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Simulation of Hydraulic Fracturing Fluid Cleanup for Partially Degraded Fracturing Fluids in Unconventional Gas Reservoirs

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Abstract : A stable, fast and robust three-phase, 2D IMPES simulator has been developed for assessing the influence of; breaker concentration on yield stress of filter cake and broken gel viscosity, varying polymer concentration/yield stress along the fracture face, fracture conductivity, fracture length, capillary pressure changes and formation damage on fracturing fluid cleanup in tight gas reservoirs. This model has been validated as against field data reported in the literature for the same reservoir. A 2-D, two-phase (gas/water) fracture propagation model is used to model our invasion zone and create the initial conditions for our clean-up model by distributing 200 bbls of water around the fracture. A 2-D, three-phase IMPES simulator, incorporating a yield-power-law-rheology has been developed in MATLAB to characterize fluid flow through a hydraulically fractured grid. The variation in polymer concentration along the fracture is computed from a material balance equation relating the initial polymer concentration to total volume of injected fluid and fracture volume. All governing equations and the methods employed have been adequately reported to permit easy replication of results. The effect of increasing capillary pressure in the formation simulated in this study resulted in a 10.4% decrease in cumulative production after 100 days of fluid recovery. Increasing the breaker concentration from 5-15 gal/Mgal on the yield stress and fluid viscosity of a 200 lb/Mgal guar fluid resulted in a 10.83% increase in cumulative gas production. For tight gas formations (k=0.05 md), fluid recovery increases with increasing shut-in time, increasing fracture conductivity and fracture length, irrespective of the yield stress of the fracturing fluid. Mechanical induced formation damage combined with hydraulic damage tends to be the most significant. Several correlations have been developed relating pressure distribution and polymer concentration to distance along the fracture face and average polymer concentration variation with injection time. The gradient in yield stress distribution along the fracture face becomes steeper with increasing polymer concentration. The rate at which the yield stress (τ_o) is increasing is found to be proportional to the square of the volume of fluid lost to the formation. Finally, an improvement on previous results was achieved through simulating yield stress variation along the fracture face rather than assuming constant values because fluid loss to the formation and the polymer concentration distribution along the fracture face decreases as we move away from the injection well. The novelty of this three-phase flow model lies in its ability to (i) Simulate yield stress variation with fluid loss volume along the fracture face for different initial guar concentrations. (ii) Simulate increasing breaker activity on yield stress and broken gel viscosity and the effect of (i) and (ii) on cumulative gas production within reasonable computational time.

Keywords : formation damage, hydraulic fracturing, polymer cleanup, multiphase flow numerical simulation
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