

Application of Pulsed Neutron Technology for Hydraulic Stimulation Effectiveness Assessment

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Abstract

Hydraulic fracturing is a necessary procedure for the stimulation of formations which lack of the ability to naturally flow hydrocarbons. During most fracturing treatments proppant is pumped in a slurry with the injection fluid using modeled rates and pressures to stimulate occurrence of fractures. Once injection is stopped, fluid pressure decreases, and injected proppant helps keep induced fractures open enabling flow of hydrocarbons. Determining the efficiency of this procedure is an industry challenge from both a technology and a methodology point of view. The determination must evaluate pre-existing formation conditions in the near and far field away from the wellbore as well evaluate how formations will respond to the treatment. In this paper we will present field example of formation evaluation before and after fracturing treatment applied in addition to evaluating treatment efficiency using logging technologies. The subject well has open and cased hole log data. Zones of interest were perforated and produced before the well was plugged for further evaluation of by-passed intervals and re-stimulation of the existing fracked intervals. Two logging technologies - acoustic and pulsed neutron - were deployed in the cased hole environment before and after the second stimulation treatment. The pre-stimulation acoustic logs through were analyzed for evaluation of geomechanical properties of potential by-passed intervals as well as faced intervals during first stimulation processes for potential understanding of stimulated region orientation, shape and characteristics. During the second stimulation treatment, a gadolinium tracer was added and sintered uniformly into every proppant grain. Pulsed Neutron technology was deployed before the second frac treatment in order to benchmark formation responses, where post frac logging was performed to detect the location of proppant enriched with the gadolinium tracer. The high neutron capture cross section of gadolinium produces characteristic gamma rays in sufficient quantities to be detected by the pulsed neutron logging tool. On the other hand, silica grains as the major proppant material, have very low capture cross-section but undergo inelastic and capture interaction with neutrons. In addition, silica experiences activation interactions with neutrons that are also detectable by the Pulsed Neutron tool. By analyzing the results of interactions with gadolinium, inelastic, capture and activated silica, pre-and-post second fracturing treatment, efficiency of the stimulation was analyzed for each of the tool's detectors along the tool and having progressively deeper depths of investigation. The integrated workflow also includes sensitivity improvements on capturing neutron interactions with gadolinium. Sensitivity improved by a factor of 2 to 3 when compared to standard sensitivity described traditionally.