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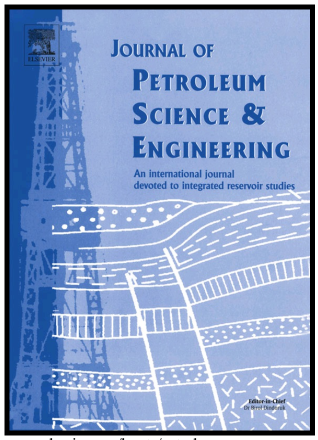

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The Plugging Performance of Preformed Particle Gel to Water Flow through Large Opening Void Space Conduits

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Abstract

Preformed particle gels (PPGs) is a diverting agent that is used to solve the conformance problem in low permeability rich oil zones. They are injected to reduce thief zone permeability and then divert displacing fluid into poorly swept zones. However, PPG propagation and plugging mechanisms through heterogeneous void space conduits (VSC) still remain unpredictable and sporadic. This study examined the effect of gel strength and conduit heterogeneity on PPG plugging performance to water flow. Tubes with different internal diameters were used to emulate different sizes of VSCs. Two conduit models were designed, including (1) a uniform conduit diameter model and (2) a non-uniform conduit diameter model. Gel particles decreased uniformly the permeability across the conduit, and their plugging performance to water flow decreased when gel strength decreased. Gel particle injection pressure increased substantially when the conduit became heterogeneous. Some gel particles accumulated at the choke point and some passed through. This passing mechanism caused a significant rise in PPG resistance to water flow. In contrast to the uniform conduit diameter experiment results, gel plugging performance to water flow improved when the gel strength within conduit reduced. The increase in plugging performance was caused by conduit diameter heterogeneity and increasing gel particle sizes. This paper demonstrates important impact elements of gel propagation and water flow for different opening conduit situations.

Keywords

Preformed particle gels, void space conduits, plugging performance to water flow, conformance control.

Introduction

Void space conduits, fractures, and fracture-like features contribute significantly to low oil sweep efficiency and excess water production. They can expedite undesirable water channeling and early water breakthrough during water flooding. Gel treatments have been successfully used to reduce the fluid flow in these large open features. Understanding the gel injection mechanism and plugging performance are the primary keys to achieving successful conformance control treatment.

Reducing the water flow in fractures or super-permeability channels using in-situ gel materials has been previously studied by many researchers (Seright, 1995, 1997, 1998, 1999, and 2001; Sydansk, 1990; Liu and Seright 2000; Ganguly et al. 2001; Sydansk et al. 2005; Wang and Seright 2006; Wilton and Asghari 2007; McCool et al. 2009). All of these previous studies used bulk or in-situ gel in their experimental work rather than preformed gels. Preformed particle gels (PPGs) have recently been developed and applied to improve the sweep efficiency of water flooding. PPGs are a specific kind of superabsorbent polymer. Their size can be controlled in nanometer, micrometer, and also millimeter ranges. PPGs were developed to overcome some drawbacks inherent in an in-situ gelation system such as lack of gelation time control, gelling uncertainty due to shear degradation, chromatographic fractionation, or dilution by formation water (Chauveteau et al. 2001; Bai et al. 2007a, 2007b).

To better understand PPG injection and plugging performance, researchers have carried out many studies to clarify its propagation mechanisms. Bai et al. (2007b) investigated PPG transporting mechanisms through porous media. They observed that PPGs could still flow through porous media even when PPG sizes were larger than the pore throat size. Zhang and Bai (2011) investigated PPG extrusion through fractures. They studied PPG injectivity and plugging efficiency when the fracture width was less than the gel particle size. They observed that PPGs propagated like a piston when the PPG size was larger than or close to the fracture width. Imqam et al. (2015a) investigated PPG injection and placement mechanisms through conduits under conditions where the conduit opening size was larger than, equal to, or smaller than the swollen PPG size. Their results indicated that PPG strength affected injectivity more significantly than did the ratio of particles to conduit diameters. However, previous recent research pertaining to PPG injection assumed that the conduit's geometry is uniform and did not consider their heterogeneity