AADE-25-NTCE-029

Advanced Single Sack Loss Circulation Technology Sealing Larger Fractures suitable to use in Depleted Reservoir conditions

Michael C. Barry, Ajay Addagalla and Autumn Shepherd; Baker Hughes, Houston, USA

Abstract

Loss circulation is a major problem in the oil and gas industry costing operators and service companies millions of dollars and large amounts of non-operating time (NPT) leading to delayed well deliveries and production loss in the event these losses are in the reservoir. The scope of this paper discusses a novel loss circulation prevention system designed to seal larger fractures (>5 mm) in depleted reservoir conditions.

The lost circulation system is single-sack, designed for ease of mixing and deployment. It is acid-soluble (> 95% in 15% Hydrochloric Acid) and can be integrated in aqueous based mud system and non-aqueous mud system (with spacers). Due to its broad range of particle size distribution, this system is capable of sealing large fractures across a variety of applications. The SSAS was tested across different sizes of slot discs ranging from 1 - 10 mm in a 500 ml Particle Plugging Apparatus (PPA) cell and observed to seal and hold for at least 5 minutes. This product works by particle plugging and bridging. until the pill reached its maximum threshold limit of pressure around 4,000 psi. An aqueous-based drilling fluid was formulated and mixed with SSAS Loss Circulation Material (LCM) on a paddle mixer. This SSAS LCM is very beneficial in accomplishing well delivery due to its versatility and broad range of application scope. If needed, a simple acid job can help to remove or solubilize as a post-job acid flush.

Introduction

Loss circulation, whether from either drilling or completion fluid, in the wellbore poses significant challenges to well safety and hydrocarbon recovery. Effectively, prevention and managing loss circulation is critical to ensuring efficient, safe, and cost-effective drilling operations. The importance of promptly addressing and mitigating loss circulation events is underscored by their potential to lead to non-productive time (NPT), delays in well delivery, and financial losses associated with fluid loss and associated hidden costs. while drilling and controlling losses immediately are very important for a quick, safe, and economic drilling operation. This highlights the importance of mitigation of the loss circulation event to acceptable levels by proper evaluation and testing of loss circulation materials to select superior and high-performing LCM products for the loss zone (Al-Arfaj, M, 2018). Loss circulation events can occur at any stage of the operation, including drilling, casing running, logging, and completion. This problem is one of the major reasons contributing to NPT leading to delay in well delivery schedule to the oil and gas operators, along with financial impact for the fluid lost to the wellbore and other hidden costs. These events are classified based on the severity of losses into three categories.

1. Seepage Losses
2. Partial Losses
3. Severe or Total Losses

In most cases, seepage losses and partial losses can be cured by adding the conventional LCM (fibers, flakes, and coarse products) to the drilling mud at higher concentrations, typically in the range of 50-150 ppb depending on down hole limitations, and pumping the pill to plug or bridge the loss zone. The conventional bridging materials were successful, to some extent, to cure seepage and partial losses, but these systems were defeated with severe and total loss circulation incidents. The thought to increase concentration of conventional bridging materials to combat severe losses has the limitation of pumping through drilling assembly, which can and will adversely induce more losses with extra pressure being exerted across the formation. The approach to perform cement plugs to combat severe losses would be uneconomical to the operator that is losing time in tripping to run in hole with a cement stringer prior to perform the cement job (Prahlad et.al, 2017). The other option is to pump a specialized or un-conventional LCM pill; this should be prepared with fresh water, sea water, or brine rather than drilling fluid to avoid any chance of failure. These specialized pills (polymeric, high fluid loss, high solids) depend on a specific mechanism to form plugs (with or without compressive strength) which helps to cure or control the losses.

In case of total losses, operators will try multiple loss circulation pills to control losses, or a combination of specialized pills can be pumped. In the case where losses are unable to cure after trying several pills and are unable to drill further, operators may perform a cement plug and try to drill a side track which is not the ideal choice. This approach seems uneconomical where the operator is losing time while tripping to run a cement stringer prior to performing the cement job. The conventional cement system is hampered in performance due to its lack of thixotropic behavior downhole with several factors contributing to poor performance (accurate bottom hole temperature, contamination with formation and drilling fluids, mix water source, etc.) (Al-Azmi, B., 2014).

Loss circulation can be natural or induced. Natural losses occur in formations with high permeability typically like limestone and dolomite. These fractures provide the primary pathways for hydrocarbon migration and production, but they can also act as conduits for drilling fluid and minimize or eliminate losses during drilling and cementing operations (Addagalla, 2020).

Induced losses occur when hydraulic forces in the wellbore exceed the formation strength and break down the weaker formations. The possibility of having induced losses is likely due to poor engineering planning (incorrect mud weight or pore pressure prediction) and inappropriate drilling practices (high flowrates, fast tripping).

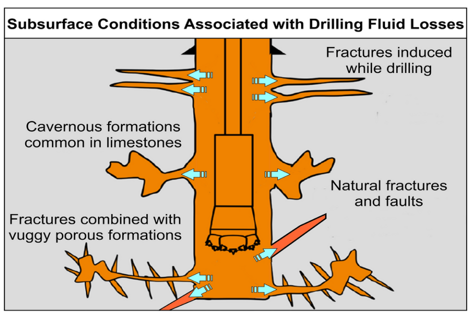

Figure1: Journal of Petroleum Exploration and Production Technology volume 12, pages 83–98 (2022)

Technology Details

A single-sack loss circulation material (LCM) was developed to improve the efficiency of mixing and deployment while addressing large fractures and vugs in the wellbore. The system was designed for use in both solids-free and low solids content mud systems, making it adaptable to various drilling conditions to drill the reservoir and non-reservoir wellbore. Its high acid solubility enables effective use in reservoir sections by reducing the potential for formation damage and preserving hydrocarbon flow paths.

The bridging material was formulated to accommodate a range of loss circulation scenarios, ensuring adaptability across different well conditions.

It has the capability to effectively seal large fractures ranging from 1 to 2 mm alone and 3 to 4 mm when used in combination with other materials. When used with foam based products, it shows effective sealing fractures up to 10 mm.

A summary of initial testing results is provided in Table 1.

Table 1: Summary of product performance at different slot disc size

Slot Disk Size	Sealed	ml of Fluid Loss	Pressure Held
1 mm slot	Yes	7	Yes
3 mm slot	Yes	10	Yes
5 mm slot	Yes	50	Yes
8 mm slot	Yes	30	Yes
9.4 mm Vug	Yes	25	Yes

Laboratory Test Data

Performance Test or Fluid Loss Test

To evaluate the efficiency of this system, a series of tests were conducted using LCM on slot disks in a particle plugging apparatus (PPA). These tests were performed under challenging lab conditions, including larger slot sizes and increasing pressure levels. The test were run in stepwise fashion with 5-mm slots and progressed to 10-mm slots, with pressure increasing incrementally by 500 psi. Pressure started at 500 psi and reached a maximum of 4000 psi. The increasing slot size calls for the need of larger LCM particles; this requires adjustments to the rheology of the fluid for effective suspension. Larger particles, due to their increased mass, require more viscous fluids to remain suspended; this ensures the particles remain homogenized allowing for a more effective plug.

The LCM system tested included particle sizes ranging from a Dv(10) of 272 microns to Dv(90) of 1580 microns. An 11 lb/gal water-based mud made with sodium chloride was used. As slot sizes increased, the system required larger particles to form effective plugs, and foam-based supplemental products were used to support the plugging mechanism and maintain pressure balance.

Several tests were performed leading up to the 10-mm slot, most of which were not included in this report. The first successful run used less than one pound of supplementary foam product up to a pressure of 2,000 psi. To achieve the pressure hold, a supplementary product needs to be added beyond this pressure overbalance. A total of 4 tests were run before a seal was made at different concentrations of LCM that seal up to 2,000 psi overbalance. Tests were successful until about 8 mm slot disc with minimal change in the product concentration. Finally, the 10-mm slot was tested with the addition of a high concentration of supplementary foam product with the same mud system that sealed successfully, holding a pressure of greater than 4,000 psi overbalance for a minimum of 5 minutes.

In conclusion, the fluids were designed successfully to bridge 10 mm slot disks and hold pressure greater than 4,000 psi. Additions of flaked calcium carbonate (medium and/or coarse size) and supplementary foam-based product were required for the slotted disks greater than 5 mm.

Figure 2: Slot cell after test with disk removed

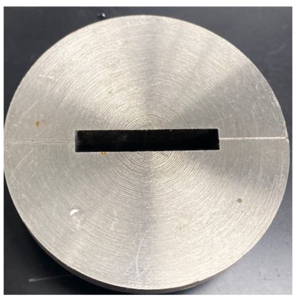

Figure 3: 5-mm slot disk

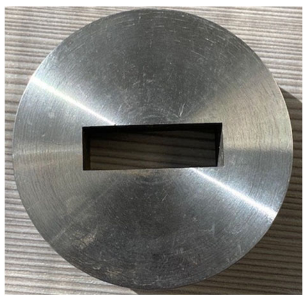

Figure 4: 10-mm slot disk

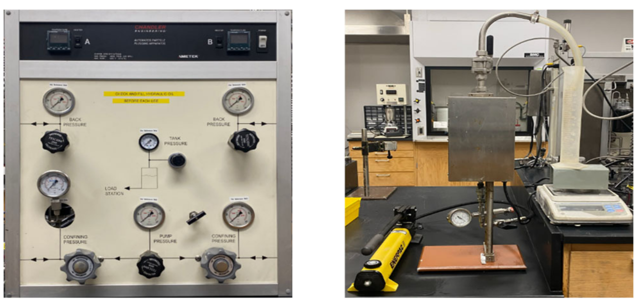

Figure 5: Slot disk automated PPA assembly unit

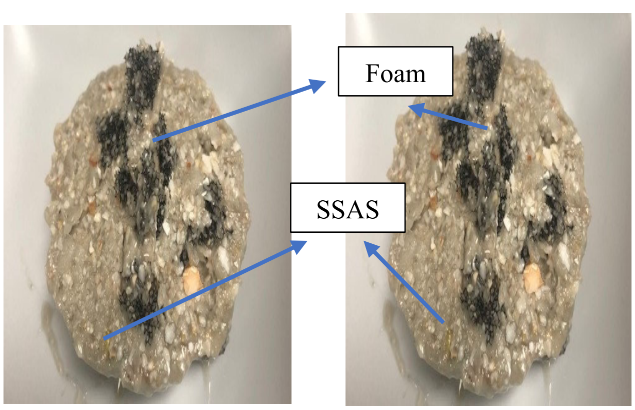

Figure 6: Filter cake pictures showing the integrity of the cake built on slot disc after the test

Acid Solubility

Acid solubility tests were performed using 15% hydrochloric acid on the filter cakes built from the PPA after the tests. Most of the tests showed an acid solubility greater than 92% which shows it is suitable to pump in reservoir conditions.

Table 2: Test Results on different slot size and Different pressure

Product	1	2	3	4
11.0 ppg WBM, bbl	1.0	1.0	1.0	1.0
SSAS LCM, ppb	120	120	120	120
Flaked Calcium Carbonate C, ppb	20	30	30	30
Foam M, ppb	0.5	0.5	0.75	1.0
Foam C, ppb	0	0.5	0.75	1.0
Slot Size, mm	5	8	10	10
Pressure Hold, psi	2000	2000	2500	4000
Did it Seal?	YES	YES	YES	YES

Conclusion

- SSAS LCM has ability to bridge the fractures up to 10-mm and can hold pressure of about 4,000 psi.
- This SSAS LCM system is suitable to add the into the existing mud system to conserve rig time and cost.
- SSAS LCM is suitable to pump in the reservoir as a pill considering the high acid solubility and particle size distribution.
- Addition of regular filtration agents like PAC and/or polysaccharide increase the suspension of the product without impacting the setting mechanism or performance of the pill
- Supplementary foam-based product helps in plugging

the larger-sized slot disks and holding the overbalance pressure beyond 2,000 psi.

- It is always recommended to consider the down hole tool limitations.

Acknowledgments

The authors would like to thank the management of Baker Hughes for granting permission to publish this paper and the personnel involved in the laboratory work and Research and Development team involved in product development.

Nomenclature

LCM = Loss Circulation Material
SSAS = Single Sack Acid Soluble system
NPT = Non- Productive Time
ppb = Pounds Per barrel
mm = Millimeter
lbs/gal = Pound per gallon
lb/bbl = Pounds per barrel
C = coarse
M = Medium
psi = Pounds- Per Square foot Inch
PAC = Poly-Anionic Cellulose
µm = micro-meters
ml = milli-liters
WBM = Water Base Mud
bbl = barrel
PSD = Particle Size Distribution
Dv (10) = 10% particles are smaller than the mentioned size
Dv (90) = 90% particles are smaller than the mentioned size
PPA = Particle Plugging Apparatus

References

Yadav, P., Sarma, P., Jadhav, P., Agrawal, G., Kosandar, B., Al Tawat, N., Addagalla, A., 2017. “New Phase Transformation Fluid Based Loss Circulation Material: Hi-Strength, Year Round Use to Cure Severe to Total Loss in Reservoir and Non Reservoir Sections.” SPE Middle East Oil & Gas Show and Conference, Manama, Kingdom of Bahrain, Mar 6-9, 2017. SPE-183945-MS https://doi.org/10.2118/183945-MS

Al-Arfaj, M., Md. Amanullah and Al-Ouhail, R.,2018. "Loss Circulation Materials Testing Methods: Literature Review", SPE International Heavy Oil Conference and Exhibition, Kuwait City, Kuwait, Dec 10-12, 2018. SPE-193678-MS https://doi.org/10.2118/193678-MS

Addagalla, A., Jadhav, P., Yadav, P., Sarmah, P., Maley, I., and Anerao, A., 2020. “A Novel Phase Transition Loss Circulation Solution for Severe Losses Scenario: Case Histories from Middle East and Africa”, SPE Asia Pacific Oil & Gas Conference and Exhibition, Perth, Australia, Nov 18-19, 2020. SPE-202234-MS https://doi.org/10.2118/202234-MS

Al-Azmi, B., Al-Mayyan, M., Al-saleh, F., Godara, V., Panchat, R., Kosandar, B., Tobeh, S., Jadhav, P., Yadav, P., and Samir, A., 2015 "A Cross-link Polymer Sealant for Curing Severe Lost Circulation Events in Fractured Limestone Formations", SPE Asia Pacific Oil & Gas Conference and Exhibition, Adelaide, Australia Oct 14-16, 2014. SPE-176533-MS https://doi.org/10.2118/176533-MS