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Horizontal well fracture interference – Semi-analytical modeling and rate prediction

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ABSTRACT

A semi-analytical superposition model for analyzing pressure and rate data from wells where production characteristics were altered because of interference from nearby fracture operations is presented. In previous work (Thompson (2017)), specialized numerical simulations showed that these production changes could be explained by changes to the total fracture half-length and fracture permeability; in turn, these parameters alter the completion's linear flow parameter, $\sqrt{k}A$, (which we loosely refer to here as the well's linear "flow capacity") and "skin" pseudopressure drop (i.e., steady-state unit rate pseudopressure drop between the matrix and the wellbore). Superposition equations that govern fracture interference events under the assumption of linear flow to the fracture system are presented. The model is semi-analytical since no account is taken of variable gas compressibility effects in the superposition equation. Application of the technique allows quantification of interference-induced changes to both flow capacity, ($\sqrt{k}A$) and skin pressure drop. By inverting the model, a method of predicting the well's production performance post-interference, given the changes to flow capacity and skin and a bottom-hole pressure production schedule, is developed. The predicted rate schedule is valid as long as the well remains in linear flow. The validity of the model is illustrated by applying it both to synthetic and a field production data. Based on the synthetic data, it is demonstrated that the superposition model can accurately describe changes to flow capacity and skin, and that the obtained model parameters can be used to reproduce the model rates given imposed bottom hole pressures. The method is applied to a field example where an interference event occurred, and demonstrates very good agreement between model predicted rates and observed field data.

1. Introduction

With increased density development drilling of vertically fractured horizontal wells in the Woodford shale, interference from infill well fracture operations has often resulted in significant decreases in preexisting parent well productivity.; see, for example Ajani and Kelkar (2012), Kurtoglu and Salman (2015). A multitude of papers have focused on trying to understand and quantify the effects of fracture interference in shale plays; Yu et al. (2016) provided an excellent review on the literature available up to 2016. They noted that "the impact of spatial changes in fracture conductivity, number of connecting fractures, and complex fracture geometry on the pressure response of well interference have not been systematically modeled in previous studies". They presented a semi-analytical segmented fracture model for simulating fracture "hits" and showed good agreement between their model and a numerical simulator. Tang et al. (2017) presented a 3D coupled compositional reservoir simulator and multi-segment wellbore model to simulate the performance of parent and infill wells under the impact of fracture interference. They showed that fracture interference could result in increases or decreases in the impacted parent well's productivity. A productivity increase results from an infill well whose completions enlarge the stimulated reservoir volume (SRV) of the parent well, whereas a productivity decrease results from the infill well sharing some of the parent well's SRV.

Fig. 1 shows a typical Woodford parent well production response as a result of fracture interference; in this shale play, the typical effect of fracture interference is to significantly and permanently reduce parent well productivity and economic value. For wells exhibiting this behavior, the common rate transient analysis tools, i.e., linear superposition time or square root of material balance time analysis (Moghadam and Mattar (2011), Agina et al. (2012)), are difficult if not impossible to interpret. Fig. 2 shows the specialized linear superposition time (LST) plot for the gas rate data for the well in Fig. 1; before the interference event, the LST plot shows typical linear behavior with the slope approximately indicative of the well's flow capacity, ($\sqrt{k}A$) and the intercept reflecting pressure losses in the reservoir matrix to well fracture conduit. After the

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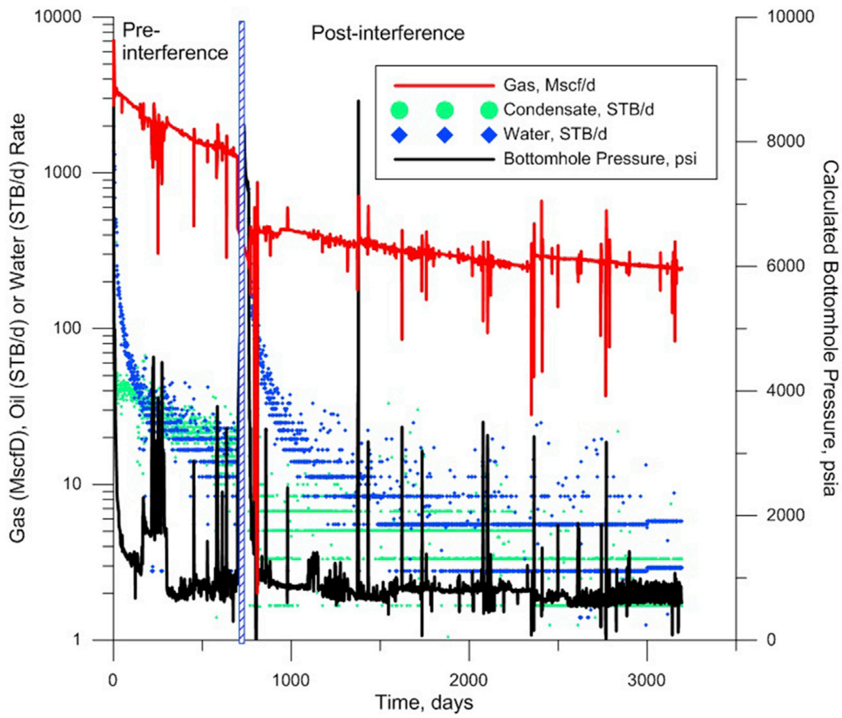

Fig. 1. Gas rate versus time pre- and post-interference.

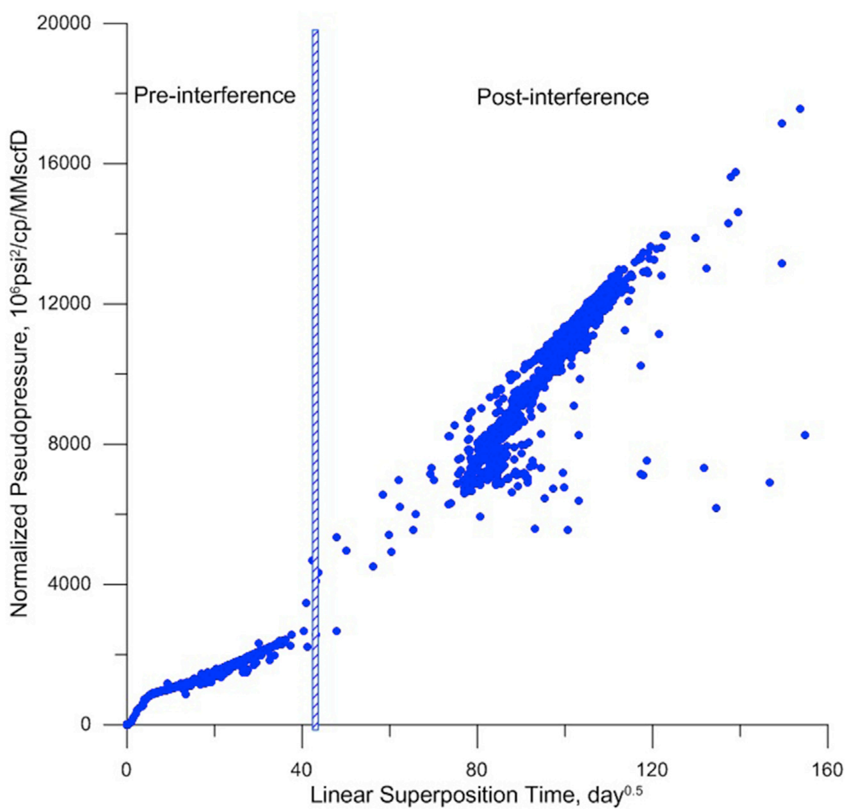

Fig. 2. Interference Linear Superposition Time plot.

interference event, the slope appears to have steepened considerably, and the intercept appears to be negative. While a steeper slope makes intuitive sense, (i.e., decreasing flow capacity after interference), the negative intercept, which would normally be associated with an increase in fracture network conductivity) is difficult to explain physically. In Thompson (2017), we showed that likely effects of fracture interference were a combination of reduction in productive fracture half-length and reduction in fracture conductivity. In the following section, we develop a semi-analytical model, based on the principle of superposition, (Lee et al. (2003)), which quantifies the changes in the well's flow capacity and skin