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Candidate Evaluation, Well Preparation, And Stimulation Strategy For Mature Carbonate Reservoir Restimulation

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Summary

Restimulation design and treatment workflow for mature well conditions are based on the experience in the Middle East region. A substantial enhancement has been demonstrated for proper stimulation design.

In mature carbonate reservoirs, the potential for bypassed or under-stimulated pays need to be addressed in order to enhance the productivity of the wells. Reservoir restimulation is one of the viable option to do this. However, due to issues with completion, perforation and other associated issues that given wells may have, restimulation should be designed and implemented such that well productivity is enhanced while simultaneously maintaining the requirements for well completion integrity. Proper design for restimulation in thick carbonate reservoirs could eliminate any negative issues that may occur during completion and prevent integrity failure during the process.

In thick carbonate reservoirs, like those found in the Middle East, the aforementioned criteria contain both petrophysical properties and current production profile obtained by production logging, establishing good foundation for implementing restimulation. Petrophysical properties help define the stimulation strategy necessary based on log potential, while the current production profile identifies the best location to stimulate over the existing completed perforated interval. In thick carbonate stimulation, uneven reservoir recovery is often observed and considerable parameters must be set during the stimulation design. Major changes to consider during the candidate evaluation for the restimulation in thick carbonate reservoir are: non-uniform pressure depletion across the formation, various pressure drawdowns, and change in PVT properties. In addition, wormholes which formed during the initial reservoir stimulation are major factor for consideration. These wormholes may act as thief zones during restimulation work and could lead to improper zonal coverage.

Some uncertainties that may occur in the mature carbonate formation are such as existing wormholes from past stimulation treatments; reservoir pressure variation due to uneven recovery; near wellbore saturation change due to production behavior; perforations of new interval(s) and/or reperforation for additional shot density; recovery factor that could alter the water/gas level; initial completion design; additional damage from the workover activities; and well integrity issues

Existing wormholes from the past stimulation are not detected in any petrophysics information. The effect of existing wormholes in carbonate formation is mainly enhancing the production by giving more conductive pathways to the formation. On the (re-) stimulation treatment, existing wormholes would give also more conductive pathways, i.e. least resistance path, to the formation. Fail to take into account of the existing wormholes leads to improper placement of the stimulation fluids. Existing wormholes can be identified on a stimulated well by comparing the petrophysics conductivity to well test conductivity and production log profile. The pressure variation occurred as a result of uneven hydrocarbon recovery. On the high permeability zones, the formation gives higher capacity to produce than the lower permeability zones. The same analogue applies during stimulation, without proper diversion techniques, the stimulation fluid goes to this high permeability layer and eventually enhances the productivity of this higher permeability layers but leaves the other lower layer unstimulated and eventually produces less. The higher drawdown applies to a reservoir, the more depleted a reservoir due to respective hydrocarbon recovery. Based on this analogue, the most depleted reservoir, i.e. lowest reservoir pressure, takes also most fluid on the stimulation treatment. In addition to the pressure depletion effect, on a gas well, producing below the dew point leads to a flow assurance issue as the near wellbore saturation would change and may lead to liquid banks.

Perforating of new interval(s) as well as reperforation to increase shots per foot (SPF) may change flow resistance during restimulation. The new interval(s) that never been stimulated previously can be continued as untreated zone without proper attention. Estimate ultimate recovery will be related to the estimated depth of the free water level or free gas level. It is recommended to avoid excessive wormhole generation that may connect to free-water level or free-gas level. This becomes pitfalls when the least resistance path is really close to these levels. In the event of diversion failure, all the stimulation fluid would go to these least resistance paths and connect the unwanted zones. Different drawdown applied in producing the well may lead to different recovery and misinterpretation of the hydrocarbon in place.

Mechanical skin normally happens due to initial completion. Some partial cased-hole perforation to generate the limited entry during initial completion may become an additional restriction when the reservoir become mature and require more wellbore flowing pressure. The same analogue applies during pumping stimulation treatment. The limited entry, i.e. the mechanical skin, would restrict the stimulation fluid flow path. This may bring advantage and pitfalls at the same time. In case of the partial limited entry, stimulation fluid will be delivered to the less mechanical limitation hence stimulate more in that particular zones.

Additional damage from work over services may induce different resistances to flow on each layer of reservoir. Different permeability would expose different severity of damage it may take. Normally, the higher the permeability the more severe damage it would be. The damages from work over activities mostly is incompatibility issue between fluids, i.e. formation fluid and work over fluids. Improper work over fluid selection would lead to scaling issues, emulsion, and saturation change in the near-wellbore. Scale, emulsion, and saturation change induce the additional resistance to flow for both hydrocarbon and injection fluid. On the stimulation treatment, damaged layer would not be treated first as the nature of the fluid would go to the least resistance path, while damaged layer has more resistance to flow. On the other hand, the stimulation objective is normally restoring the damaged layers or unlocking the potential layers.

Well integrity issues come into the uncertainties from several points. First, the cement integrity behind the casing that normally deteriorates over the time and second, the possible rock wash out behind the cement sheath due to past stimulation treatments. The cement bond deterioration can be detected from the cement bond log and based on this evaluation; bonding improvement could be made before any stimulation treatment. Rock wash-out happens when the stimulation fluid is not injected with the correct injection rate so the fluid makes general face dissolution or ramified wormholes instead of dominant wormholes as different rate has different effect to the wormhole generation. The absence of near wellbore integrity leads to less resistance path on that particular layer and drives all the fluids into it leaving the other ones unstimulated.

To enhance productivity of the wells, the potential for bypass or under performance layers need to be concentrated thru proper candidate evaluation. The latest well condition can be acquired through analysis of petrophysical properties, production profile obtained by production logging, and pressure transient analysis. Understanding of uncertainty based on reservoir characteristic, results of production, uneven depletion, completion, and work over activities will provide significant value in order to optimize the fluid volume and placement point of view.

Fluid selection, placement technique, volume determination, and diverter design would be tailored based on the understanding of available uncertainties risk and restimulation treatment objectives. Studies in this work show that severe uncertainties in the restimulation treatment candidate may lead to a requirement of more robust diversion system to have optimum fluid coverage.

Restimulation design and treatment workflow for mature well conditions are based on the experience in the Middle East region. A substantial enhancement has been demonstrated for proper stimulation design.