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Gas Condensate Relative Permeabilities in Propped Fracture Porous Media: Coupling Versus Inertia

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Abstract

Hydraulic fracturing is one of the most common well stimulation techniques for gas-condensate reservoirs. In recent years considerable effort has been directed towards understanding of flow around hydraulically fractured wells especially for tight gas reservoirs. However, there has been no report of a study of flow behaviour within propped fractured porous media for these low interfacial tension (IFT) systems.

It is now a well established finding both experimentally and theoretically that the flow of gas-condensate fluid systems in porous media is affected by both coupling (the increase of relative permeability (k_r) as velocity increases and/or IFT decreases) and inertial (i.e., the reduction of k_r as velocity increases) effects. However, the interaction of capillary, viscous and inertial forces within highly conductive propped fractures is yet unknown.

In this work, we report a series of steady state gas-condensate relative permeability values for a proppant filled and a sand packed fracture with permeability of 146 D and 15 D, respectively. These sets of k_r data, which have been measured using our unique experimental facilities, covers IFT and velocity values ranging between 0.85 and 0.15 mNm⁻¹ and 250 to 3000 md⁻¹, respectively.

The results indicate that inertia is quite dominant at all the tested conditions albeit to a greater extent at lower IFT and higher gas fractional flow rates. In the case of the fracture with the higher permeability, some k_r values measured at the higher IFT are also reported, which are higher than the corresponding values at a lower IFT. We also compare the results with the corresponding predicted k_r values by the generalized k_r correlation, which we reported recently and expresses the combined effect of coupling and inertia with universal parameters. The unique contribution of inertial forces, as observed in the experiments and predicted by the correlation, is mainly attributed to the impact of the fracture properties and the fluid flowing in the fractures.

Introduction

Gas condensate flow around hydraulically fractured wells (HFWs) in gas condensate reservoirs has been the subject of investigation for a long time [e.g., Carlson (1995), Settari (1996)]. This subject has received renewed attention with the significance growth in the need for production from tight gas reservoir using this technique [e.g., Wang et al. (2000), Rostami et al. (2007)]. These studies mainly focused on the flow mechanisms that affect fracture performance by considering a reduced permeability region due to condensate banking in the matrix around the fracture only. The negative impact of inertial flow within the propped fracture porous media based on the single-phase flow of gas has also been widely studied [e.g., Guppy et al. (1982), J.L. Gidely (1991), and Settari et al. (2002)]. The main shortcoming of these studies is not correctly accounting for the variation of gas condensate relative permeability with velocity and interfacial tension in the matrix. They also ignore the two phase flow effects inside the fracture.

Gas effective permeability at high velocities decreases due to inertial flow, Non-Darcy flow or Forchimer flow (Forchimer, 1914). A reduction in interfacial tension (IFT) improves relative permeability of low IFT fluid systems (Bardon and Longeron, 1980). The improvement of relative permeability of condensing systems due to an increase in velocity is also a relatively well established experimental finding (Danesh et al., 1994, Henderson et al. 1996). The improvement in relative permeability of such low IFT systems as velocity increases and/or IFT decreases, known as the coupling effect, has been attributed to the simultaneous coupled flow of the gas and condensate phases with intermittent opening and closure of gas passage by the condensate at the pore level (Jamiolahmady et al. 2000, 2003). Experimentally measured k_r data