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Measurement of Gel Cleanup in a Propped Fracture with Dynamic Fracture Conductivity Experiments

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Abstract

The effect of residual fracture fluid gels on the conductivity of propped fractures has commonly been measured in the laboratory with a static fracture conductivity procedure in which a certain amount of proppant is placed in a fracture conductivity cell, and then fracture fluid is injected into the cell. This test does not capture all of the physics of the process of proppant placement and fracture closure as it occurs in an actual fracturing treatment. In particular, the interactions among the transport of fracture fluid down the fracture and leakoff into the formation can result in a completely different distribution of residual polymer in the proppant pack in the real fracturing process compared with the static conductivity test.

To more closely simulate actual fracturing conditions, we have developed a dynamic fracture conductivity procedure. In these experiments, fracture fluid/proppant slurry is injected into a fracture conductivity cell at injection rates representative of conditions in an actual fracture. Leakoff conditions are also set to mimic actual field rates. To be able to control leakoff at realistic rates, we use 3-inch thick core samples in the conductivity cell, rather than the 1/4 to 1/2 inch thick samples used in a standard API conductivity cell. After flowing the fracturing fluid slurry for some length of time, the cell is shut in, the fracture is closed by applying stress with a load frame, and then gas is flowed through the cell to represent the flowback period. During the gas flowback period, we repeatedly measure fracture conductivity to determine the amount of gel cleanup occurring.

We have conducted a series of dynamic fracture conductivity experiments using a crosslinked guar-based fracture fluid at 150 ºF. One of the most significant findings is that the fracture conductivity measured with the same proppant loading using the static conductivity procedure is about twice as high as that obtained with a dynamic test. We also show how gel cleanup depends strongly on the gas flux through the fracture, on the presence of breaker, and on the polymer loading.

Introduction

The goal of hydraulic fracturing is to create a long, highly conductive flow path from the wellbore which extends deep into the formation. For low permeability reservoirs, gel damage is one of the factors that have a large effect on the effectiveness of a fracture treatment. Gel residue in the fractures result from unbroken polymer. This residue can cause permeability impairment in the proppant pack yielding low fracture conductivity and short effective fracture length.

Effective fracture length is the part of a propped fracture that cleans up and contributes to gas production. Lee and Holditch (1981) presented an analysis of effective fracture length from hydraulically-fractured, low permeability reservoirs. The results indicated that effective fracture length averaged only 5 % to 11 % of the designed length. This calculation was based on achieving pseudo-radial flow. Peles et al. (2002) concluded that effective fracture length is often less than 10% of the total propped fracture length.

Fracture conductivity has been under investigation since the inception of hydraulic fracturing. The effect of gelling agents and fluid loss on the fracture conductivity was first studied systematically by Cooke (1975). Cooke developed a conductivity cell with sandstone wafers used for the walls of the fracture. Proppant slurry was pumped into the cell, and then the fracture was closed on the proppant. There was no cleanup phase simulated in these pioneering experiments. The experiment was conducted with polymer concentrations which varied from 50 to 480 lb/1,000 gal to simulate the high concentration of the polymer in the fracture because of the loss of filtrate through leakoff into the fracture walls.

Much and Penny (1987), Penny (1987), and McDaniel and Parker (1988) conducted complex experiments to simulate field fracturing conditions. They built an experimental apparatus that permits job-like fluid mixing, tubing shear history, formation shear, heat up, dynamic fluid leakoff through formation core, and the placement of proppant. Fracture conductivity and permeability were measured after the cleanup process. They studied the effects of crosslinked fracturing fluid and fluid