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Effect of Injection Fluid Properties on the Hydraulic Fracture Geometry: A Case Study from Texas

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Abstract

Subsurface fractured injection (sometimes called cuttings re-injection, drill cuttings injection, or slurry injection) has been proven over the past decades to be the safest, most efficient, and the lowest-cost technology for disposal of certain kinds of oil and gas waste. This technology involves creating a hydraulic fracture in a subsurface injection formation followed by an intermittent process of pumping the slurrified waste into the fracture. The objective of this study is to investigate the impact of changing the rheological properties of the slurrified waste on the hydraulic fracture geometry.

The investigation was conducted in two main steps: first, using the geophysical information a geotechnical earth model was built to estimate the mechanical properties of different subsurface formations. This allowed the selection of a porous/permeable injection formation which is over-laid and under-laid by proper stress barriers. Second, a commercial 3-D fracture simulator (@Frac 3D) was used to study the impact of changing the rheological properties of the injection fluid such as viscosity, solids concentration, and injection rate on the geometry of the hydraulic fracture and net pressure. The results show that solids concentration, injection rate and fluid viscosity are proportional to the fracture width and net pressure.

Keywords: Drill-cuttings injection; Cuttings reinjection; Slurry injection; Oil-field waste management; Injection fluid rheology; Fracture simulation; Fracture geometry

Introduction

The advancement in drilling, completion and production operations has led to an increase in the volume of E&P waste generation. Until the 1980s, little thought was given to the disposal of oil field wastes, particularly during drilling operations [1]. Typically, these wastes were discharged overboard in offshore operations or buried when drilling in land-based locations onshore. In the later 1980s and 1990s, environmental awareness and regulatory scrutiny increased globally leading to the development management techniques to enable a reduction in the environmental impacts of the disposal of oil and gas wastes.

Presently, fractured injection (sometimes called drill-cuttings injection, slurry injection, or cuttings reinjection) has been established as a proven method for the safe and permanent disposal of E&P drilling waste by injecting it into an engineered subsurface strata/formation [2]. In general, fractured injection is a process in which accumulated solids (i.e., drill cuttings) and liquids (i.e. flowback, contaminated runoff water, frac-water etc, produced water etc) are conveyed through series of components that break, degrade, mix and condition them into a slurry which can be pumped. This slurry is then pumped/ injected into a hydraulically created fracture in subsurface formation at safe depth with a containment layer for permanent isolation.

Methods and Objective

Available geophysical data was used to perform a detailed geotechnical and stress analysis as shown in Figure 1 [3]. This aids in selecting the best injection formation, i.e. one with significant overlaying and underlying stress barrier to restrict fracture growth and prevent it from migrating in different (i.e. unpermitted) zones. The major challenge after selecting the candidate formation is to select an optimum combination of injection fluid rheology, solid concentration and injection rate which optimizes subsurface storage capacity in the chosen formation. Failure in doing so can cause formation or well plugging and in some extreme cases waste breaching to unintended zones. Both are serious concerns for an operator.

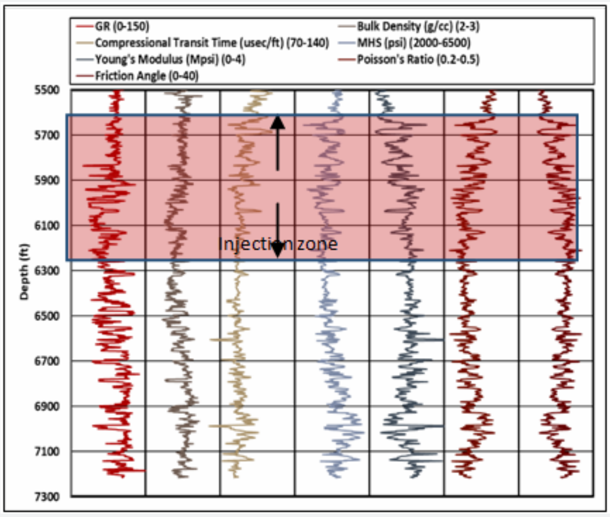

Figure 1: Geotechnical Analysis of the injection and its overlaying and underlaying formation [3].

A case study is performed on a fractured injection well operating in Texas of the United States of America. The targeted formation for slurry injection is comprised mainly of interbedded sand and shale layers. The study shows the effect of different combinations of fluid rheology, solids concentration and injection rate on the fracture geometry and net pressure (fracture pressure minus fracture closure pressure). This analysis helps to determine the maximum capacity of the formation along with the volume of waste it can hold and also provides an estimate of surface treating pressure [4].

$$P_{surface} = BHTP + \Delta P_{friction} + \Delta P_{perf} + \Delta P_{net} - \Delta P_{hydrostatic}$$

Where,

BHTP= Bottomhole Treating Pressure (Frac Gradient x Depth), psi

$\Delta P_{friction}$= Treating pipe friction pressure (psi) @ injection rate, psi

ΔP_{perf} = Friction pressure through perforations, psi

$\Delta P_{hydrostatic}$= Hydrostatic pressure, psi

ΔP_{net}= Net pressure, psi

A commercially available fracture simulator @Frac 3D is used to carry out fracture simulations as it provides an assurance of the waste containment within the engineered strata [5]. Different cases were run with varying injection fluid viscosity, solids concentration and injection rate as shown in Table 1.

Table 1: Fracture Simulation Run With Varying Injection Fluid Properties.

Case #	Injection Time (Mins)	Solids Concentration (%)	Injection Rate (BPM)	Viscosity (cP)
1	600	15	10	10
2 (Base Case)	600	15	10	30
3	600	15	10	50
4	600	10	10	30
5	600	20	10	30
6	600	15	8	30
7	600	15	12	30

Result and Discussion Effect of Solid Concentration

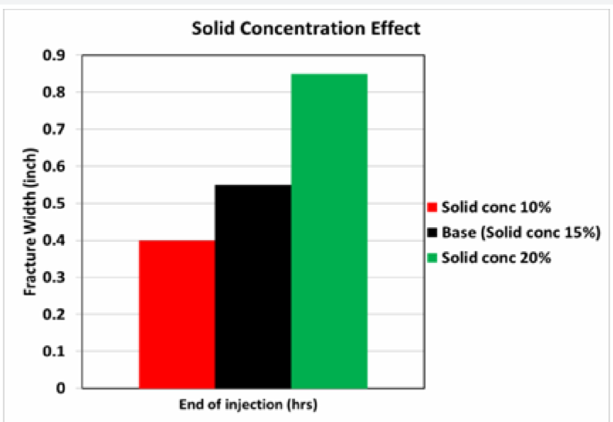

Figure 2: Solids concentration effect on fracture width.

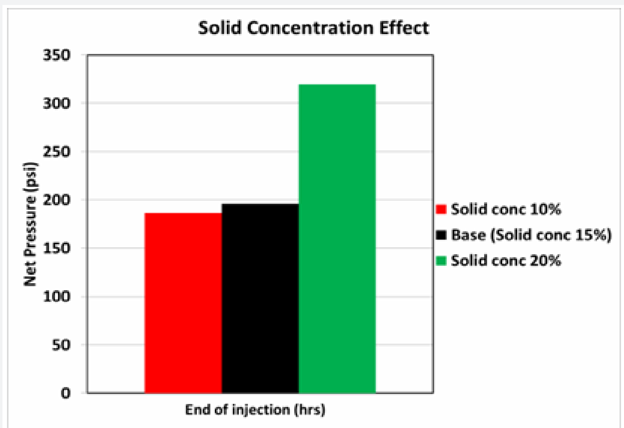

Figure 3: Solids concentration effect on net pressure.

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Three simulation cases were run for 10 hours with varying solid concentrations, keeping the injection fluid viscosity and the injection rate constant at 30cP and 10BPM respectively. The results show that the fracture width and net pressure is proportional to the solids concentration (Figure 2 & 3). The surface pressure (Figure 4) decreases with an increase in solid concentration, this is because the hydrostatic head increases with an increase in the injection fluid density.

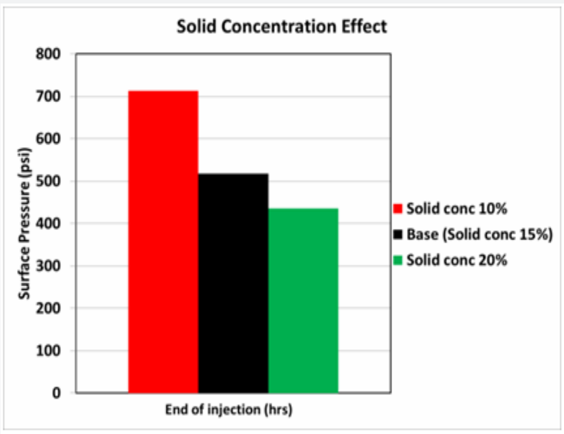

Figure 4: Solid concentration effect on surface pressure.

Effect of Injection Rate

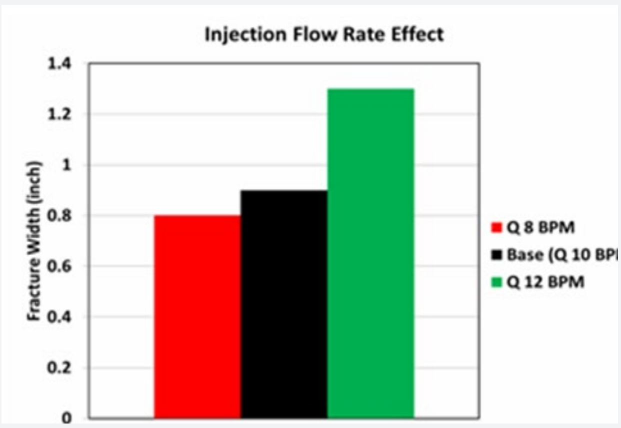

Figure 5: Injection rate effect on fracture width.

Three simulations were run for 10 hours at three different injection rates of 8BPM, 10BPM and 12BPM while both solids concentration and injection fluid viscosity constant at 15% and 30cP respectively. The results are shown in Figure 5 & 6 where it is observed that the injection rate is proportional to both the fracture width and net pressure [6]. This is because with an increase in the injection rate, the net pressure increases, which ultimately drives fracture growth and forces the walls of fracture creating a width and length sufficient to allow the entry of slurry. Figure 7 shows an increase in surface pressure with increasing injection rate, as the net pressure increases and the hydrostatic head is constant.

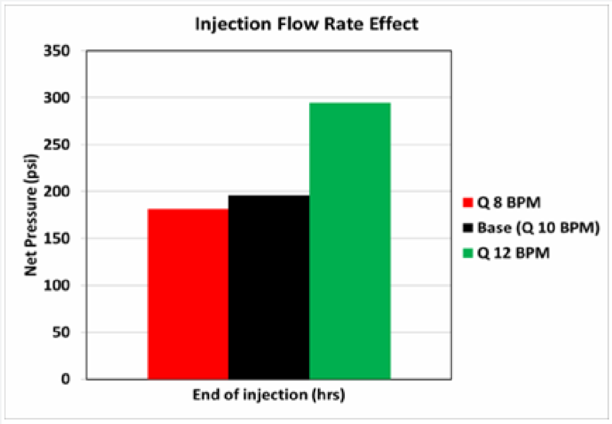

Figure 6: Injection rate effect on net pressure.

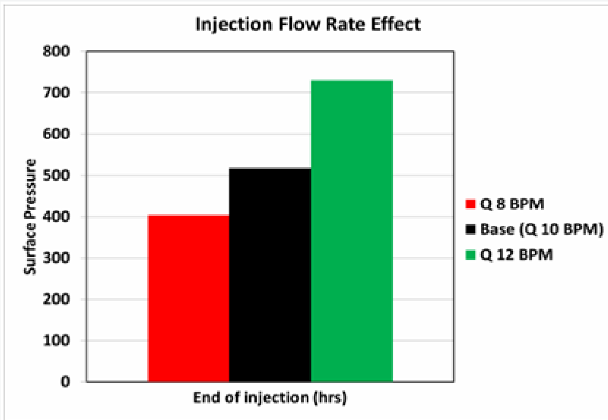

Figure 7: Injection rate effect on surface pressure.

Effect of Injection Fluid Viscosity

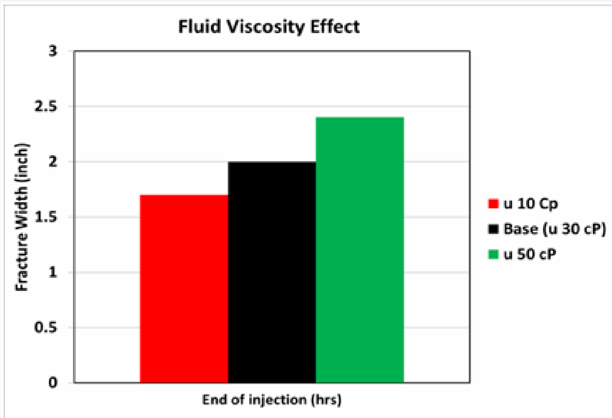

Figure 8: Injection fluid viscosity effect on fracture width.

Three different simulation cases were run for 10 hours keeping injection flow rate and solids concentration constant at 10BPM and 15% respectively, but varying viscosity at 10cP, 30cP and 50cP. Figure 8 & 9 shows that the fracture width and net pressure has direct relation with viscosity. The increase

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in net pressure forces the fracture wall apart, ultimately increasing its width [7]. The surface pressure also increases with increase in viscosity (Figure 10) which is due to constant hydrostatic head and increase in net pressure.

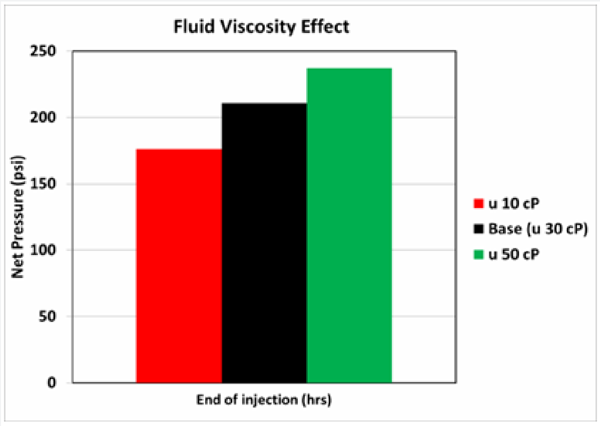

Figure 9: Injection fluid viscosity effect on net pressure.

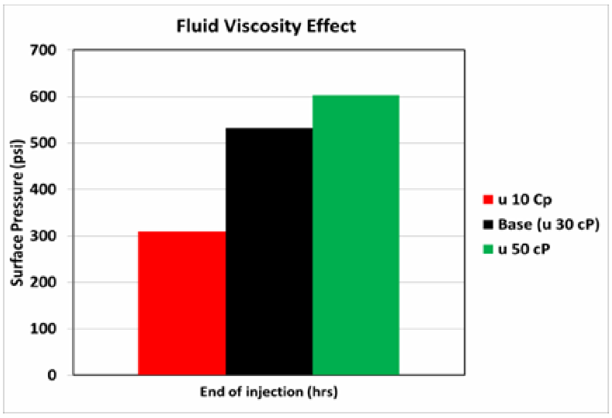

Figure 10: Injection fluid viscosity effect on surface pressure.

Conclusion

In the current study, seven fracture simulation cases have been run using commercial simulator software "@FRAC" to address the effect of the injection fluid properties on the fracture propagation behavior. Based on the results of the fracture simulation cases the following conclusions can be drawn:

1. Wider fractures are created when at high solids concentration, injection flow rate and fluid viscosity because higher net pressure is observed inside the fractures.

2. With an increase in the injection fluid viscosity and injection rate the surface pressure increases as this change increases the net pressure keeping the hydrostatic head constant.

3. With an increase in solid concentration, the net pressure increases and so does the fluid density which ultimately increases the hydrostatic head, so a decline in surface pressure is observed.

4. Fluid properties within the study limits didn't affect the vertical propagation of the hydraulic fracture. The fracture remains contained within the injection horizon for all simulated cases.

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