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Stress behavior in the near fracture region between adjacent horizontal wells during multistage fracturing using a coupled stress-displacement to hydraulic diffusivity model

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ABSTRACT

This work presents results for the application of finite element simulation to determine changes in stress orientation and magnitude during a multistage fracturing job in horizontal wellbores. A technique that couples stress-displacement with hydraulic diffusivity was used to account for effective in-situ stress and to estimate pore pressure distribution in the near fracture region. The results captured in this study aid understanding of propagation of induced fractures in a multistage fracturing job and in a multiple horizontal wellbore scenario. This study is a valid and reliable estimation of effective stresses in the near fracture area because effective stresses control strain in a saturated poroelastic material. Additionally, reorientation of in-situ stress in the same near region to the fracture was confirmed. The local reorientation of in-situ stresses will consequently cause the reorientation of subsequent fractures which will stop growing transverse to the horizontal wellbore. As a result, induced fractures do not propagate as expected, creating a non-efficient drainage pattern in the reservoir.

1. Introduction

Two of the most relevant technologies that have made successful the developing of unconventional shales in the last decade are horizontal drilling and hydraulic fracturing. Unconventional shales have been identified as very low permeability reservoirs. Because of this condition, it is broadly accepted that spacing between horizontal wells and between hydraulic fractures must be controlled. Previous research done regarding spacing between fractures indicates that to achieve production at commercial rates, it is necessary to minimize the spacing. Yu and Sepehrnoori (2013) elaborated on the study of optimization of multiple hydraulically fractured horizontal wells in unconventional gas reservoirs. They concluded that, "The economic success of shale gas reservoirs depends on optimization of the number of treatment stages and number of fractures and horizontal wells." Jacobs (2014) discussed briefly the evolution of hydraulic fracturing jobs in shales, highlighting zipper fracture as a methodology to improve production compared with other hydraulic fracturing methods in a multi-well completion scenario. Jacobs remarks that relatively tight spacing between horizontal wells and configuration of the fracture stages on the horizontal sections are the main aspects to have success when applying novel fracturing techniques. The success of these completions techniques is partially explained by the stress shadow effect occurring when hydraulically fractures are closely spaced and developed in a short period of time. Several authors, Roussel and Sharma (2011), Taghichian et al. (2014), and Zangeneh et al. (2015) among them, have studied about the so-called stress shadow region. Roussel and Sharma (2011) included a review of publications related to this subject. They elaborated on stress perturbation created in the region between fractures and stated that Soliman et al. (2008) and Cheng (2009) discussed this issue and corroborated it by using micro seismic technology. Fisher et al. (2004) and Mayerhofer et al. (2006) documented these findings. Recently, Qiu et al. (2015) presented a quick and valuable review of work done in the subject of simulation of fracturing completion techniques. Also, Nagel et al. (2013) presented an interesting study showing the results of numerical evaluation of the effect of multiple fractures on stress shadow as function of several reservoir conditions, including the presence of natural fractures. The relevance of the work presented in this new study rests on the premise that hydraulic diffusivity is coupled with a traditional stress-displacement analysis to attempt a better simulation of the multi-physics events occurring during a hydraulic fracturing job.

Various types of completion methods have been implemented in the field regarding wellbore and fracture spacing. Among the completion methods are conventional sequential fracturing (CSF), zipper fracturing (ZF), and modified zipper fracturing (MZF). Jacobs (2014) provides an excellent review of these methods, emphasizing the challenges they

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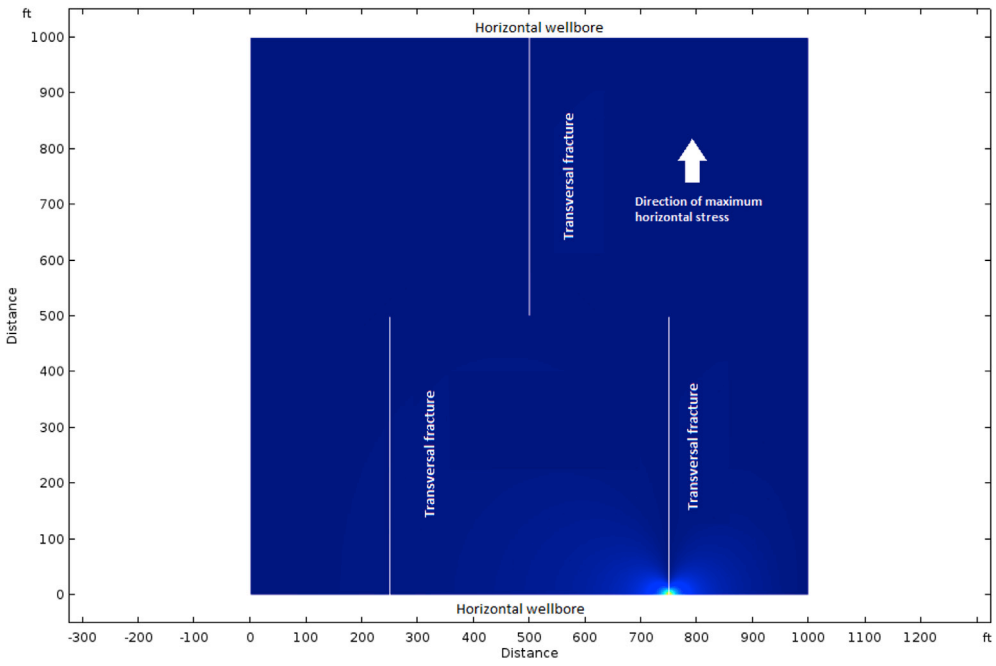

Fig. 1. This figure represents the 'top view' of the general model used in this study.

Table 1
Input data used in simulations to run the base case.

Input Parameters	Value	units
Young's modulus, E	2.5E6	Psi
Poisson's ratio, υ	0.208	Dimensionless
Total overburden, σ_V	6 000	Psi
Biot's coefficient, α	0.7	Dimensionless
σ horizontal min, σ_{Hmin}	3 000	psi
σ horizontal max, σ_{Hmax}	3 200	psi
Pore pressure, *Po*	2 800	psi
Permeability, *k*	1E-15	m2
Porosity, θ	0.07	Dimensionless
Total injection rate, q_i	35	Bl/min
Density of fluid injected, ρ_f	1 000	Kg/m3
Viscosity, μ	100	cP

represent. Among other authors, Yu and Sepehrnoori (2013) and Qiu et al. (2015) provided insight about wellbore and fracture spacing for completion of multiple horizontal wells and multistage fracturing scenarios. Qui et al. analyzed cluster spacing, varying it from 60 to 100 feet and wellbore spacing from 300 to 800 feet. In the same way, Qui et al. and Jacobs explained that the significant difference between all these completion techniques is the elapsed time between the executions of two consecutive fractures.

2. Model

Stress-displacement analysis coupled with hydraulic diffusivity occurring in the saturated porous medium was implemented to analyze

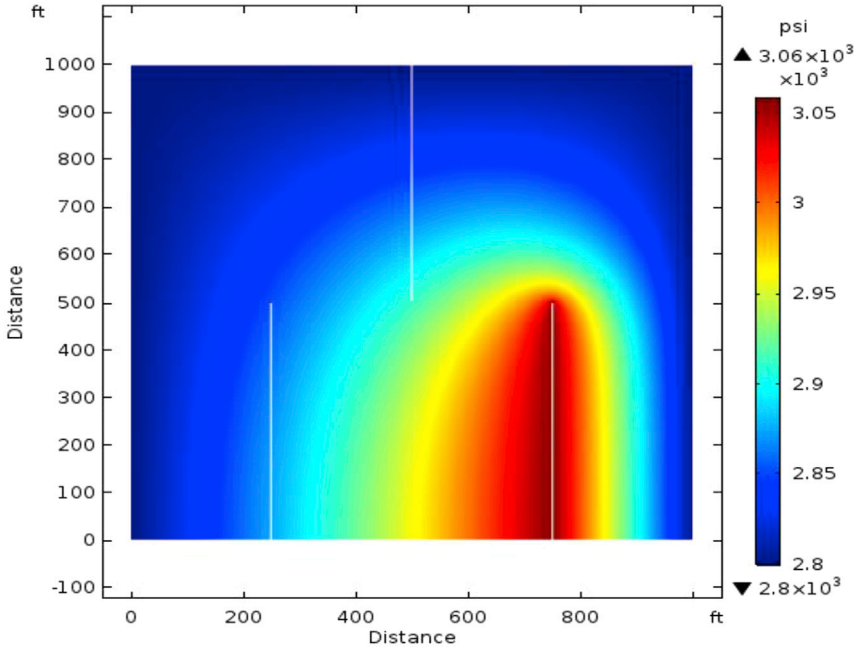

Fig. 2. Contour plot showing changes in formation pore pressure due to hydraulic diffusion process.