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Optimum Well Completion Plan for Tight Gas Reservoirs

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Extended Abstract

The most optimum completion strategy for tight reservoirs, nowadays, is hydraulic fracturing. The performance of the well is severely affected by the interfering effects inside the fracture and inter-fractures.

The stress reorientation around a fractured vertical well has two sources: (a) opening of propped fracture (mechanical effects) and (b) production or injection of fluids in the reservoir (poroelastic effects).

In this paper, the coupling of both phenomena was modeled to quantify the extent of stress reorientation around fractured production wells. Both of the factors which are responsible to set up stress reorientation in the vicinity of the fracture (known as the stress reversal region) and also cause a reoriented stress profile in the outside of the vicinity can impact refracturing operations.

Numerical investigation was made to evaluate the potential of the orthogonal refracture to increase production in shale and tight gas formations. Mechanical and poroelastic contributions to stress reversal have been shown to differ in these two formations suggesting that reservoirs may be more prone to one source of stress reorientation or the other depending on their properties.

Conclusions drawn from the paper allow an operator to (a) select candidate wells, (b) choose the timing of the refracture operation in the life of the well, and (c) evaluate the potential increase in well production after refracturing.

The stresses around fractured production wells are reoriented because of non-uniform depletion of the reservoir. Initially, the direction of maximum horizontal stress is aligned with the initial vertical fracture. During production, the maximum horizontal stress decreases faster than the minimum horizontal stress because of higher depletion in the fracture direction, causing stress reversal to occur in the vicinity of the fracture. As a result, the second fracture may propagate orthogonally to the initial fracture. Past the isotropic point, the maximum principal stress switches back to its original direction, causing the refracture to gradually reorient parallel to the initial fracture. The distance between the well and the isotropic point (which limits the stress reversal region) is called Lf'. It is a good indication of the potential of refracturing operations. The stress reversal region grows at early production times before reaching a maximum extent. If refracturing is implemented at this time (optimum time for refracturing tmax), incremental production should be maximized.

The effects of relevant reservoir, fluid and fracture parameters on the size of the stress reversal region generated by a producing propped-open fracture, and on the relative importance of poroelastic and mechanical stress reorientation, are discussed in the paper.

The extent and timing of the stress-reversal region were calculated for typical parameters of the shale and tight gas formations. The numerical simulation of the superposition of mechanical and poroelastic effects is compared to calculations of the poroelastic stress reorientation only.

In the shale formation, stress reversal extends up to 174 feet from the well after 42 months of production. Taking into account mechanical effects, the maximum extent of the stress reversal region grows to 213 ft, while the optimum time-window for refracturing is pushed to 58 months. The extent of stress reversal from poroelastic effects is much smaller for the tight gas well, mainly because of a thinner pay zone. Stress reorientation is maximum after little more than a month of production.

Production from the two field cases (shale gas and tight gas) was numerically simulated assuming the wells are refractured at the optimum time for refracturing.

The cumulative production from the refractured wells is compared to what would have been produced by just the initial fracture.
- In the case of the tight gas well, the additional production from refracturingis limited as shown in Fig. 1. The incremental recovery goes through a maximum a few days after refracturing and quickly goes to zero (Fig. 2). This is the consequence of a relatively high permeability and a low potential for poroelastic stress reversal.
- The low matrix permeability of the shale gas reservoir leads to a slow depletion of the reservoir around the fracture. By propagating the refracture far into less depleted parts of the reservoir, significant production gains are obtained (Fig. 3). The incremental recovery from refracturing increases with time and even surpasses 50% after 14 years (Fig. 4).
- A new model to calculate the extent of stress reversal around a producing well has been presented taking into account both the mechanical effects associated with the opening of the initial fracture and the poroelastic effects associated with fluid production.
- It was shown that in unconventional gas reservoirs (tight or shale gas), both mechanical and poroelastic effects contribute significantly to stress reorientation.
- The proposed numerical model can also be used to estimate incremental production from refracturing.
- The potential of the refracturing technique to add production and reserves was demonstrated in very-low-permeability reservoirs such as shales. Incremental recoveries of more than 50% may be achieved.

The propagation of the refracture away from the initial fracture can be improved by
- maximizing the size of the stress reversal region through initial fracture design (fracture length) and timing of the refracture, and
- Creating a favorable stress orientation outside in the reoriented stress region through improved field design and production schedule.

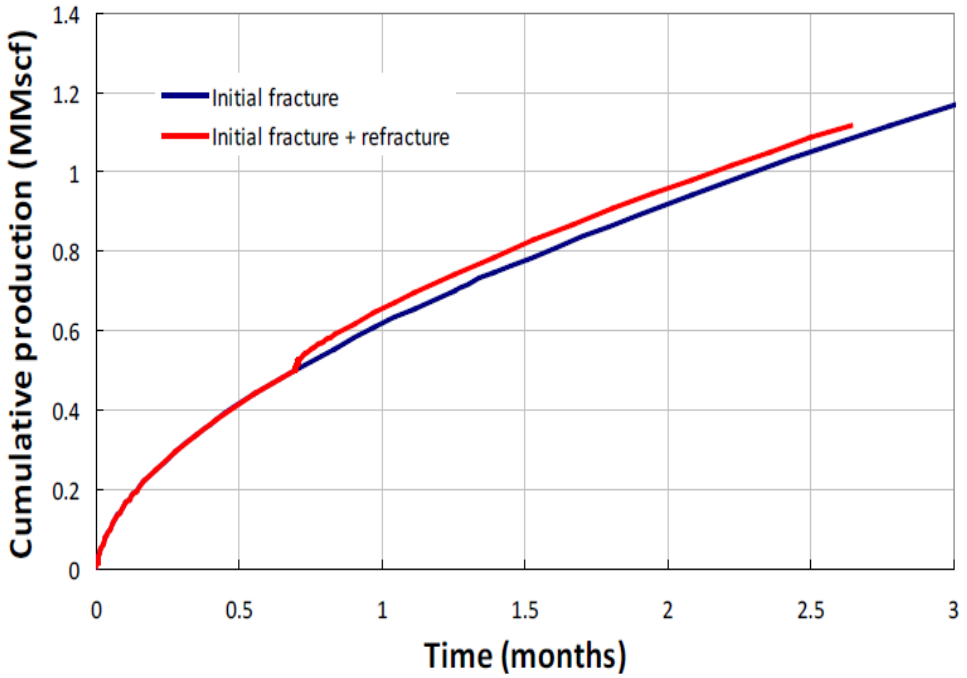


Figure-1: Cumulative production from the initial fractures and refractures in a tight gas well

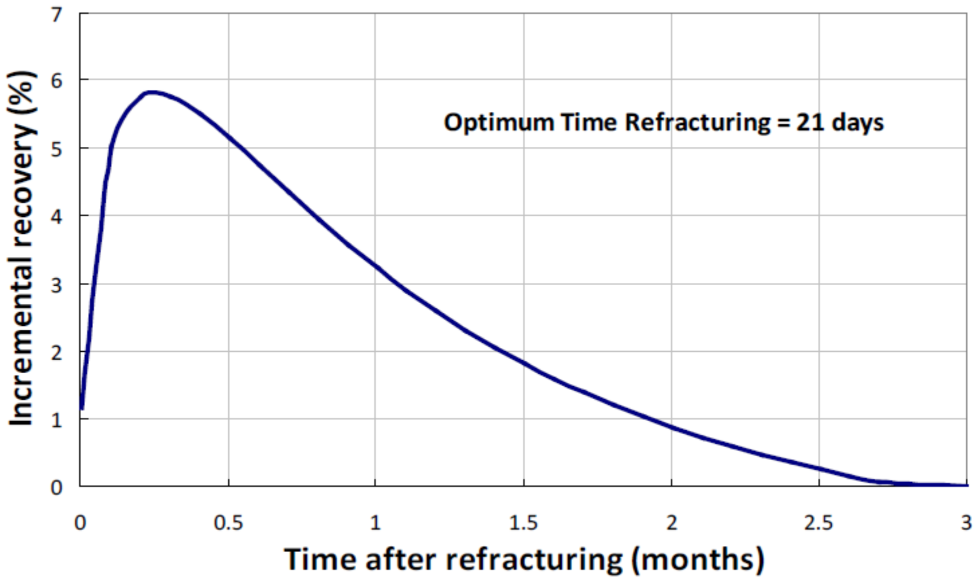
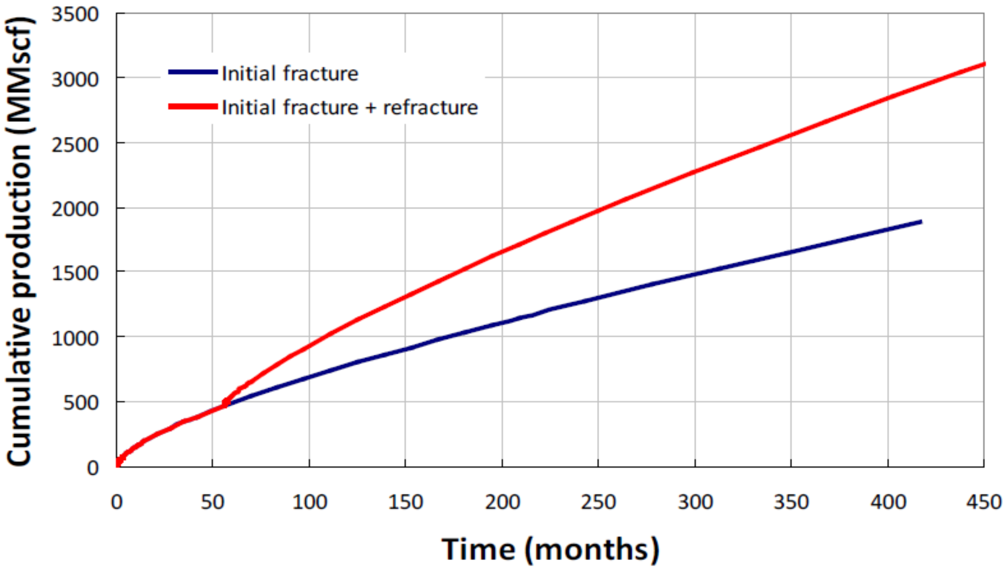


Figure-2: Incremental gas recovery (%) from refracturing wells in a tight gas well



Figuure-3: Cumulative production from the initial fractures and refractures in a shale gas well

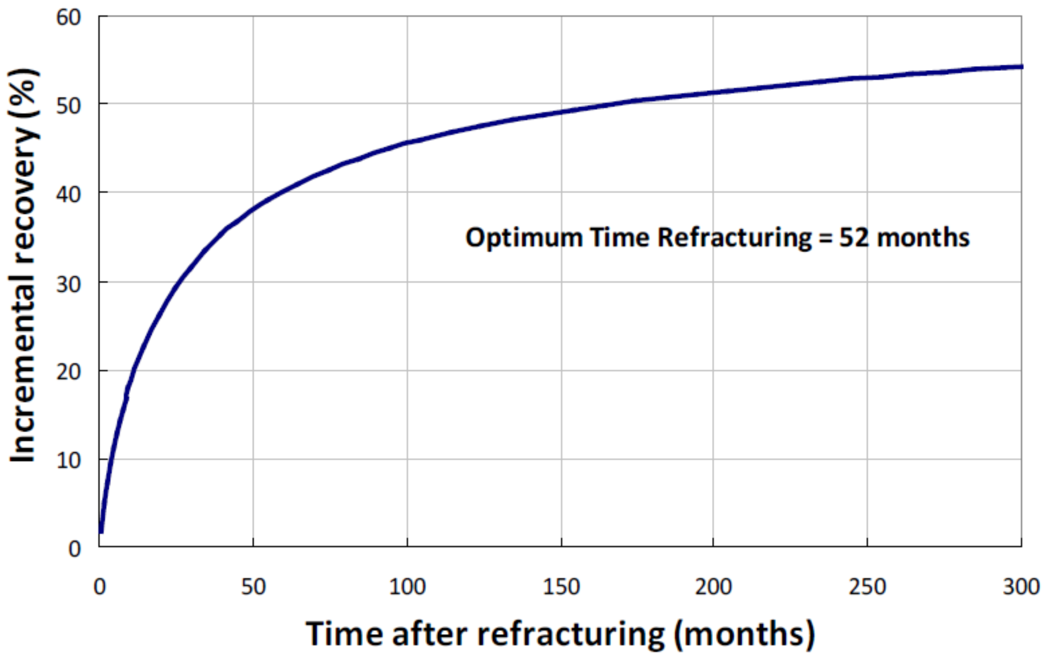


Figure-4: Incremental gas recovery (%) from refracturing wells in a shale gas well