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Evaluation of sodium silicate/urea gels used for water shut-off treatments

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Abstract

A sodium silicate gelling system with an internal activator, urea, was extensively evaluated in the lab with bulk gelation experiments, compatibility tests, and coreflood testing using reservoir core plugs (calcite). The gelation mechanism and kinetics of this silicate/urea system were investigated in detail.

Urea solutions hydrolyze at high temperatures, and the products initiate gelation. The rate of gelation depends on temperature, sodium silicate concentration, urea concentration, and salt concentration. Bulk gelation experiments indicated that the gelation time decreased with increasing urea concentration. However, the relationship between the gelation time and sodium silicate concentration exhibited a minimum at approximately 7 wt.% sodium silicate when the urea concentration was 3.6 wt.%.

Gel compatibility with formation brine was examined. The results showed that sodium silicate/urea solutions tolerated sodium chloride up to 3 wt.%, while calcium chloride was tolerated at concentrations up to nearly 0.08 wt.%. These two salts reduced the gelation time of silicate/urea solutions.

Arrhenius-type plots showed that the activation energy of the gelation of silicate/urea was 120.5 kJ/mol at 9 wt.% sodium silicate, with no significant effect of urea concentration. As sodium silicate concentration was increased at urea concentration of 3.6 wt.%, the activation energy increased slightly. These results were compared with literature results for colloidal silica and polyacrylamide/Cr(III) gelling systems. The sodium silicate/urea system has the highest activation energy, meaning that at a given temperature it will have the longest gelation time.

Coreflood results showed that the gel reduced core permeability by at least three orders of magnitude, and that the gel was stable in the core at pressure gradients up to 56.6 MPa/m.

Keywords: Sodium silicate gel; Water shut-off; Conformance control; Urea

1. Introduction

Excessive water production causes major economic loss due to decreased oil production, and increased

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