Modeling on Matrix and Fracture Permeability Alteration by Fluids Imbibition and Its Impacts on Post-frac Well Performance

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ABSTRACT

Multi-stage hydraulic fracturing has been one of the key techniques for commercial development of shale formations. Tremendous amount of fracturing fluids are injected during the treatment with only a small fraction recovered by flowback. The retained water is believed to interact with formation rocks during the imbibition process. New observations from laboratory measurements showed different impacts of water imbibition on permeability in matrix and fracture media. Thus, it is critical to understand how the dynamic fracturing fluids distribution and near- fracture-face permeability alteration affect the performance of hydraulic fractured wells. A series of alternating spontaneous imbibition tests and permeability measurements were performed on shale samples from three different formations to establish a relationship between imbibed fluid volume and permeabilities of matrix and fracture media. In this work, a numerical simulation model was constructed to properly capture the laboratory results through specially designed relative permeability curves and investigate the effects of permeability change caused by fracturing fluid imbibition on well productivity. Matrix media follow the relative permeability curves during the imbibition process driven by capillary and hydraulic forces. The fracture network created during the fracturing treatment may experience both relative permeability and stress-dependent permeability effects. However, some of the sealed fractures can be reactivated by imbibition through physical or chemical interactions between water and fracture filling materials after the treatment. The simulation results showed that most of the near- fracture-face imbibition occurs within the first day and that different porous media behave differently. The shale matrix exhibited significant permeability reduction within a short period and the damage due to imbibition can lead to water blockage problems. Hydraulic fracture induced fracture network is also adversely affected by the fluid imbibition but much less significantly. While sealed natural fractures untapped by fracturing treatment demonstrate opposite tendency through reopening by imbibition, which may coincide with the follow-up micro-seismicity recorded after treatment. It is found that natural fracturing spacing, fracturing design and shut-in time have significantly impacts on well productivity behaviors through imbibition. Natural fracture spacing determines the deliverability of fracture media. Larger fracture network increases the volume of imbibed water. Extended shut-in may be favorable for productivity depending on matrix capillarity and cementation of fracture filling materials. Understanding imbibition effects on water saturation changes and permeability alterations provides significant insight to shale formation damage and reservoir management. Detailed fracture characterization, proper fracture design and managed shut-in can contribute to optimum post-frac well performance.