Using surface drilling data for a geologically and geomechanically constrained 3D planar frac simulator and fast reservoir simulation – application to engineered completions and well interference prevention

A. Ouenes[1,2], D. Elmadhun[1], S. Soza[1], X. Li[1], R. Smaoui[1] present a practical application of surface drilling data to estimate key reservoir properties along wellbores and distribute them in 3D so they can be used in 3D planar frac and fluid flow simulators for well interference management and estimation of NPV.

Introduction

Modelling unconventional reservoirs requires increasingly complex physics to describe the phenomena that affect the performance and efficiency of horizontal wells. For example, poroelastic geomechanical simulation (Ouenes et al., 2017b) is needed to model frac hits and well interferences resulting from the presence of stress and pressure dependent natural fractures and other geologic factors that see their permeability increase during stimulation. Recent field observations related to stress relaxation required the introduction of viscoelasticity (Peterson et al., 2018) to better understand the effect of timing during fracing. Lastly, the importance of interfaces and their impact on fracture height growth required the introduction of 3D damage mechanics (Aimene et al., 2018) to model the propagation of hydraulic fractures in a more realistic rock volume that considers the layering of the various lithologies and the resulting weak interfaces that will in turn interact with hydraulic fractures. This increasing complexity in physics is also combined with the need to provide solutions very quickly, if not in real time

As the physics of unconventional reservoirs becomes more complex, the data available at each well to correctly model that physics is dwindling at an alarming rate. The introduction of the continuum multiscale approach (Ouenes et al., 2017b) and the use of surface drilling data provide the unique opportunity to address both the lack of data and the increasingly complex physics. In the absence of wireline logs and seismic data, surface drilling data collected at each well is used at different scales ranging from wellbore to reservoir scale. In this process called 'Inverse Design and Validation', the information contained in the surface drilling data is used 1) during the drilling to optimize the landing zone and geosteering, 2) during the design of the completion to geoengineer the stages to account for the variability of the rock, and 3) to build 3D models that will allow the correct estimation of petrophysical, geomechanical properties and stresses needed in 3D planar frac simulators as well as fluid flow simulation. These various applications are examined in the next sections.

Surface drilling data and its applications in the unconventional well cycle

When using a rigorous workflow that combines multiple disciplines, the information contained in the surface drilling data is extracted and used in multiple stages of an unconventional well's life cycle. During drilling and immediately afterwards, Ouenes et al. (2017a) and Jacques et al. (2017) have shown the benefits of deriving, in real time, geomechanical logs, pore pressure, stresses and natural fractures and propagating them in 3D for geosteering and planning ahead of the drill bit. The 3D models derived from the drilling-derived logs allow the driller to remain in a tight drilling window which will ultimately affect the performance of the stimulation and the resulting production. Paryani et al. (2018a, 2018b) have shown how the drilling-derived logs are used to geoengineer completions and to provide the necessary 3D input to modern frac simulators. In this case study we will illustrate the entire 'Inverse Design and Validation Process' where multiple wells with only surface drilling data are used as a basis for an entire 3D modeling effort designed to better understand the interference between two wells. The unique workflow described in the next sections illustrates how surface drilling data is transformed to provide the necessary input required by fast physics-based simulation tools to address complex problems. A pad with two wells in a major North American gas basin is used to illustrate these concepts.

Critical logs in every unconventional well - extracting value from surface drilling data

The Mechanical Specific Energy (MSE) computed from commonly available surface drilling data such as torque (T), rate of penetration (ROP) and weight on bit (WOB) has been widely

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from the FMM simulator (Figure 9B) shows the same features as those seen in the pressure depletion estimated in the classical reservoir simulator (Figure 9A). The same conclusions can be seen when examining the pressure distribution in a cross-section view as shown in Figure 10. There is a major difference between the two runs: the one using the compositional classical reservoir simulator takes six hours on a workstation owing to the large number of components while the FMM simulator results were derived in less than one minute. With such a rapid evaluation tool and robust workflow that leverages the multiple constraints derived from the use of surface drilling data, the complex balance between finding the optimal NPV per well or per section could be easily estimated in a few days. Using the current industry tools to achieve the same objective will take many months and will have a large uncertainty if no well logs or seismic are available as was the case in this study.

Conclusions

The use of surface drilling data provides valuable information along each wellbore. This information includes an estimation of geomechanical logs, pore pressure, stresses, porosity and natural fracture. These rock properties could be used as a first approximation to geoengineer completions. However, combining these various logs from different wells into 3D reservoir models provides more opportunities including using them in reservoir geomechanics, grid based 3D planar frac design and reservoir simulation. When using all these 3D models and their results in a Fast Marching Method simulator the impact of the interference between two wells could be estimated quickly while providing similar results as those derived with a classical reservoir simulator. By combining all these tools into a single software platform, this fast and constrained approach allows for the mitigation or management of well interference and the correct estimation of the NPV for each development scenario.

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