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Laboratory study investigating the impact of different LCMs additives on drilling mud rheology and filtration

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Abstract

Drilling operations in Basra's oil fields, particularly targeting the Dammam, Hartha, and Shuaiba formations, are facing significant challenges related to lost circulation. This study investigates the effects of incorporating lost circulation materials (LCMs) into bentonite-based and polymer-based drilling muds. Experiments were carried out using a high-pressure high-temperature filter press to evaluate the rheological properties and filtration performance of the different mud systems prepared using bentonite and polymer mixed with various compositions of additives. The results showed that the incorporation of LCMs increased the plastic viscosity and yield point of the polymer mud by 25-30%, while the impact on the bentonite mud was less significant. Notably, the using of fine-sized LCMs influenced the rheological characteristics of the polymer mud system, resulting in a 35-40% increase in parameters as the LCM concentration was raised. In terms of filtration performance, the bentonite mud exhibited the highest total fluid loss, whereas the polymer mud showed the lowest. The adding of LCMs led to a 20-25% reduction in fluid loss for both mud systems, with fine-sized LCMs at higher concentrations proving most effective in the polymer mud. In conclusion, this study demonstrates the substantial influence that the type, size, and concentration of LCMs can have on the rheological and filtration properties of drilling muds. It is confirmed that the polymer mud system is particularly sensitive to these LCM parameters. Desalination elimination of 80.95% associated with a maximum power output of 420 mW/m^3 in the system.

Keywords: lost circulation; Iraqi Basra oil fields; lost circulation materials; Drilling mud; polymer mud.

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1- Introduction

lost circulation is one of the most common issues in drilling operation, as it wastes funds on time spent on rig operations and expensive mud, efforts are typically taken to lessen the severity of the loss by using specific additives to increase the drilling fluid's viscosity [1]. Hundreds of new materials are introduced each year by service providers and manufacturers of lost circulation materials (LCM). Present lost circulation management solutions, such as ready-made pills developed by service companies, cement plugs, and non-formation-specific formulations, have reached their current efficacy limits, especially in complex conditions such as conductive fractures as well as weak and depleted formations [2, 3]. One technique is to apply settable composition into an issue region to prevent or reduce flow, an additional strategy whereby lost circulation material is inserted into the zone of loss or pumped with high-yield stress fluid. develops a particular gel fluid that can be employed at temperatures lower than 90 °C to regulate severe loss circulation, this specific gel develops viscoelastic properties due to polymer cross-linking, which obstructs communication between the wellbore and the formation [4]. The amount of loss for the rock samples was calculated, and after adding rice, the percentages of drilling mud losses and improvements in circulation were determined to be 46% and 96%, respectively. Two steps were involved in the addition of rice materials: a) The curing rate increased from 30.67% to 100% With 24 lb/bbl of fine rice and 1 lb/bbl of course rice. b) A 92.12% improvement in curing was obtained by adding 24 Ib/bbl of fine rice and 6 Ib/bbl of course rice [5]. Lost circulation materials can be classified as fibrous, flaky, granular, or a combination of these. The effectiveness of an LCM depends on how strong the bridge it builds inside cracks is to withstand the different mechanical forces applied to it, to properly seal pores and cracks that conventional mud alone might not be able to sufficiently seal, LCMs play the role of enlarging the size of mud particles [6]. The most often utilized additives are as follows: Bentonite is used to make drilling mud more viscous, which slows the fluid moves through the nearby formations. Polymers are used to make drilling mud more viscous compared to bentonite [7]. Treatments for lost circulation are either

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identified as concentrated pills or continuously added to the drilling fluid to reduce losses depending on the type of loss or formation under consideration [8]. According to [1] after lost circulation happens, efforts are typically made to lessen the severity of the loss by using specific additives to increase the drilling fluid's viscosity. Drilling can now proceed unhindered. The most often utilized additives are as follows: a) Bentonite is used to increase drilling mud's viscosity, which decreases the flow of fluid in the surrounding formations. b) Drilling mud is made more viscous by the use of polymers. Nevertheless, their cost surpasses that of bentonite. In order to control lost circulation in drilling fluids, the study assesses the effectiveness of novel, environmentally friendly lost circulation materials (LCMs). These LCMs work well in highly permeable and fractured reservoirs. One of them, pomegranate peel LCM, is more affordable and eco-friendly materials than traditional LCMs. Field tests demonstrate that the LCMs as designed are capable of controlling severe lost circulation that is beyond the scope of standard processes [9]. LCMs are routinely added to the mud system to fill the vugs and fractures made during drilling in order to stop lost circulation. The method is not consistent because materials are chosen through trial and error, even though using these materials lowers the loss rate. Furthermore, it is unclear how long LCMs are stable and effective in the loss zone, as well as the extent to which the loss rate can be reduced [10].

2- Experimental work

Experiments were conducted in the laboratory utilizing a High-Pressure High-Temperature (HPHT) filter press as illustrated in Fig. 1. The apparatus is composed of a pressurized collection cell that can maintain the correct back pressure to prevent the filtrate from flashing or evaporating, regulators, a drilling fluid cell that can contain working pressures ranging from 600 to 1800 psi, an appropriate stand and a heating system for the cell. A thermometer well, oil-resistant gaskets, support for the filter media, and a valve on the filtrate delivery tube allow for the control of the flow from the drilling fluid cell.

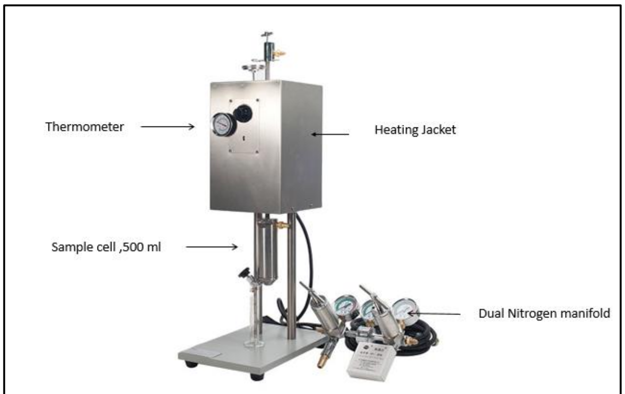

Fig. 1. Main components of high-pressure high-temperature filter press

2.1. Fluid description

Various compositions of Bentonite and Polymer muds have been utilized as drilling fluids in this study as listed in Table 1. Bentonite served primarily as a weighing ingredient in the Bentonite Mud. Bentonite was mostly used as a weighting agent in polymer mud, whereas Caustic soda was included for PH regulation, particularly in cementing jobs [11, 12].

Table 1. The compositions of drilling fluid systems

Mud system	Base fluid	Additives	Function)
Bentonite Mud	Water	Bentonite	Weight agent
		Na_2CO_3	Treatment of cement pollution
		NaOH	PH control
		PAC-LV	Viscosifier
		XCD	Increase shearing force
		PHPA liquid	Inhibition
		HPAN	Inhibitor
Polymer Mud	Water	Bentonite	Weight agent
		Na_2CO_3	Treatment of cement pollution
		NaOH	PH control
		PAC-LV	Viscosifier
		XCD	Increase shearing force
		PHPA liquid	Inhibition
		Lubricant	Decrease torque
		KCL	inhibit shale swelling

The various mud systems that were being employed were tested twice: once with and without the addition of lost circulating materials (LCMs). Contrary to the other mud groups, which contained 5, 10, and 15 lb/bbl of LCM, respectively as illustrated in Table 3, with 3 different types of LCM fine, medium, and granular respectively as illustrated in Table 2, note (the chemical composition is same for all 3 types).

2.2. Viscometer measurement

A viscometer model 3500 manufactured by Chandler company has been conducted to evaluate rheology properties and gel strength of drilling muds. Plastic viscosity and yield point of Bentonite and Polymer muds were determined using the Bingham model, Viscometers with coaxial cylinder designs work as rotating viscometers. It uses a transducer to measure the angle at which the fluid sample under test causes the bob to rotate. The bob, which is attached to a shaft and biasing spring for the fluid, and the rotor are separated by this space. The torque produced by the fluid's viscous resistance on the bob is detected by the transducer, which then calculates the angular shift. With this angular shift, the processor uses preset calculations that take the bob displacement figure and shear rate into account to compute and transmit comprehensible data about the sample's properties.

Table 2. Properties of lost circulation materials

Type	Size range	Mean particle size	Oil absorption	Density	Chemical composition
Fine	0-160 µm	30	<10	1.4	Caco3 99.1% Mgco3 0.8% Fe2co3 0.03%
Medium	60-400 µm	140	<10	1.7	Caco3 99.1% Mgco3 0.8% Fe2co3 0.03%
Granular	0.63-1.8 mm	N/A	N/A	N/A	Caco3 99.1% Mgco3 0.8% Fe2co3 0.03%

Table 3. Tested drilling fluid packages

Parameter	Size	LCM concentration bl/bbl	Fluid
Bentonite mud	-	-	1
Bentonite mud	Fine	5	2
Bentonite mud	Fine	10	3
Bentonite mud	Fine	15	4
Bentonite mud	Medium	5	5
Bentonite mud	Medium	10	6
Bentonite mud	Medium	15	7
Bentonite mud	Granular	5	8
Bentonite mud	Granular	10	9
Bentonite mud	Granular	15	10
Polymer mud	-	-	11
Polymer mud	Fine	5	12
Polymer mud	Fine	10	13
Polymer mud	Fine	15	14
Polymer mud	Medium	5	15
Polymer mud	Medium	10	16
Polymer mud	Medium	15	17
Polymer mud	Granular	5	18
Polymer mud	Granular	10	19
Polymer mud	Granular	15	20

2.3. Mud balance

Mud balance is one of the key characteristics of drilling fluids. The density of the mud column in the hole is the basis for all calculations related to pressure control, which is what it is used for. The density of drilling fluid is calculated using the Baroid Mud Balance method. The device consists of a constant volume cup that is calibrated to read the drilling fluids' density directly using a lever arm and rider [13]. Table 4 displays the densities and rheology properties of the Bentonite Muds (fluids 1–10) and Polymer Muds (fluids 11–20).

Rheology is the study of the deformation and flow characteristics of all substances. A fluid's apparent viscosity (AV), plastic viscosity (PV), yield point (YP), Gel strength (GS) and other rheological measurements are used to predict how the fluid will behave under various circumstances. Given its resistance to flow, this information is essential for designing mud circulating systems that are needed to accomplish specific targeted goals in drilling operations [14].

Table 4. Muds rheology

Fluid	Densities (ppg)	θ600 [lb/100ft²]	θ300 [lb/100ft²]	PV (cp)	YP [lb/100ft²]	GS (10s)	GS (10min)
Fluid 1	8.68	10	7	3	4	8	23
Fluid 2	8.76	10	7	3	4	8	25
Fluid 3	8.84	11	7	4	3	9	27
Fluid 4	8.93	11	7	4	3	10	31
Fluid 5	8.80	24	15	9	6	8	24
Fluid 6	8.88	26	16	10	6	8	24
Fluid 7	8.97	27	17	10	7	9	25
Fluid 8	8.84	23	15	8	7	7	24
Fluid 9	8.88	24	16	8	8	8	27
Fluid 10	8.92	25	16	9	7	9	30
Fluid 11	9.58	56	36	20	16	6	20
Fluid 12	9.75	72	46	26	20	6	20
Fluid 13	9.75	71	46	25	21	7	22
Fluid 14	9.91	74	46	28	18	7	23
Fluid 15	9.66	60	38	22	16	6	22
Fluid 16	9.58	61	39	22	17	6	21
Fluid 17	9.83	76	49	27	22	7	23
Fluid 18	9.58	54	34	20	14	6	22
Fluid 19	9.91	71	45	26	19	7	25
Fluid 20	9.99	79	50	29	21	9	30

3- Results and discussion

Type, shape, size, composition, concentration, and strength are some essential factors to consider when creating an effective solution for particulate LCM and the right drilling mud must be chosen with efficient additives to reduce chemical interactions between formation and drilling fluids [15,16]. As LCMs were added, bentonite muds only slightly changed in their rheological characteristics as compared to plain mud, with all the parameters roughly staying within the same range of values. As shown in Table 5 comparing polymer mud to Bentonite mud, significant variations were seen in the rheological characteristics overall. The viscometer results of the polymer system showed a considerable increase in plastic viscosity and yield point, when LCMs were introduced. Compared to the plain polymer fluid, the addition of the LCM with the fine size had a significant impact on every parameter of the polymer system. The rheological characteristics of the polymer fluids 12 and 14 significantly increased when the concentration of the additional fine-sized LCM was increased from 5 lb/bbl to 15 lb/bbl, respectively.

This indicates that the fine-sized chemicals have an impact on the polymer system's rheological behavior. However, when applied to Bentonite mud, the same additional concentration of 15 lb/bbl fine-sized LCM caused the least amount of system behavior change, suggesting that it has little influence on this kind of system.

Tests on bentonite fluids were conducted at 25˚C, with 150 psi of applied pressure from the top of the fluid sample cell and 100 psi of backpressure from the bottom. In contrast, testing on polymer muds was conducted at 60˚C with pressure delivered from the top of the fluid sample cell and backpressure provided from the bottom at 150 psi and 100 psi, respectively.

The importance of these parameters to the overall performance of the drilling mud is the main justification for selecting to study the rheological characteristics, plastic viscosity, yield point, filtration properties, fluid loss, and filter cake as the basis for comparison. The yield point (YP) measures the annulus cuttings' ability to be carried by drilling mud. Since the fluid is not Newtonian, Cuttings will be carried more efficiently by a fluid with a high YP than by one with a lower YP of comparable density. Frictional pressure loss and YP are also closely associated. It is important to keep in mind that when the drilling mud is being circulated, excessively high YP causes significant pressure losses [17].

Table 5. HPHT- filter press lab results

Fluid	Mud system	LCMs type	LCMs-concentration bl/bbl	API-HPHT Filtrate ml
Fluid 1	Bentonite	-	-	24
Fluid 2	Bentonite	Fine	5	24
Fluid 3	Bentonite	Fine	10	23
Fluid 4	Bentonite	Fine	15	23
Fluid 5	Bentonite	medium	5	16.8
Fluid 6	Bentonite	medium	10	16.5
Fluid 7	Bentonite	medium	15	16
Fluid 8	Bentonite	granular	5	17.1
Fluid 9	Bentonite	granular	10	17
Fluid 10	Bentonite	granular	15	17
Fluid 11	Bentonite	-	-	5
Fluid 12	Bentonite	Fine	5	4.6
Fluid 13	Bentonite	Fine	10	4
Fluid 14	Bentonite	Fine	15	3.8
Fluid 15	Bentonite	medium	5	6.1
Fluid 16	Bentonite	medium	10	4.6
Fluid 17	Bentonite	medium	15	4.7
Fluid 18	Bentonite	granular	5	4.4
Fluid 19	Bentonite	granular	10	4.1
Fluid 20	Bentonite	granular	15	4.2

a. Impact of LCM type, concentration, and material

The efficiency of Lost Circulation Material (LCM) is greatly influenced by the kind of LCM material that is used in drilling fluids. The various properties of LCM materials affect how well they can reduce fluid loss in permeable formations while drilling [18]. The total filtrate is highest for bentonite mud and lowest for polymer, as Fig. 2 illustrates all of the additives' filtering qualities have been enhanced by the addition of the additives in various concentrations over plain mud. A considerable decrease in the overall filtrate has occurred. More than 70 % of Bentonite mud is coarse size and more than 66% of Bentonite mud is medium size, while 82% of polymer mud is fine size. As seen in Fig. 2 all systems' total filtrate amounts have decreased as a result of raising the additives' concentration from 5 lb/bbl to 15 lb/bbl.

b. Impact of LCM size

Using three different sizes of fine, medium, and coarse additives, the impact of the LCM size distribution was investigated, the drilling fluid's LCM content can be affected by the distribution of particle sizes. Desired rheological characteristics, like viscosity and gel strength, can be preserved with the aid of an appropriate distribution, and these characteristics are crucial for efficient drilling [19,20]. The fine-sized LCM addition significantly reduced the total filtration in the polymer system when compared to the Bentonite mud when the mud systems were tested using additives of the same size. If the entire set of data examined more closely, it can be also noticed that the best performance has the lowest overall filtrate decrease while employing the fine-sized LCM in polymer mud. Fig. 3 illustrates the total filtrate obtained from utilizing different sizes of LCMs, which suggests that the medium size is the highest performer specifically for the Bentonite mud system. While Fig. 4 illustrates the total filtrate obtained from utilizing different sizes of LCMs in polymer mud, which suggests that the fine size is the highest performer specifically for the polymer mud system.

The addition of LCMs to the polymer system results in a significant decrease in total filtration when compared to the plain mud. The granular-sized particles perform similarly across the whole range of LCM concentrations, but the Fine-sized particles perform best at higher concentrations, such as 15 lb/bbl, to reduce the amount of filtration that enters the formation as illustrated in Fig. 4. All things considered, it is evident that of the two mud systems, the polymer behavior in combination with the LCM reduces the filtration to the lowest possible degree.

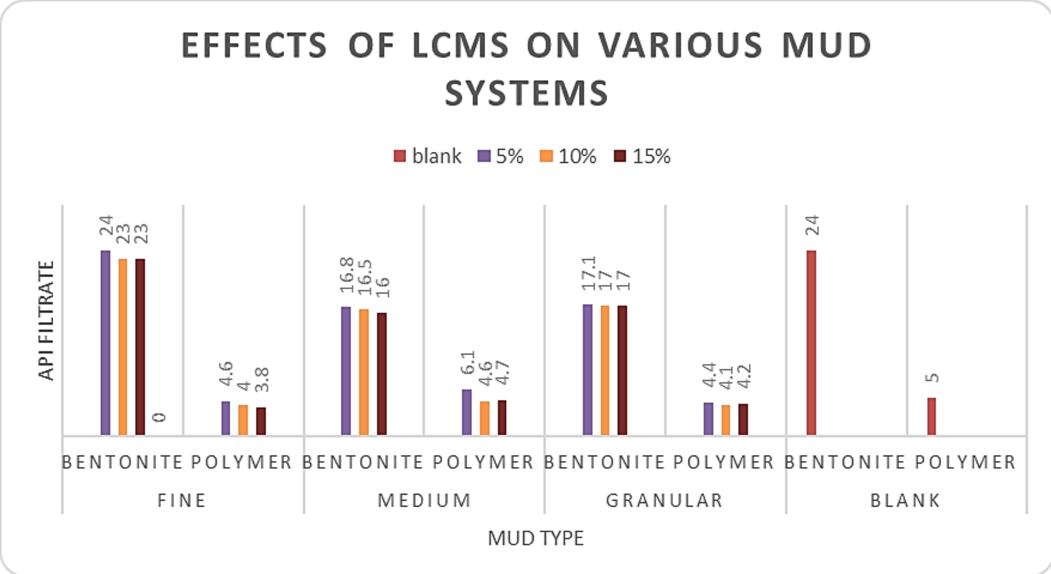

Fig. 2. Effects of LCMs on various mud systems

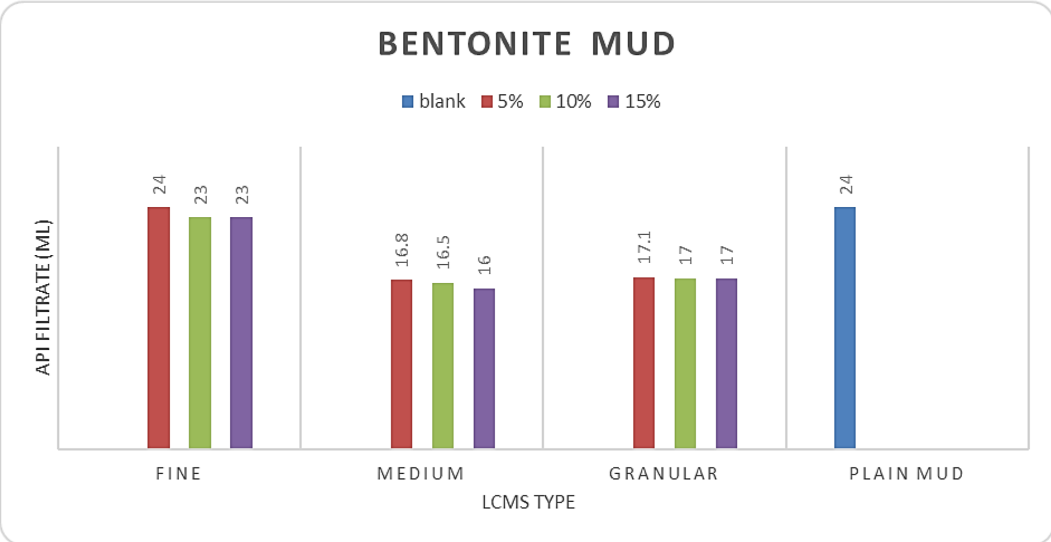

Fig. 3. Impact of LCM size for bentonite mud system

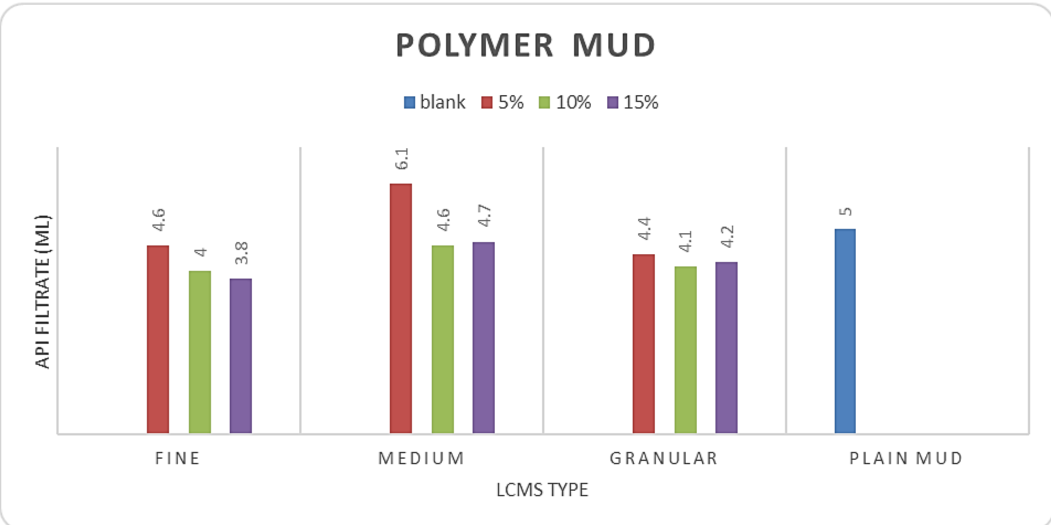

Fig. 4. Impact of LCM size for polymer mud system

4- Conclusion

The addition of LCMs had a more significant impact on the rheological properties of the polymer-based mud compared to the bentonite-based mud. Specifically, the plastic viscosity and yield point of the polymer mud increased by 25-30% with addition of LCMs. Fine-sized LCMs had a greater influence on the rheological behavior of the polymer mud system compared to the bentonite mud system. Increasing the concentration of fine-sized LCMs from 5 lb/bbl to 15 lb/bbl resulted in a significant increase of 35-40% in the rheological parameters of the polymer mud. At a higher concentration of 15 lb/bbl, the fine-sized LCMs reduced the fluid loss by up to 40% compared to the medium and coarse-sized LCMs.

In terms of filtration performance, the total fluid loss was highest for the bentonite mud (25% higher than plain mud) and lowest for the polymer mud (35% lower than plain mud). Adding LCMs at increasing concentrations (from 5 lb/bbl to 15 lb/bbl) reduced the total fluid loss by 20-25% across both mud systems.

Abbreviation

LCM	Lost Circulation Material
PSD	Particle Size Distribution
ECD	Equivalent Circulating Density
HPHT	High-Pressure High-Temperature
PAC-LV	Partially Hydrolyzed Polyacrylamide
XCD	Xanthan Gum (XCD Polymer)
PHPA liquid	Partially Hydrolyzed Polyacrylamide
HPAN	Hydrolyzed Polyacrylonitrile
PV	Plastic Viscosity
YP	Yield Point

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تجربة عملية حول تأثيرات إضافة LCM على خصائص طين الحفر والترشيح

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الخلاصة

تواجه عمليات الحفر في حقول النفط في البصرة، لا سيما من خلال تكوينات الدمام والحرثة والشعيبة، تحديات كبيرة في فقدان التدوير. درس هذا البحث تأثير إضافة مواد فقدان التدوير (LCMs) إلى أطيان الحفر (البنتونيت و البوليمر) , أجريت التجارب باستخدام جهاز الترشيح لتقييم الخصائص الريولوجية وأداء الترشيح لأنظمة الأطيان حيث تم اجراء اختبار على نوعين من سوائل الحفر و اضافة عدة انواع من المواد المستخدمة لمعالجة مشكلة فقدان السوائل بتراكيز و احجام مختلفة لمعرفة تأثيرها على الخواص الريولوجية لاطيان الحفر والترشيح . أظهرت النتائج أن إدماج LCMs زاد من plastic viscosity and yield point إلى البوليمر بنسبة ٢٥–٣٠٪، بينما كان التأثير على البنتونايت أقل وضوحًا. أثر استخدام LCMs ذات الحجم الدقيق بشكل خاص على الخصائص الريولوجية لنظام البوليمر، مع زيادة بنسبة ٣٥–٤٠٪ في المعاملات مع زيادة تركيز. LCMمن حيث أداء الترشيح، كان إجمالي فقدان السائل أعلى لأطيان البنتونايت وأقل لأطيان البوليمر. أدى إضافة LCMs إلى تقليل فقدان السائل بنسبة ٢٠–٢٥٪ في كلا النوعين ،حيث أفضل أداء للبوليمر مع LCMs ذات الحجم الدقيق عند تركيزات أعلى. بشكل عام، يُظهر الدراسة أن نوع وحجم وتركيز LCMs يمكن أن يكون له تأثير كبير على الخصائص الريولوجية وأداء الترشيح لاطيان الحفر، مع إظهار نظام طين البوليمر أكبر حساسية لهذه المعلمات. معظم المواد المستخدمة لبناء هذا المقال جاءت من بيانات ميدانية فعلية تم جمعها في حقول النفط في البصرة. يتم توفير مراجعات وملخصات شاملة للمجلات التقنية، والأبحاث، والمصادر العلمية، والأدلة التي تتناول مسألة فقدان دورة مائع الحفر. الهدف من هذه الدراسة هو تقييم ومقارنة أداء LCMs المختلفة و النوع والتركيز على أدائها الخلية.

الكلمات الدالة: دورة سائل الحفر المفقودة، الحقول النفطية في البصرة، طين الحفر، بوليمر.