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Optimizing Fluid Compatibility in Produced Waters

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Abstract

As new regulations are limiting the availability of freshwater and operators look for ways to reduce their water disposal costs, the use of produced waters to complete wells has increased. These waters must be treated to reduce potential of damage to the formation and to ensure compatibility of other fracturing chemical additives. While treatment methods can improve chemical compatibility, the variability in water composition impacts the selection of friction reducers (FR). The performance of FRs is directly dependent on water quality and any changes can impact volumes used and total chemical spend for the well completion. This work outlines field studies where produced and recycled waters were monitored during hydraulic fracturing operations along with the FR performance in the laboratory and field.

The studies show that a unified approach can generate data that improves selection of fluids that can meet the changing water conditions. On-site monitoring and testing tracked changes in water composition and the effect of water quality on FR performance and dosage. The data was correlated to field results and used to make fluid design changes that improved efficiency and resulted in cost-savings.

Monitoring showed water composition varied greatly from site to site, highlighting the need for an in-depth understanding of water composition. FR performance also varied from pad to pad on the same lease. Performance changes correlated with water composition changes. This suggested that standardizing a fluid based on previous water data does not always result in optimal performance. The ability to optimize FR selection to existing water conditions could result in cost-savings to the operators when produced water is used.

Introduction

Friction reducers (FRs) are the main component of slickwater fluids, which make up the highest volume of fracturing fluid used in unconventional reservoirs today. These FRs enable the high pump rates needed to fracture shale formations, while reducing the resulting friction pressures in the wellbore. The performance of these FRs is dependent on the quality of the water used and any changes can reduce effectiveness, increase the volumes of FR needed, and impact the total completion costs for the well.

The quality of water used for hydraulic fracturing operations continues to change. Limitations on freshwater availability and water disposal regulations are driving operators to look at produced water re-use to meet their water needs. Water demand for well completions has increased over the last few years, with longer laterals and stages per well. The average water demand for one well is ~ 18MM barrels of water and in certain basins is expected to increase (Pena, 2019). To maintain a supply of water to meet this demand, multiple sources including produced water are used and, in some areas, produced water is the only option available. Produced water, however, cannot be used as-is for completion operations. The water must be treated to remove key impurities that can lead to formation damage, such as suspended solids and iron. This process, often referred to as water recycling, has broad criteria for what is deemed usable water. The costs associated with recycling of the water also limit the extent of treatment that is performed, with a primary focus of removing solids and iron at the lowest cost per barrel. Effective solutions for these treatments have been identified and fit-for-purpose application can be deployed (Walsh, J., & Sharma, R. 2018).

The recycling process can help mitigate the potential for formation damage but does not address the impact that water quality can have on FR performance. The selection of FR is based on water quality, primarily the Total Dissolved Solids or TDS. Produced waters can have TDS values up to 350,000 ppm versus fresh or brackish water with TDS lower than 30,000 ppm. The large fluctuations in TDS can negatively affect FR performance, reducing effectiveness, seen as higher treating pressures during completion operations. In efforts to reduce these pressures, higher dosages of friction reducer are used, resulting in higher chemical costs. Treatment to reduce TDS to levels of brackish water are cost prohibitive, with most operators opting to use the water as-is with no change in TDS and only removal of the potentially damaging components, suspended solids and iron.

There are many commercially available FRs with brackish water to medium TDS tolerance (50,000 ppm TDS) but at higher TDS concentrations, the options are more limited. FR manufacturers continue to optimize the FR chemistry to increase the performance to ranges closer to 300,000 ppm. However, the fluctuations in these TDS values make it difficult to implement one FR solution for all water types. Higher TDS tolerance also increases the cost of the FR by several dollars per gallon. Cost savings realized by low cost produced water treatments can be wiped out by the need for these complex FR products, further impacting economical efficiencies for well completion.

Studies of hydraulic fracturing operations for two Permian based operators were conducted and the findings are reported. The studies focused on the water re-use programs, fracturing fluid design, water quality, and chemical usage. Monitoring programs were implemented to identify changes in water quality and friction reducer performance. The changes to water quality along with impact on chemical performance and spend are presented. Optimization opportunities were identified, and the results of implementation are discussed.

Current Optimization Approaches

To minimize the impact water quality has on FR performance, many operators have opted to use a high TDS tolerant FR across all their produced water operations. This reduces the need to monitor for water changes from site to site and provides a standard fluid design across operations. While this approach can minimize the effects of water quality changes, high TDS tolerant FRs are still susceptible to the individual dissolved solids in the water. High concentrations of calcium and magnesium can render some FR products ineffective even if they are designed for high TDS applications. The performance ranges used to select these FRs are based on a subset of waters, which cannot fully encompass all the water compositions encountered in the field. Usage of the same FR as a one-size fit all, can fail if source water compositions change. If water quality improves, a lower cost option could have been used. If water quality diminishes, the dissolved solids composition could exceed the limitations of the FR.

Another solution that has been explored to extend the performance range of FRs are boosters. These surfactant-based products can improve friction reduction of FRs that would otherwise not work in high TDS waters. The effectiveness of booster systems in preventing performance degradation in saline water with the effects of monovalent cations, such as sodium and potassium, divalent cations like calcium and magnesium have been tested. The results showed that the addition of the surfactant-based products can improve performance and extend the salt tolerance of a friction reducer. (Seymour, B., Friesen, D., & Sanders, A. 2018). The ability to use FR's with a booster can provide a lower cost point than a high TDS FR. Some of the limitation of this approach are that boosters do not work on all FRs, so further analysis is needed to determine effectiveness. Operators are also reducing the number of chemicals that comprise their frac fluid and addition of a booster may not be a favorable approach.

Field Monitoring and Testing

A monitoring process was implemented for two operators in the Permian basin to track changes in water quality and friction reducer performance during produced water re-use operations.

Water quality was monitored real-time by measuring water pH, total dissolved solids (TDS), chlorides, hardness, and oxidizer residuals at various intervals and when water sources were changed. The measurements were tracked to determine the consistency in water quality throughout frac operations.

On-site friction reducer performance evaluations were performed using a mobile friction loop. The friction loop measures the percent (%) friction reduction each FR can achieve in the test fluid. To quantify the performance, the pressure drop across a length of pipe was monitored at a controlled flow rate at ~51,000 Reynolds number. Pressure changes were measured before and after the addition of the FR. The resulting pressure change was reported as % friction reduction. Tests were completed with field water samples and field chemicals obtained from storage tanks on-site. Use of the same water being pumped during the fracturing operation eliminated variations in water quality compared to samples collected days prior and ensured any treatment chemicals were also present (oxidizing biocides).

Results and Discussion – Operator A

Water monitoring results for three consecutive fracturing operations (Frac A-C) for Operator A are shown in Figure 1. Initial fluid design specifications targeted a TDS level of approximately 50,000 ppm and a medium brine friction reducer, FR-1, at a dosage of 0.5 gal/1000 gal. Water was sourced from three different locations and comingled at a central pond. The water quality of each source was not known prior to delivery to the pond and a water analysis was completed on the comingled sample. Freshwater was used to dilute the water to meet desired TDS, with a target blend ratio of 50% freshwater. The friction reducer had been selected by the service company based on its performance rating for up to 50,000 ppm TDS water.

Frac A water quality met the target water quality specification for the 15-day operation. Frac B, which was started 5 days after Frac A, had water quality which increased in TDS within the first three days. Higher TDS resulted in a higher FR dosage required to maintain pressure, with an average 1 gal/1000 gal pumped. The increased use of FR prompted the operator to assess the cost implication of increased FR usage and to identify an alternate friction reducer option. The service company recommended FR-2, a high brine tolerant anionic product rated for up to 150,000 TDS. The FR-2 was compared to the FR-1 on-site with the 80,000 ppm TDS water, those results are shown in Figure 2. For the mobile friction loop tests, 60% or greater friction reduction was considered ideal performance. FR-1 was tested up to 1 gal/1000 gal and failed to meet the target friction reduction. FR-2 performance met the friction reduction target at 0.5 gal/1000 gal, suggesting the FR-2 would perform better than FR-1 in the field.

The operator performed a cost/performance analysis on both products to determine the viability of changing the FR in the fluid design. A comparison of the cost versus dosage for each FR (Figure 3), suggested that FR-2 was a better option if dosage rates were maintained at 0.5 gal/1000 gal. With the potential for water quality to continue to diminish, FR dosages for either product were expected to increase, so a third option was proposed. Both friction reducers would be used during the job, FR-1 would be used when water quality was below 50,000 ppm and FR-2 would be used when TDS values were higher.

Implementation of this new approach (Figure 4), resulted in a cost savings of $51,300 on the dual FR system versus using FR-1 alone. Forty nine stages pumped were completed with FR-1 and 26 stages completed with FR-2. This allowed the operator to further reduce chemical spend by using water quality data to adjust FR usage on-the-fly. Monitoring and optimization during the frac operation identified the impact water quality has on FR performance. While changes to water quality could not be controlled, the fluid chemistry was adjusted to provide an economical solution. The water for Frac C, which was sourced one month after Frac B, had four times higher TDS than the previous fracs. The test and field data from Frac A and B were used to modify the fluid design with only FR-2 used for those well completions.

Results and Discussion – Operator B

A pre-job selection process was implemented to evaluate friction reducers under standard conditions to determine viable field trial candidates. Fluid design specifications required a product that could work in 25% to 100% produced water at a dosage of 0.5 gal/1000 gal. Initial FR tests were performed by the service company two weeks prior to the start of the job. Two FR candidates, FR-X and FR-Z were evaluated in various ratios of fresh and produced water (Figure 5). Friction loop target performance range for these tests was 75% or greater friction reduction. Both FRs showed comparable friction reduction and were selected for comparison in the field. Each FR would be pumped on adjacent 2-well pads, with the same water source for direct comparison of product efficiency.

On rig-up, water analysis and an on-site friction loop test were performed to validate target FR dosages. Test results differed from the lab tests completed two weeks prior (Figure 6). FR-X test data differed significantly from initial tests, with on-site results with poor performance at 0.5 gal/1000 gal. When tested at a higher dosage, 1.0 gal/1000 gal, FR-X had 10% lower friction reduction than 0.5 gal/1000 gal of FR-Z. Performance of the FR-X was not comparable to the results generated before the job and required further investigation. Results suggested FR-X was not suited for the water being used for the job.

On-site friction loop test results for FR-Z were comparable in performance tests to the performed before the job, with a target dosage of 0.5 gal/1000 gal. The water analysis results showed that water quality had changed over the two-week period, with 50,000 ppm higher TDS, attributed to higher chlorides and doubling of the total hardness of the field water versus the original water samples for pre-job tests.

The operator performed a cost/performance analysis on both products to determine the cost implications of the higher dosage requirements of FR-X (Figure 7). FR-X was the more economical option and the comparison showed that continued use of FR-X at higher concentrations up to 1 gal/1000 gal was still within the maximum budget of $100,000. FR-Z was more costly and cost prohibitive above 0.5 gal/ 1000 gal. The field trial of both products under comparable conditions would provide better correlation to observed friction loop tests and cost implications.

Frac 1, was completed with FR-X and required higher FR dosages to complete stages where recycled water ratios were greater than 50%. Dosages ranging from 0.5 to 0.75 gal/1000 gal were used at 50% or lower recycled water blends and 1.0 to 1.25 gal/1000 gal was used when water blends were higher. Frac 2, completed with FR-Z was successful with 100% recycled water used and a dosage of 0.5 gal/1000 maintained for both wells. A cost comparison for each completion (Figure 8) was performed and results suggested that while the FR-Z was a higher cost product, the ability to use a lower dosage resulted in savings of ~ $23,300 for the two well pad.

Conclusions

Water quality plays a critical role in fluid selection and overall chemical spend for the completion of a well. While costs related to chemical consumption can be directly measured, there are other associated costs with poor FR performance. Water quality can also impact equipment maintenance and non-productive time (NPT) as a result of using more corrosive waters and increased equipment sand erosion.

General

- Produced water quality changes regularly
- Pre-job testing may not be representative of field conditions
- Performance versus cost analysis can lead to better product selection
- On-site verification of performance can ensure fit for purpose use of friction reducers

Case Study Results

Monitoring and optimization results during fracturing operations for both operators identified opportunities to optimize chemical usage to work with changing water quality. The impact of implementing these changes into subsequent operations reduced water quality related costs with Operator A saving an estimated ~$667,615 and Operator B ~$950,180 annually based on their well completion rates for 2019.

Graphics

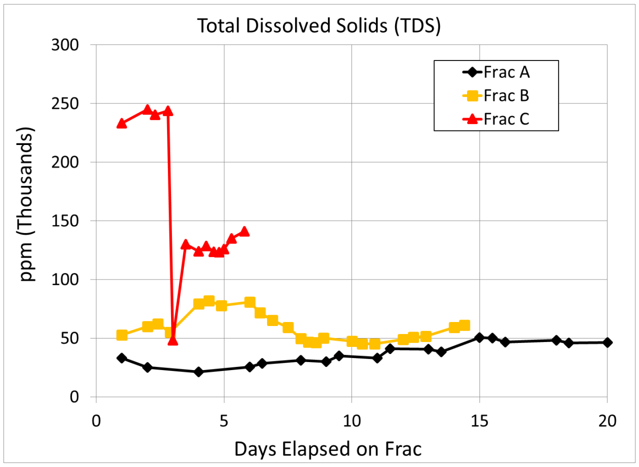

Figure 1 – Total dissolved solids concentration for three produced water reuse fracturing operations.

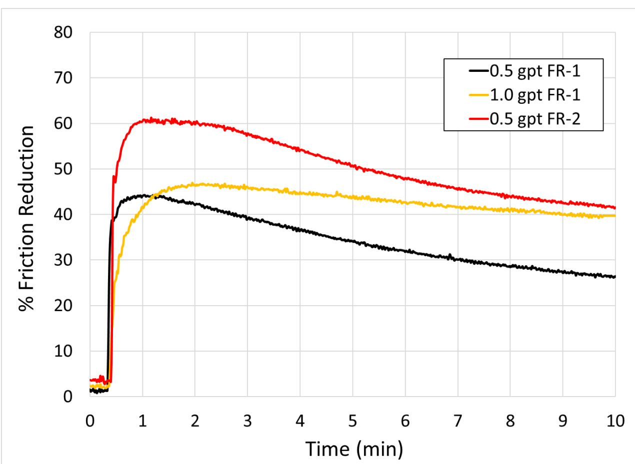

Figure 2 – On-site friction loop test results for mid-brine and high brine friction reducers in 80,000 ppm total dissolved solids field water.

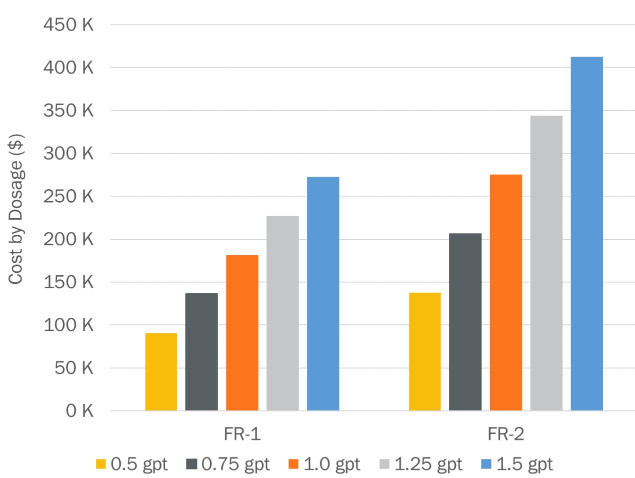

Figure 3 – Cost versus dosage comparison of FR-1 and FR-2.

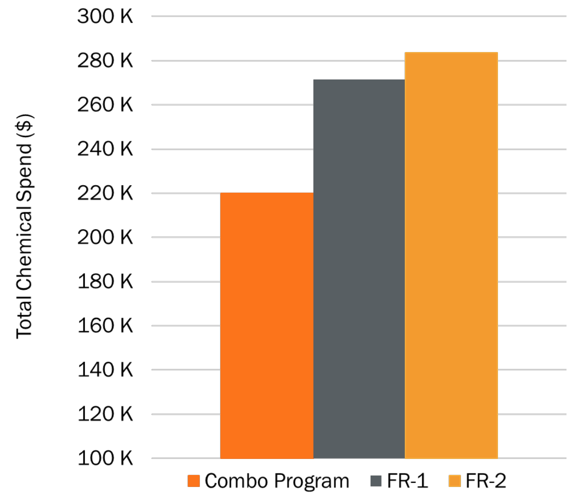

Figure 4 – Post frac treatment chemical spend comparisons for FR-1 and FR-2.

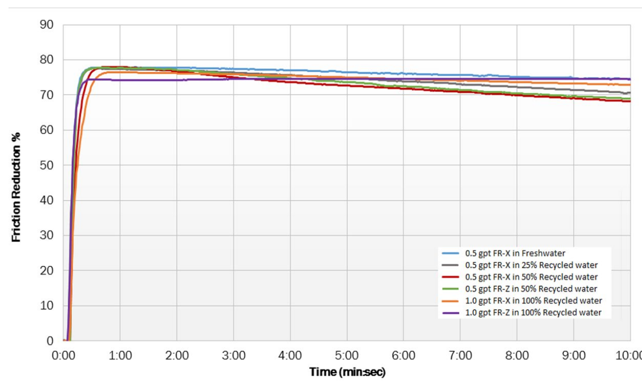

Figure 5 – Pre-job friction loop results of FR-X and FR-Z at various dosages and recycled water blends completed two weeks before start of fracturing operations.

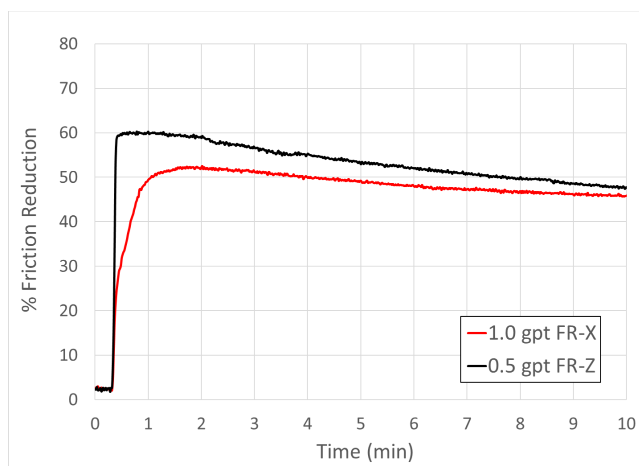

Figure 6 – On-site friction loop results for FR-X and FR-Z in 100% recycled water.

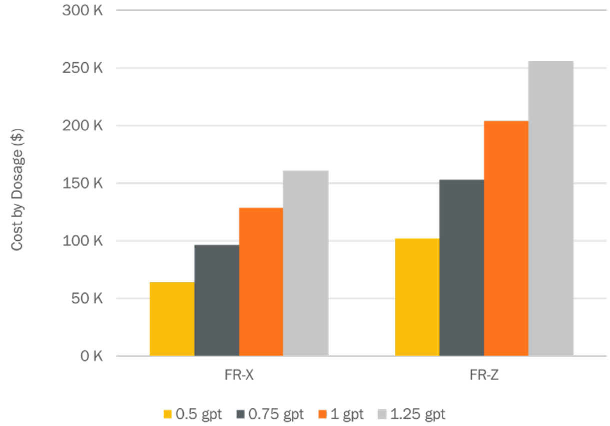

Figure 7 –Cost comparison of FR-X and FR-Z versus dosage.

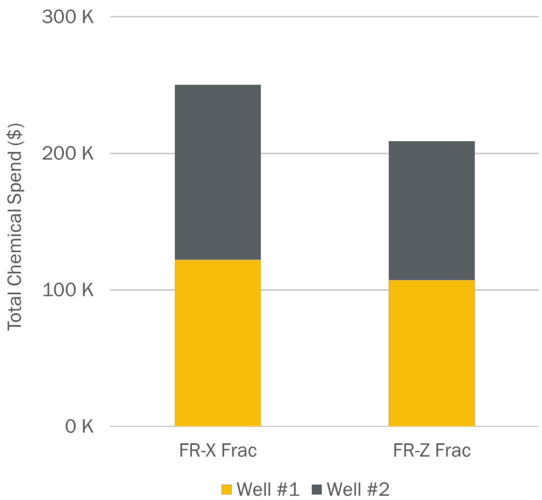

Figure 8 – Post frac treatment chemical spend comparisons for FR-X and FR-Z

Acknowledgments

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Nomenclature

Define symbols used in the text here unless they are explained in the body of the text. Use units where appropriate.

ppm = *Parts per million*
MM = *million*

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