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Novel Effective and Adaptable Breaker Package for Diutan Gels in Gravel Packing Application

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Abstract

Xanthan and diutan gums are widely used as viscosifiers within oil and gas industry applications, including drilling, fracturing, and particularly for use in gravel packing (GP) fluids at temperatures up to 180°F for xanthan and 180 to 270°F for diutan. For lower temperature applications (less than 180°F), diutan can be used at a reduced polymer loading compared to xanthan. However, a suitable internal breaker is necessary for temperatures below 180°F. The absence of an internal breaker can lead to removal issues and subsequent damage, and thus lower regained permeability. This paper discusses a new internal breaker system that allows the use of diutan gels in GP fluids at temperatures below 180°F.

The new internal breaker system includes an initiator, an organic acid and an activator combined to provide unique chemistry. The absence of any of the three components prohibits polymer degradation. The breaker system mixes easily on location and can provide a break within a short time frame of 72, 48, or 24 hours or less, depending on the individual chemical concentrations. Furthermore, regained permeability values of >80% indicate minimal potential system damage.

Traditional internal breakers begin working immediately, and thus additional polymer is sometimes required to retain the necessary rheology for a period of time. The unique new breaker system allows the user to reduce the amount of polymer used in GP treatments below 180°F. The system also allows breaker components to be used at concentrations low enough to prohibit salting out of the diutan polymer. These benefits help reduce overall operational costs while still providing the desired operational characteristics.

Introduction

GP is a commonly used sand-control method wherein larger sand/proppants are placed near the wellbore, which helps filter out fine particles and prevent them from flowing into the well during production. The primary objective of this treatment is to stabilize the formation while causing minimal impairment to well productivity.

During common GP methods, a mechanical screen is placed in the wellbore and the surrounding annulus is packed with a particulate of a larger specific size designed to help prevent the passage of formation sand or other fines. Typically, larger sized gravel is placed in the annulus with the help of water based fluids. Because the density of the sand is greater compared to the density of the water, polymer based viscosity-increasing agents are used to increase the suspension properties of the fluid and help place sand in the wellbore. Typical water-soluble polymers used in well treatments include water-soluble polysaccharides and water-soluble synthetic polymers (e.g., polyacrylamide).[1]

Among different types of GP fluids, Xanthan and diutan gels are well known because of their excellent properties in terms of gravel carrying capacity, fluid loss or leakoff, controllable viscosity reduction, and minimal damage to the formation.[2]

Of these two gels, diutan is superior because of its improved sand settling and thermal properties. Additionally, higher thermal stability of diutan has the potential to cover low temperature applications below 180°F with a reduction in polymer loading compared to xanthan.

After the sand/proppant is placed, the fluid must be removed from the wellbore without damaging the conductivity of the sand/proppant bed or in the case of leakoff to the formation without damaging the formation. To accomplish this removal, the viscosity of the treatment fluid must be reduced to a very low viscosity, preferably near the viscosity of water, for optimal removal from the proppant bed. Generally, internal breakers are added to the sand/proppant carrier fluid to reduce the molecular weight of the polymers. This results in a reduction in viscosity and facilitates the flowback of residual polymer, which allows for cleanup of the proppant/GP.

The discussed chemical breakers are generally grouped into three classes: oxidizers, enzymes, and acids. The breakers operate by cleaving the backbone of the polymer either by hydrolysis, cleavage of glycosidic bonds, oxidative/reductive cleavage, or free radical breakage.[3]

Oxidizer breakers work by cleaving the acetyl linkages in the polymer backbone. Organic acids will interact with the polymer backbone and break the gel similar to oxidizing breakers but they are much less selective.

The inappropriate use or ineffective breakers can cause significant damage in the proppant pack. Ideally, these materials would be totally inactive during the treatment and then instantly start acting when pumping stops and break the fluid to a lower viscosity.

Common acid or oxidizer breakers are used to break diutan polymer at higher temperatures; these acid breakers act by reducing the pH of the system to a level sufficient to degrade the polymer backbone. Literature shows that acid breakers provide a break time for diutan of two to three days in the temperature range of 180 to 220°F.[4] Therefore, to provide a break time of less than four days at temperatures below 180°F requires much higher concentrations of acid. Unfortunately, using higher concentrations of organic acid would adversely affect the properties of the well fluid. Higher acid loadings severely affect the particulate suspension properties of fluids viscosified with diutan. In addition, low pH can cause the polymer to salt-out from the fluid.

Similarly, oxidizing breakers are also proven to be ineffective in terms of giving a clean break to treatment fluids comprising a diutan composition when the formation temperatures are below 200°F (93°C). In addition, oxidizers ten to leave residue, which affects the regain permeability of the formations.

Test conducted in the laboratory indicate that the combination of oxidizing and acid breakers at reasonable concentrations is also insufficient to break the viscosity of a fluid viscosified with diutan at low temperatures (less than 180°F). These concentrations create issues, such as poor regained permeability and salting out of diutan or clarified diutan.

Because of the previously discussed challenges, even though diutan gels are superior to xanthan their usage is restricted to temperature ranges above 180°F and there is a need to identify an alternate breaker system that can successfully reduce or break the viscosity of diutan fluids at temperature below 180°F. This paper outlines a new breaker system that can successfully reduce the viscosity of a diutan gel at temperatures below 180°F.

The following break tests illustrate the type of testing conducted to achieve the breaking of diutan at low temperatures.

Experiments

Base Gel Preparation

The treatment fluid for conducting break tests were prepared by pouring 980 mL of the appropriate brine in a 1 L Waring® blender jar. All of the tests discussed in this paper were prepared using KCl at a concentration of 7% w/v. Bactericides were added to the brine under continuous stirring at a concentration of 0.15 lbm/1,000 gal. A total of 12.0 lbm/1,000 gal of iron chelating agent was then added and allowed to dissolve completely. This was followed by the addition of 30 lbm/1,000 gal of diutan powder. The contents were allowed to mix for 10 minutes, maintaining an approximate 1-in. vortex, without entrapping any air during the mixing interval. The contents were allowed to remain static for approximately one hour to allow complete hydration of the gelling agent. Once the gel was hydrated, 20 gal/1,000 gal of surfactant was added to complete the gel preparation procedure. The initial apparent viscosity of the hydrated gel measured using a Fann® 35 viscometer at 300 RPM (corresponding to 511 sec-1 shear rate) was 27 cP and the same gel was used for all the tests given below (Table 1).

Procedure Followed for Break Tests

Break tests were performed using 200 mL of the discussed hydrated diutan gel. The gel was stirred in a 300 mL: Waring blender jar. Breakers were added to the gel and mixed thoroughly, after which the break test gel mixture was put in a glass bottle and placed in a preheated constant-temperature water bath maintained at 140°F. At the desired time interval, the test bottle was removed from the water bath and the apparent viscosity of the gel mixture was measured using a Fann 35 viscometer at 300 RPM.

Evaluation of Various Breakers at 140°F

With Organic Acid 1

Organic acid 1 breaker was added to the base gel mixture at various concentration of 20 to 50 gal/1,000 gal and the break profile was evaluated at 140°F. Table 2 shows the results of testing.

The results in Table 2 prove that, even after increasing the concentration of organic acid breaker 1 up to 50 gal/1,000 gal, there was no reduction to the viscosity of the gel, and hence use of organic acid breaker 1 at the tested concentration is not breaking the diutan polymer at a low temperature of 140°F.

With Organic Acid 2

Furthermore, to evaluate the break profile of diutan gel with other organic acids, tests were performed using another organic acid (organic acid 2) and results are depicted in Table 3.

The test results in Table 3 also proves that increasing the concentration of solid organic acid breaker 2 up to 70 lbm/1,000 gal proved there was no reduction in the viscosity of the gel and hence the tested solid acid breaker is not a good option in breaking the diutan polymer at low temperature applications. Thus, evaluation of different organic acids failed to reduce the viscosity of the diutan gel to a desired level at a lower temperature of 140°F.

Break Test with Oxidizer

Because both the organic acids failed in terms of breaking the polymer, tests were performed using an oxidizer breaker (Table 4).

Table 4 shows that oxidizer breakers were unable to break a diutan polymer backbone at temperatures below 140°F, and there is a need to identify an alternate breaker system that can successfully reduce or break the viscosity of diutan fluids at low temperatures.

Break Tests with Activator Along with Combination of Acid and Oxidizers

From the previously mentioned tests, there is a need for a breaker, which can reduce the viscosity of diutan gels at temperature below 180°F. This paper introduces the use of a breaker system, including an oxidizer, organic acid, and an activator, to break the polymer at low temperatures down to 140°F. The results of the tests are given in Table 5.

From Table 5, it can be observed that only composition 1 can give reduced apparent viscosity at 140°F in the presence of an oxidizer, organic acid, and an activator. Absence of any one of the components from composition 1 will not achieve the desired breaking.

As observed from Table 5, only composition 1 provided reduced apparent viscosity at 140°F.It was a well-known fact that an oxidizer undergoes auto decomposition and helps in terms of breaking the polymer backbone. This auto decomposition is activated with temperature; however, from Table 5, the test data confirmed that the absence of any one of the components from composition 1 will not achieve the desired breaking of the polymer. This synergism can be explained because the introduced activator helps the oxidizer to act more vigorously and aggressively than it would without an activator. This increased oxidation power is attributed to the fast production of hydroxyl radicals (OH•) in the presence of an activator or catalyst. In addition, a chain reaction is initiated, forming more radicals, which are very reactive and helps in terms of degrading the polymer at a faster rate. Being a catalyst, the activator will be regenerated and available for further reaction. In addition, the presence of organic acids lower the pH of the system, which further makes the breaker package more rapid and efficient even at a low temperature.

Optimization Studies with Activator Along with Combination of Acid and Oxidizers

Optimization studies were completed to fine tune the breaker concentration so that it would be fit for different field requirements and the results are presented in Fig. 1.

Thus, the combination of breaker system helps in terms of degrading the polymer to a very low apparent viscosity of less than 5 cP within a short time of less than three days at 140°F. The advantage of this breaker system is the use of concentrations of the breaker system (and any one of its components) at less than the concentration that would contribute to salting out of the of the diutan to achieve short break times at temperatures between 140 and 180°F, making it practical for field applications.

Regained Permeability Testing

Regained permeability measurements were taken using a cylindrical aloxite core (400 md permeability to air) 1-in. in diameter and 2-in. in length. One end of the core was considered as the injection end and the other end as the production end. The core was placed inside a Hassler sleeve assembly. The entire Hassler sleeve assembly was placed inside an air oven maintained at the test temperature of 140°F. An overburden pressure of 1,100 psi was applied to the Hassler sleeve/rubber sleeve annulus to help ensure the flow of test fluids is through the core rather than bypassing the core and flowing through the core-rubber sleeve annulus. The initial and final permeability measurements were determined at the test temperature of 140°F by flowing API brine in the production direction before and after the treatment stage. The treatment stage was run by flowing the test fluid recipe through the core in the injection direction. The treatment stage comprised of flowing a total of 10 pore volumes of the test fluid through the aloxite core. The test fluid recipe comprised of 30 lbm/1,000 gal diutan gel mixed with a breaker system made up of 5.0 gal/1,000 gal of oxidizer, 20 gal/1,000 gal of acid, and 3.0 gal/1,000 gal activator. As depicted in Fig. 2, a regained permeability value of 82.5% was achieved.

A regained permeability value of >80% reveals that the introduced breaker package helps in terms of degrading the polymer without significantly damaging formation permeability.

Conclusions

The following conclusions are the results of this work:

- The unique new breaker system comprising an initiator, an organic acid, and activator helps reduce the viscosity of diutan gels at temperatures below 180°F.
- The system allows breaker components to be used at concentrations low enough to prohibit salting out of the diutan polymer.
- A regained permeability value of >80% reveals that the new breaker package helps in terms of degrading the polymer without significantly damaging formation permeability.

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Table 1: Concentration of additives used for preparing base gel.

Additives	Concentration
Fresh water	980 mL
KCl	7 % w/v
Bactericides 1	0.15 lbm/1,000 gal
Bactericides 2	0.15 lbm/1,000 gal
Iron chelating agent	12 lbm/1,000 gal
Diutan polymer	30 lbm/1,000 gal
Surfactant	20 gal/1,000 gal

Table 2: Tests with organic acid Breaker 1 at 140°F.

Concentration of Breaker 1 (gal/1,000 gal)	Time Duration (hours)	Apparent Viscosity (cP)
20	24	25
	48	25
30	24	25
	48	24
40	24	25
	48	24
50	24	25
	48	25

Table 3: Tests with organic acid breaker 2 at 140°F.

Concentration of Breaker 2 (lbm/1,000 gal)	Time Duration (hours)	Apparent Viscosity (cP)
40	24	27
	48	27
50	24	27
	48	26
60	24	27
	48	26
70	24	26
	48	25

Table 4: Tests with oxidizer breaker at 140°F.

Concentration of Oxidizer (gal/1,000 gal)	Time Duration (hours)	Apparent Viscosity (cP)
1	24	26
	48	26
2.5	24	26
	48	25

Table 5: Tests with activator along with combination of acid and oxidizer breaker at 140°F.

Test Composition	Diutan Loading (lbm/1,000 gal)	Breaker Composition used at 140°F			Apparent Viscosity (cP) on Fann® 35 Viscometer at 511 sec^{-1}		
		Oxidizer	Organic Acid 2	Activator	Day 1	Day 2	Day 3
1	30	5.0 gal/ 1,000 gal	20 gal/ 1,000 gal	0.75 gal/ 1,000 gal	18	7	2
2	30	5.0 gal/ 1,000 gal	—	0.75 gal/ 1,000 gal	26	26	26
3	30	—	20 gal/ 1,000 gal	0.75 gal/ 1,000 gal	26	26	26
4	30	5.0 gal/ 1,000 gal	20 gal/ 1,000 gal	—	26	26	26
5	30	—	50 gal/ 1,000 gal	—	25	25	25
6	30	5.0 gal/ 1,000 gal	—	—	25	25	25

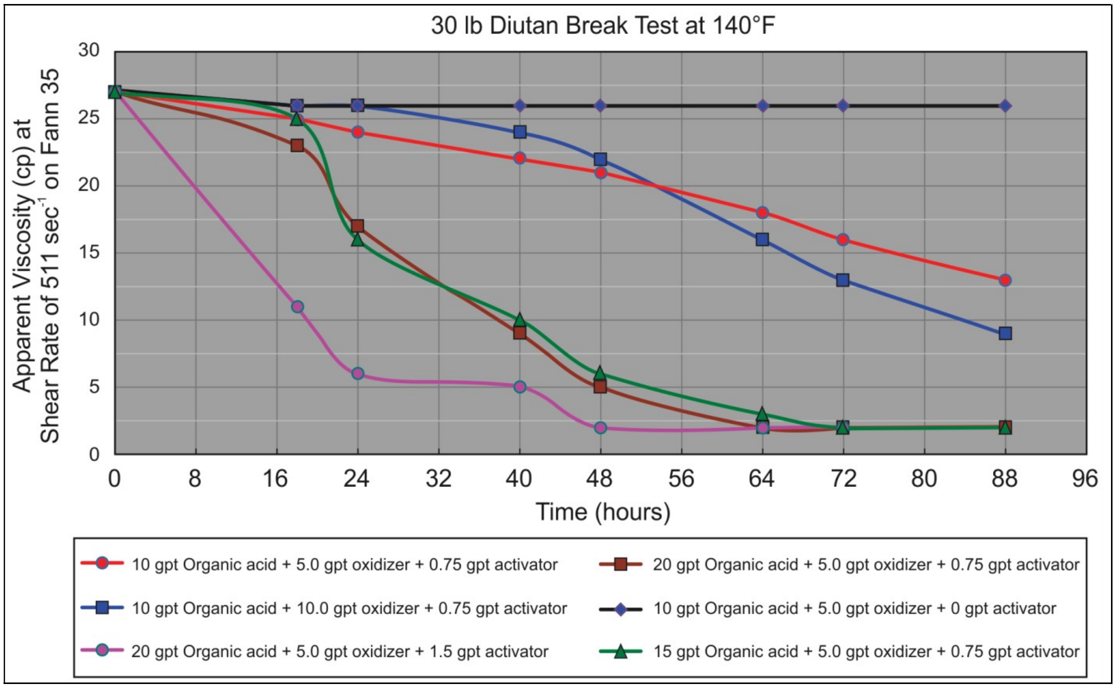
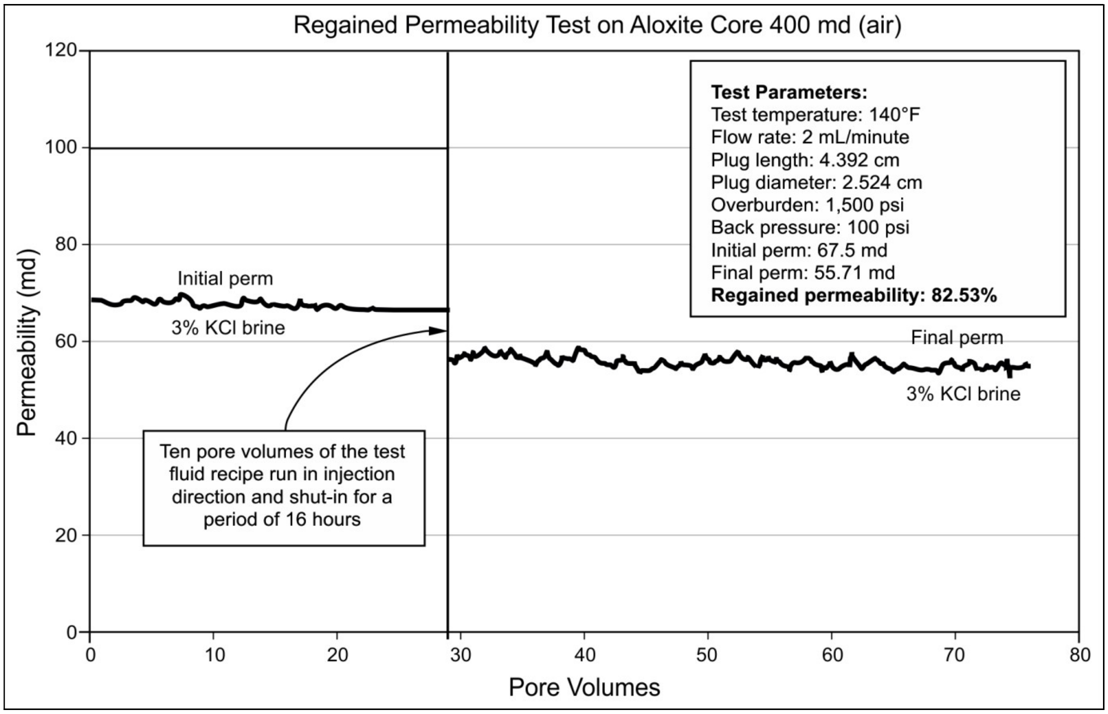


Fig. 1—Optimization studies at 140°F.



Test Parameters:
Test temperature: 140°F
Flow rate: 2 mL/minute
Plug length: 4.392 cm
Plug diameter: 2.524 cm
Overburden: 1,500 psi
Back pressure: 100 psi
Initial perm: 67.5 md
Final perm: 55.71 md
Regained permeability: 82.53%

Ten pore volumes of the test fluid recipe run in injection direction and shut-in for a period of 16 hours

Fig. 2—Regained permeability testing.