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Fracturing GeoChemistry Best Practices with Water Management in the Western Canadian Sedimentary Basin

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Summary

By designing fracturing blends differently, the fracturing job and flowback can be more compatible with GeoChemistry parameters such as reservoir fluids and formations which will increase oil production, water injection rates, and Enhanced Oil Recovery (EOR) injectivity in wells and waste disposal wells. Compatible produced fracturing fluids saves oil production companies added costs by minimizing processes, chemical treatment, and time, while maximizing the subsurface injection volume and rates.

Compatible chemistry that is commonly used with drilling, certain types of workovers, and production wells is quite different than the fluids injected semi-permanently and permanently into a formation for pressure maintenance or disposal. Using best practices in physical chemistry can increase current production from existing and new oil production wells, and have the added benefit of ensuring a long life for wells that inject fluids into the formation.

This paper will provide Fracturing GeoChemistry best practices with water management for EOR injection wells and disposal wells in the Western Canada Sedimentary Basin.

Introduction

Fluids that are used for fracturing undergo rigorous testing for many parameters. This paper provides a high-level view of common reactions that are both favourable and unfavourable. Due to the breadth of the many possible circumstances and issues, only a few will be discussed in this paper. A complete review would require a far more detailed and lengthy format to properly cover this topic. The following immediate content examines the general procedure and consideration when a fracturing job is designed and carried-out.

The purpose of fracturing a formation is to either increase the production of oil/gas from the formation to the surface, or to increase the injection rate of liquid from the surface to the formation. Many reasons exist for each of these applications, such as naturally tight formations, damage from production/injection, fluid incompatibilities, flashing of light hydrocarbons, and more.

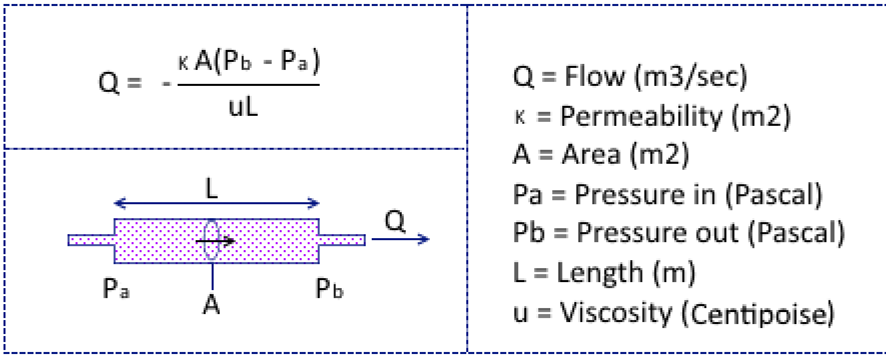
Generally, the process of fracturing is to pump fluid under high pressure to mechanically open the formation and then place proppant in the fluid which is carried to the formation and holds the new fractures open when pressure is relaxed. New fractures allow increased production of oil or injection of fluid into the formation.

Selecting a fluid for fracturing is quite important, as the properties need to be dynamic over time. When fluid is initially being injected, the best rate for the fluid entering the formation is achieved when the flow is laminar as this maximizes the energy being distributed to the formation. Turbulent flow is highly discouraged as this consumes mechanical flow energy. Chemical additives with multiple functions are used, and typically certain polymers are added to maintain maximum energy transfer from the surface to subsurface.

Once the fluid has entered the formation and sufficient fractures have been created, proppant such as sized-sand is added. The fluid will need to have sufficient LSRV (Low Shear Rate Viscosity) properties to carry the sand deep into these fractures to prevent collapsing of the newly opened fractures.

After placement of the sand in the fractures is complete, properties of the formation have been changed so that production or injection of the fluid is promoted relating to Darcy’s Law.

Figure 1. Darcy's Law[1]



Increasing permeability of the formation with fractures will increase the flow rate of fluid in/out of the formation. Further promotion of fluid flow occurs by adding a time-released breaker which lowers the fluid viscosity, as a thinner fluid in the formation is transported faster than thicker fluids, with all other parameters being equal. All fluids are designed and tested to be compatible with:

a) Formation fluids
b) Reservoir rock
c) Proppant
d) Fracture fluids

Once the proppant has been set in its final position within the formation, fracture fluid is flowed-back from the reservoir and produced at the surface in both injection and production wells. The purpose is to minimize side-reactions from the fracturing fluid and potential minor incompatibilities with the formation, reservoir rock, proppant, and the fracture fluid. After sufficient fluid has been withdrawn from the formation to remove fines and other debris, normal production resumes and the well can operate with increased injection/production.

Flowback fluid is then treated for reuse in EOR where the fluid is used for reservoir pressure maintenance or is deep well injected for permanent removal.

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[1] Schlumberger (2006), *Fundamentals of Formation Testing*, Retrieved from http://www.slb.com/~/media/Files/evaluation/books/fundamentals_formation_testing_overview.pdf.

Theory and/or Method

Three types of water-based fracturing will be introduced; slickwater, linear and crosslinked. Crosslinked will be the main focus of discussion as it produces both the desired increased viscosity when injecting fracture fluid to carry the proppant and mechanically create fractures, as well as the decreased viscosity to promote proppant retention in the formation and produce the broken fracture fluid.

<u>Slickwater Fracturing</u>

Slickwater fracturing is the simplist type of fracturing fluid with the lowest amount of ingredients. These ingredients include: water, sand, corrosion inhibitor, friction reducer, and a substance to control bacterial growth. Sand is a common proppant to keep the new fractures open while the corrosion inhibitor is used to minimize pipe corrosion and prevent iron, as rust, from reacting and causing undesirable reaction. A friction reducer is needed to keep the fluid in laminar flow which maximizes the transfer of energy from the well surface to the formation, allowing hydraulic-fracturing to occur. Bacterial growth is controlled as it can plug smaller pore-spaces and degrade ingredients in the blend casusing the blend to not function properly.

Of the three water-based fluids, slickwater fracturing has the lowest risk of formation damage due to the minimial amount of ingredients used and the low viscosity fluid. One risk of slickwater fracturing is that placement of proppant in the formation is more difficult as Low Shear Rate Viscosity (LSRV) is lacking which increases the risk of proppant being placed at the far end of the fracture. Other concerns are the typically smaller fracture width due to the lower viscosity, more water use, and a smaller fracture length.

A positive aspect of slickwater fracturing is the increased near-wellbore fracturing network that is created which increases connectivty. Formations which have long fracture-closure times prefer a slickwater fracture as the proppant remains in the fractures and proppant removal is minimized from the formation when flowing-back the well.

<u>Linear Fracturing</u>

Linear fracturing fluids are a higher viscosity version of the slickwater fracturing fluid. In addition to the ingredients in the slickwater fracturing fluid, polymers are the active ingredient to increase the fluid's visocity to assist in carrying the proppant to the farthest edges of the fracture. The added polymer depends on the properties needed for the specific fracture. Common polymers are: Guar, Hydroxyethyl Cellulose (HEC), Hydroxypropyl Guar (HPG), Carboxymethyl hydroxypropyl guar (CMHPG), and Carboxymethyl Hydroxyethyl Cellulose (CMHEC).

<u>Crosslinked Fracturing</u>

One of the more common fluids for fracturing with production and injection wells are water-based crosslinked fluids. Crosslinkers are used to improve the performance of polymer gels without increasing their concentration.

Borate crosslinked gels are commonly used fracture fluids which have about the same concentration of polymers as Linear Fracturing Fluids and can become much thicker due to crosslinking. There is a base viscosity due to the base polymer gel and the increased cross-linked gel increases the ability to transport proppant deeper into the formation which increases production/injection of the well. Cross-linked gel is also typically stable up to 150 ^{o}C (~300 ^{o}F) which is a good temperature range for many wells in the Western Canadian Sedimentary Basin (WCSB).

The purpose of frac gels are to increase the viscosity, carry proppant into the formation, form a filter cake which prevents leakoff, and increase temperature stability. Preventing leakoff maximizes the fracture effectiveness by promoting deeper fractures that have a larger cross-sectional area and can cause minor skin damage in a production well and major skin damage in an injection well. When all of the filter cake can be produced from a fracture job then there is little chance of skin damage, which is easier to remove in an oil production well. It is more difficult to cleanout filter cake from an injection well as initial flowback will retrieve only a fraction of the fracture fluid and the well will be placed in injection-mode and the entrapped filter cake will not be removed. Lack of filter cake removal makes the programming and design of a non-damaging fracture job more complicated and this lowers the amount of compatible ingredients in a fracture job. This becomes even more complicated when the flowback from an oil production well produces polymers which have been successfully removed from the well and are to be disposed in a deep-injection-well, where these ingredients then cause skin damage which can temporarily or permanently damage a water injection well.

Table 1. Broken Polymer Residue and Permeability[2]

Stress (psi)	Polymer Type	Polymer Concentration (Kg/m3)	Breaker	Residue Concentration (vol/vol)	Permeability (Darcies)
3000	Guar	22.8	Internal	0.12	115
3000	Guar	57.5	Oxidizer	0.22	90
5000	Guar	22.8	Internal	0.12	43
5000	Guar	57.5	Oxidizer	0.22	29
5000	Cellulose Derivative	22.8	Oxidizer	0.01	54
7000	Guar	28.8	Oxidizer	0.12	12
7000	Cellulose Derivative	28.8	Oxidizer	0.01	23
8000	Guar	22.8	Internal	0.12	11
8000	Guar	57.5	Oxidizer	0.22	8
8000	Cellulose Derivative	22.8	Oxidizer	0.01	16

It is important to note from the above chart that the correct breaker be used to reduce the viscosity of the gel once the proppant has been placed in the formation. The typical standard for fully breaking a gel will have a final visocity below 10 cP, which will increase the permeability of the conducting fracture. Unbroken gel can plug the newly created fracture, and remove benefits of a fracture job. Gel can break on its own without an added breaker,but this occurs over a very long time.

Crosslinked polymer forms a mesh which forms a filter-cake-like material that promotes increased fracture length by temporarily sealing the pore spaces tangentially to the fracture. This allows more energy from the fluid to increase the fracture length and minimize energy loss to fractures that have been formed at the beginning of the fracture job.

Using the proper breaker will promote the removal of the filter cake material by lowering its thickness and also lowering the differential pressure needed for flowback to the wellbore. Reduction in the viscosity will also promote the return of fluid to the wellbore and increase the velocity in the fracture to promote debris removal. This lower broken viscosity will also keep the current proppant in its place while the fracture-closure-pressure is met.

[2] Xiao, J., and Sun, X., (2017), New Insights of Formation Damage Caused by Borate Crosslinker Fracturing Fluids, Oil Gas Res 3:128. Doi: 10.4172/2472-0518.1000128

In the case of a poorly broken or non-broken fracture fluid, if fluid flowback were to occur before the fracture-close pressure has occurred the proppant would flow back to the wellbore, lowering the effectiveness of the fracture job.

Caution should be used when using oxidizers in a sour formation that also contains some common cations such as barite or strontium. Oxiders will chemically oxidize Hydrogen Suphide (H_2S) to a Sulphate (SO_4^{2-}) which will form insoluble scale such as Barium Sulphate or Strontium Sulphate. In rare occasions, these particles will plug pore throats and damage can be so severe as to negate the overall intent of the fracture job. This scale can form in the fracture or the pore throat within the formation, which makes the well non-producible.

Once a proper and broken fracture job has occurred, then the flowback is typically produced back to a tank and the well is flow-tested. Fracture fluid that is unbroken will partially remove proppant from the wellbore and fracture and then will be deposited in the surface fracture fluid tanks. On one hand, it will be easier to remove the debris from the surface tank by transferring the fluid to a truck, on the other hand, the unbroken fluid means that the production of fluid from the formation will be hindered because of the increased fluids LSRV. According to Darcy's Law, doubling of the viscosity from 1 cP to 2 cP will cut the well prodution in half. This reinforces the need for Good Laboratory Practices (GLP) for proper evaluation testing at bottom hole temperatures and pressures, which will maximize the effectiveness of the fracture and the production of fluids in the formation.

Most trucking companies are able to load and transport broken or unbroken fluids with ease. If there are many solids then a vacuum-truck would be required for transportation.

Both broken and unbroken fluids are received at a waste dispoal site for safe disposal. Unbroken fluids can be safely treated which separates solids from the fluid, however they have specific challenges, as extra treatment and processing is required. In outlying cases, some fluids cannot be broken by conventional means and require added treatment and processing. Some treatment can be performed at local treatment sites while others require specialized treatment sites to treat the fluid. The reason why this treatment is required is for the same reasoning that the fracture fluid is to be broken after the proppant has been properly placed during a fracture job, which are to minimize the transmission of solids and to allow injection of the fluid according to Darcy's Law.

Conclusions

In summary, recommended best practices are to have the fluid and all material property tested as a proxy for the fracture job during the stages of pumping, proppant placement, breaking, fluid flowback, fluid transportation, and disposal. The flowback fluid is to be completely broken by the time the flowback has reached surface which implies that the correct mixture of the fracture fluid has been created and maximum efficiency of mechanical energy has occurred. Broken fluid is then transported and disposed.

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