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

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Abstract
Subsurface drill-cutting 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 slurred waste into the created fracture. The objective of this study is to investigate the impact of changing the rheological properties of the slurred waste on the hydraulic fracture geometry, i.e. fracture length, height, and width.

The investigation was conducted in two main steps: first, using the geophysical information a geo-mechanical 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. The results show that both solid concentration and the fluid viscosity are inversely proportional to the fracture length while solid concentration is proportional with the fracture width. On the other hand, the injection flow rate is proportional to both the fracture length and the fracture width.

Keywords: Drill-cutting injection; Oil-field waste management; Injection fluid rheology; Fracture simulation; Fracture geometry

Introduction

The advancement in the drilling, completion and production operations has led to an increase in the volume of drill-cuttings and waste generation. Until 1980s, little thought was given to the disposal of drill cuttings and excess drilling fluids. Typically, in offshore operations this waste was discharged overboard or buried when drilling in land-based locations (onshore). In later 1980s and 1990s the environmental awareness increased globally and the oil & gas industry and the environmental regulatory boards understood the potential impact of drilling waste on environment. This challenge has ultimately led the oil and gas industry to develop management techniques to curb the disposal of drilling waste without compromising the environment.

Nowadays, the drill-cutting injection is a proven technology to dispose the drilling waste by injecting it into an engineered subsurface strata/formation for the safe and permanent storage. In general, drill cutting injection is a process in which accumulated cuttings (solids) and liquids (flow back, contaminated runoff water, frac-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

The available geophysical data was used to perform a detailed geo-mechanical and stress analysis as shown in Figure 1. This helps in selecting the best injection formation with a significant overlaying and underlying stress barrier to restrict the fracture growth and prevent it from migrating in different zones. The major challenge after selecting the candidate formation is to select an optimum combination of injection fluid rheology, solid concentration and injection rate to conduct smooth injection. The failure is in doing so can cause...
formation or well plugging and in some extreme cases waste breaching to unintended zones which is a serious concern for an operator.

A case study is performed on a drill cutting 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 combination of fluid rheology, solid concentration and injection rate on the fracture geometry (change in fracture length, height and width). This analysis helps to determine the maximum solid capacity of the formation. 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. Nine different cases are run with varying injection fluid viscosity, solid concentration and injection rate as shown in Table 1.

![Figure 1: Geomechanical Analysis of the injection and its overlying and underlying formation.](image)

Table 1: Fracture simulation run with varying injection fluid properties.

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<tr>
<th>Case #</th>
<th>Injection Time (mins)</th>
<th>Solid Concentration (%)</th>
<th>Injection Rate (BPM)</th>
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Results and Discussion

Effect of solid concentration

Three simulation cases were run with varying solid concentration and keeping injection fluid viscosity and the injection rate constant at 30cP and 10BPM respectively. The results show that the fracture width

is proportional to the solid concentration (Figure 2) while higher solid concentration values resulted in shorter fracture length (Figure 3). This is because the treating pressure is constant with varying density which makes it difficult to push slurry with higher density into the fracture so the pressure at fracture tip decreases with increase in solid concentration. Also, the maximum fracture height was almost similar for the three simulations which suggest that the solid concentration does not have a significant effect on fracture containment and in all cases the fracture propagated within the injection layer.
Figure 2: Total solid concentration effect on fracture width.

Figure 3: Total solid concentration effect on both fracture length and fracture height.

Figure 4: Injection rate effect on fracture width.
Effect of injection rate

Three simulations were conducted at three different injection rates of 8BPM, 10bpm, and 12BPM while both solid concentration and injection fluid viscosity constant at 15% and 30cP respectively. The case is allowed to run for 1.5 days as better results are expected with longer runs. The results are shown in Figure 4 & 5 where it is observed that the injection rate is proportional to both the fracture width and the fracture length. This is because with an increase in the injection rate, the net pressure (fracture pressure minus fracture closure 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. The maximum fracture height as shown in Figure 5 is almost the same for the three simulations [1-7].

Effect of injection fluid viscosity

Three different simulation cases were run keeping injection flow rate and solid concentration constant at 10BPM and 15% respectively, with varying viscosity of 10cP, 30cP and 50cP. Figure 6 and Figure 7 shows that the fracture width and fracture height has direct relation with viscosity, as the net pressure increases with an increase in the viscosity which ultimately forces the fracture walls apart. Also, Figure 7 shows that the fracture length decreases with increase in viscosity as viscous slurry exerts less pressure towards the tip of the fracture.
Conclusion

In the current study, nine 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:

a. Higher injection rate, lower fluid viscosity, and lower solid concentration tend to create longer fractures, which are desirable for waste injection applications to reduce stress build up near the wellbore and increase the well storage capacity.

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

c. 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.

References