Case Study

RapidMATRIX system improves production from carbonate reservoirs

International, Saudi Arabia
RapidMATRIX System

Background

The Khuff is a carbonate formation deposited on a shallow continental shelf in the Ghawar structure of eastern Saudi Arabia. It is subdivided into four separate intervals, A to D, with production mainly coming from the two gas-bearing layers: Khuff-B, a tight dolomite and Khuff-C, a more prolific calcite.

Since its initial appraisal in the late 1970s, the majority of Khuff development activities have been focused in the Permian Khuff-C. Extensive heterogeneity in stress, reservoir quality and reservoir fluids throughout the field, combined with the deep and hot nature of the reservoir, makes effective stimulation of all layers a challenging task. Because of this, all Khuff gas producing wells require acid stimulation either by acid fracturing or matrix acidizing to obtain high production rates and sufficient flowing wellhead pressure to be tied into production facilities.

Challenge

Matrix acidizing is a method of stimulating carbonate reservoirs for oil and gas production. Unlike acid fracturing, matrix acidizing creates flow channels, also known as wormholes, which possess much higher conductivity compared to the reservoir rock. These conductive channels transport reservoir fluids from within the formation matrix directly into the wellbore overcoming both low permeability and near wellbore damage.

In matrix acidizing of moderate to prolific carbonate reservoirs, efficient acid placement is a major challenge as acid tends to flow preferentially toward intervals with the highest permeability. This can result in overstimulation of these intervals, leaving the lower permeability areas untreated. A significant percentage of improper job design and acid placement. In some cases, an increase in water production is observed after a stimulation job as a result of preferential stimulation of high permeability sections associated with water.

Until the middle of 2011, the majority of Khuff horizontal gas wells were drilled toward the maximum horizontal in situ stress ($\sigma_{\text{max}}$) to enhance wellbore stability and achieve the best possible penetration rates. However, when multi-stage fracture stimulation is desired, if the well is drilled in the $\sigma_{\text{max}}$ direction, the fractures will grow longitudinally (parallel to the wellbore) and cause potential risk of overlapping with subsequent fractures. Therefore, initiation of the second and third fractures becomes a challenge because of possible pressure communication across the first induced fracture. To avoid fracture overlapping, a well slated for multi-stage fracturing should be drilled toward the minimum horizontal in situ stress ($\sigma_{\text{min}}$), which allows transverse fracture growth (perpendicular to the wellbore). Drilling wells toward $\sigma_{\text{min}}$ often poses challenges such as wellbore instability and differential sticking, but
the improved long-term productivity justifies this strategy.

In the more prolific zones of the Khuff-C formation, there are wells that could only be drilled in the \( \sigma_{\text{max}} \) direction because of proximity to other boreholes and resulting danger of the wells colliding with each other. Acid fracturing of these wells could have led to the creation of a single linear fracture that would propagate parallel to the wellbore and possibly cause pressure communication with adjacent stages across the rock matrix. To prevent this, an innovative approach to achieving a deep, high-rate matrix acidizing treatment was required that used limited entry to enhance acid stimulation.

**Solution**

The Packers Plus RapidMATRIX® open hole multi-stage completion system is a successful technology that has opened access to several major carbonate reservoirs. In this system, stages are created by isolating sections of the wellbore using RockSEAL® packers and multiple RapidJET™ nozzles, which are spaced out in the sections of interest. Unlike standard single-entry-point StackFRAC® completions that are typically designed with uniform stage spacing, multiple jet nozzles are adjusted and placed according to reservoir characteristics, thus enabling controlled injection and leak off for distributed flow of the acid into the entire length of each stage. The designed treatment is thereby effectively placed at an optimal rate and pressure within each stage, resulting in the maximized development and complexity of the wormholes throughout the stimulated reservoir length.

**Results**

A candidate well in the Khuff-C, which was drilled parallel to \( \sigma_{\text{max}} \), was chosen to test whether the Packers Plus RapidMATRIX system could increase production. After thorough analysis of the geomechanical properties of the formation and the open hole log data, a 3-stage RapidMATRIX system was designed with a Hydraulic FracPORT™ sleeve for the first stage and six RapidJET nozzles for each of the second and third stages. The system was successfully deployed to the target depth in the 1,635 m (5,367 ft) lateral, the acid was pumped below the formation fracture pressure according to the treatment design and pumping schedule. The opening of each interval and the pumping of the acid treatment went as per design without operational issues.

Production from the RapidMATRIX completed well was compared with three offset wells: an open hole dual lateral well that was completed using conventional coiled tubing matrix acidizing (Well-1), and cased hole deviated and vertical wells that were both completed with acid fracturing (Well-2 and Well-3, respectively). As shown in the figure below, the RapidMATRIX completed well had the highest production of the four wells.

This study shows that for prolific carbonate formations, high-rate, limited entry matrix acidizing using Packers Plus RapidMATRIX open hole multi-stage completion system is an enabling technology that provides superior placement of acid treatments and results in improved production profiles compared with conventional coiled tubing matrix acidizing and cased hole acid fracturing.