze technique. A standard size pill contains 80 to 120 ppb of HFLS LCM and any needed reticulated foam LCM for the specific slot size being tested. A total of one laboratory barrel (1 bbl) of the pill and water were mixed on a low shear mixer at a speed that created a 0.5-in. vortex for 5 minutes. If reticulated foam was needed for the current pill, it was added and mixed for an additional 3 minutes. The entire 1 bbl was added to a PPA cell with the piston completely lowered. The slot was added, and the custom top pieces were affixed to the cell. The entire setup was placed in a PPA jacket, and the hydraulic pump was attached. A drain hose was attached to the top of the setup because the pill was a full 1 bbl. and the receiver body capacity was only approximately 250 ml.



Fig. 3—The adjustable slot, shown face down (left) and the cell cap custom piece (right).

The standard PPA test protocol is not used for these tests because of the requirement that a hesitation squeeze be used for the application of this unique HFLS LCM. The test has three different phases of pumping schemes, including the initial sealing, growing the plug, and strengthening the plug by compaction. The first sealing phase consists of stroking the pump at a rate of 2 to 4 seconds per stroke with a specific wait-time afterward. The second growing the plug phase consists of pumping at the same rate as previously, then waiting for similar specific time. The final strengthening the plug by compaction phase consists of stroking the pump at a rate of 2 to 4 seconds per stroke until the pressure reaches 500 psi on the hydraulic pump, then waiting for similar specific

time. This step can be repeated in 500 psi steps until the target pressure is reached. After the target pressure is acquired, the pressure is held for 30 minutes.



Fig. 4—Receiver body with top cap attached.

Results and Discussion

Table 1 presents the comprehensive summary of the laboratory testing described in the previous section. All of the testing presented was performed at room temperature. The HFLS LCM successfully plugged a 3000 micron slot on its own. The results presented in Table 1 demonstrate that, by supplementing the HFLS LCM with medium- and coarse-sized reticulated foam LCM, plugging can be extended to slots as wide as 9800 microns. The plugs were formed with as little as 500 psi of applied pressure. The resulting plugs formed at 500 psi can withstand the application of 1,000 lb of pressure in a borehole type condition. The use of seawater does not change the ability of the HFLS LCM to plug slots up to 9800 microns with the reticulated foam. The pill can also be weighted with barite without any loss in performance. Fig. 5 shows an image of the HFLS LCM plug formed on a slotted disc. The formation of thick cake is apparent for typical high fluid loss squeeze LCM pills owing to the rapid defluidization. In reality, this would indicate that a HFLS LCM

would from an instant seal within highly fractured/vugular formations arresting the losses.

Table 1: Summary of Laboratory Testing on the HFLS LCM and Reticulated Foam LCM.

Slot, microns	Combination that Plugged the Slot	Maximum Pressure*, psi
3000	100 ppb HFLS LCM	4000
4000	100 ppb HFLS LCM + 0.25 ppb medium-sized reticulated foam LCM	4000
5000		4000
6000		4000
7000		4000
8000		3000
9000	100 ppb HFLS LCM + 0.5 ppb medium-sized reticulated foam LCM + 0.5 ppb coarse-sized reticulated foam LCM	4000
9800	120 ppb HFLS LCM + 0.5 ppb medium-sized reticulated foam LCM + 1 ppb coarse-sized reticulated foam LCM	4000

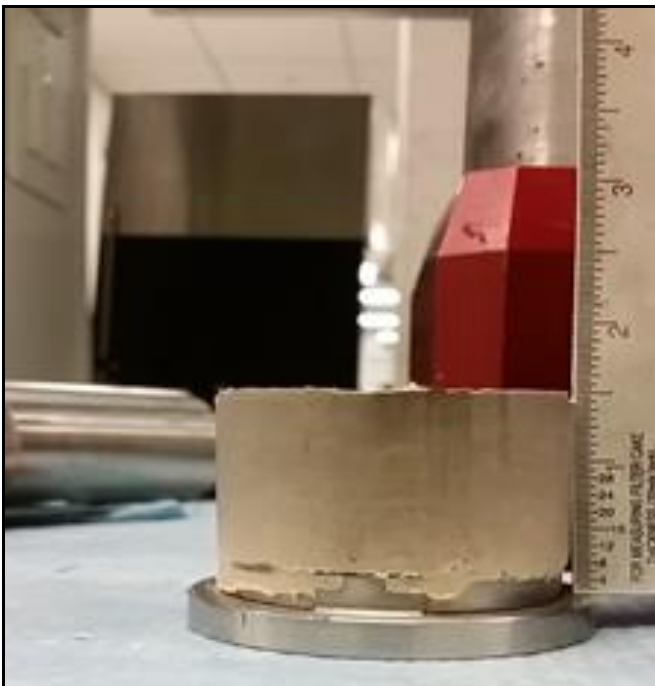


Fig. 5—HFLS LCM plug formed on the slotted disc after de-fluidizing.

The laboratory testing shows that the benefit of having this HFLS LCM and the reticulated foam LCM available as a contingency for severe to total losses can be substantial. The HFLS LCM pill can be mixed ahead of time as a stand-by option. Whenever severe losses occur, the pill can be pumped (with or without weighing it up). In most cases, when the fractures are within the range of plugging capability of the HFLS LCM, the losses may be cured. Situations in which the HFLS LCM does not cure losses, however, could potentially indicate that the downhole fractures may be larger than the fine-sized reticulated foam LCM. In that case, a second pill can be prepared by supplementing with medium-sized

reticulated foam LCM, which will extend the plugging capability to as large as 8000 microns. Finally, the coarse-sized reticulated foam LCM can be considered to be part of the HFLS LCM pill, as a last contingency option. In this way, having this HFLS LCM and the reticulated foam LCM as supplements on location may quickly mitigate severe losses while reducing NPT and overall drilling cost.

Operational Considerations

This section presents a general discussion that is primarily applicable to the HFLS LCM discussed in this paper; it may, however, also be applicable to more normal HFLS LCMs. Because the reticulated foam LCM is unique to the HFLS LCM, special consideration must be given for knowing the operational conditions (especially tools restrictions and desirable pump rates) for use during applications.

- The HFLS LCM described in this paper, like other high fluid loss LCM, must be mixed only in base fluid (preferably water or base oil).
- Viscosifiers of any type, polymeric or clay-based, should not be added to the HFLS LCM pill because they may severely inhibit the high fluid loss nature and reduce the effectiveness of the pill.
- For effective performance, it is recommended to mix the pill as water based.
- The pill can be weighed up to the required density using weighing agents. However, it is recommended to add the weighing agent to the pill just before pumping.
- The HFLS LCM, which already contains the fine version of reticulated foam LCM, can be pumped through normal bottomhole assemblies maintaining a flow rate at a minimum 5 bpm.
- When supplementing the HFLS LCM with the medium-sized reticulated foam LCM, consideration must be given to bit nozzle sizes; a minimum of 5 bpm pump rate is recommended.
- Supplementing the HFLS LCM with the coarse-sized reticulated foam LCM is often recommended in advance when total losses are expected or encountered. In such a scenario (total loss), it is also generally recommended to include a treating/bypass sub so that the pills containing large PSD LCM or fibers can be pumped without tripping for open-ended drillpipe.
- Finally, and more importantly, a hesitation squeeze application is the recommended method of application for the HFLS LCM pills.

Conclusions

- The HFLS LCM, containing the reticulated foam, based on a high fluid loss mechanism may be a very efficient backup option for severe to total loss scenarios in which the standard particulate-based LCM processes often fail.
- The laboratory testing presented in the paper provides a means of testing high fluid loss LCMs in the solution creation process for severe to total loss situations. This testing can also be used in planning for appropriate

LCMs that must be on the rig.

- The HFLS LCM on its own was demonstrated to plug slotted discs up to 3000 microns.
- Supplementing the HFLS LCM with medium- and coarse-sized reticulated foam can extend the plugging capability to slots as wide as 9800 microns. This outcome indicates that such combinations of LCMs provide good options for curing severe to total losses.
- It is important that careful consideration be given to the guidelines for mixing and pumping such LCMs in the field.
- A written document including the concentrations, mixing, and pumping procedures is recommended to be prepared in advance. Such documents can serve as valuable tools for the appropriate transfer of information to the field and may be critical for the implementation of an efficient solution in the field.
- Applications of this particular HFLS LCM will be presented at the 2016 SPE Deepwater Drilling and Completions Conference, Galveston, Texas, USA.

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