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Acid Fracturing of Gas Wells Using an Acid Precursor in the Form of Solid Beads: Lessons Learned From First Field Application

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Abstract

Acid fracturing treatments are commonly used to enhance the productivity of carbonate formations with low permeability zones. Various forms of HCl acid are used to create deep etched fractures. However, HCl reacts very fast with the carbonate rocks and unless retarded, will produce a fracture with low conductivity. In addition, concentrated HCl-based acids are very corrosive to well tubulars, especially at high temperatures. To address problems associated with concentrated acids, various retarded acids were introduced. Organic acids were also used in some cases. These acid systems were successfully used to acid fracture several wells in a deep gas reservoir in Saudi Arabia. Field data, however, indicated that there is a need to create deeper and more conductive fractures. To achieve this goal, it was decided to conduct a field trial with a newly developed acid system.

The new acid system is an ester of an organic acid in the form of solid beads. The ester reacts with water (hydrolyzes) at bottom temperature and produces an organic acid. The organic acid then reacts with carbonate minerals and etches the surface of the fracture. The system was thoroughly examined in the lab and showed promising results.

The treatment was conducted in the field without encountering operational problems. After successful placement of the solids in the fracture, the well was shut-in for 24 hours to give ample time for the ester to hydrolyze and for the generated acid to react with the formation rock. The well was allowed to flow and samples of the fluids produced were collected to understand chemical reactions that occurred during the treatment. The treatment has resulted in a slight increase in gas production. And as a result, the well was matrix acidized using 28 wt% HCl and responded very well to the matrix treatment.

This paper will discuss major reactions that occurred during this treatment, and how they impacted well response. Lessons learned and recommendations to improve the results of this new acid system will be discussed in detail.

Introduction

Various fluid systems have been employed in acid fracturing treatments conducted to enhance the productivity of deep and sour gas wells in Saudi Arabia.[1,2] The produced gases contain hydrogen sulfide and carbon dioxide. The content of these two acidic gases varies thought-out the field. This variation affected the metallurgy of well tubulars used to complete these gas wells. Low-carbon steel tubulars were used in sour wells, whereas super Cr-13 tubulars were used in wells with very low H_2S/CO_2 ratios.

The change in tubulars metallurgy affected the acid system used. For super Cr-13 tubulars, a mixture of 15 wt% HCl and 9 wt% formic acid was used.[3,4] For low-carbon steel tubulars, various forms of 28 wt% HCl were employed. These HCl-based systems included: regular acid, gelled acid, in-situ gelled acid,[5] emulsified acid,[6] and more recently, viscoelastic surfactant-based acids.[7,8] Although, the presence of acid-soluble polymers and viscoelastic surfactants have somewhat alleviated the issue of high acid leak-off rate, treatment evaluation indicates that the acid leak-off rate is high; leading to large volumes of acid being used to create an effectively etched fracture.

Organic acids provide lower corrosion rates at high temperatures. However, a campaign of twelve wells fractured using organic acid blends indicated that effective half-lengths of 40-50 ft were achieved.[9] There is a need for more retarded systems to be used in acid fracturing applications. Gelled and in-situ gelled HCl/formic acids were used to acid fracture deep gas wells completed with super Cr-13 tubing. Good field results were obtained, however the fracture half-length was less than expected.

Regular organic acids (acetic, formic and combinations of these two acids) addressed some of the concerns raised with HCl (fast reaction rate, shallow acid penetration, corrosion to well tubulars and rock softening[10]). Encapsulated citric acid[11,13] and in-situ generated acids[14] were introduced over the last few years to address some of these concerns. However, major concerns with organic acids are: (1) limited solubility of their calcium and magnesium salts and (2) their reaction with carbonate rock is reversible.[15] In other words, their reaction with carbonate rocks does not go to completion and the acid will not be completely spent in the formation.