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## **Multilaterals Drilling and Sustainable Openhole Production from Theory to Field Case Studies**

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### **Abstract**

Drilling and production optimization are two interconnected operations for successful well construction and reservoir management, in particular for extended reach of multilateral wells. Formation damage, especially permeability reduction induced during drilling, greatly affect well completion and future potential reserve production. Reservoir pressure depletion and the consequent increase in effective stresses around the well branches are the main reasons behind solid production or total wellbore collapse. Unfortunately, to date, analytical study for the stability of multilaterals has been very limited due to the complex geometry and stress state involved. This work entails a recently derived analytical solution to estimate the safe mudweight window for wellbore stability during drilling, as well as to predict the maximum pressure drawdown for a stable junction during production. The presented solution is capable of handling the complexity of 3D anisotropic state of stress as well as any mother and lateral size, inclination, and azimuth. The study shows that the design of multilateral junction, especially inclination and azimuth of both wellbores with respect to regional in-situ stresses play a crucial role in the multilateral junction stability and the critical pressure drawdown estimation to prevent solid production and wellbore collapse. A field case study of a multilateral well drilled in the Khuff-C formation, Ghawar field, Saudi Arabia, is analyzed herein with drilling data, core-retrieved rock properties, and pressure drawdown and production estimates. The results showed alternate optimized completions that could have been applied early in the drilling and branching of the laterals. Practical guidelines concerning branching optimization have been established for junction planning and execution. The new analytical modeling has also been calibrated with a published peer-reviewed large-scale experimental program simulating both the anisotropy of far-field stresses and complex junction geometry with exceptional qualitative and quantitative results.

### **Introduction**

Multilateral wells offer not only improvement in accessibility and recovery but also reduction in drilling and development costs. Their effectiveness has been confirmed in many oil fields throughout the world. Despite their increasing economic appeal, the mechanical stability of the multilateral junction remains one of the most challenging problems in the industry.

The analytical solution for the stability of multilateral junctions in general non-hydrostatic in-situ stress fields with equal or unequal mother wellbore and lateral size as well as different well trajectories has been presented by the first two authors in previous studies (Hoang et al. 2004, Hoang and Abousleiman 2008). This general solution is more versatile compared to the other existing analytical solution for multilateral junction stability with equal wellbore size and hydrostatic in-situ stresses (Aadnøy and Froitland 1991, Aadnøy and Edland 1999). Experimental simulations, to the best knowledge of the authors, have been only performed by Papanastasiou et al. (2002, 2006). On the other hand, numerical analyses of the stability of multilateral junctions, as well as the stress distribution in and around the junction, have been widely conducted (Fuentes et al. 1999, Bargui and Abousleiman 2000, Manriquez et al. 2008a and 2008b, to name a few).

This paper aims to illustrate that although extremely challenging, drilling stability of multilaterals cannot be viewed as an end in itself. Drilling and production optimization are actually two interconnected operations for successful well production and reservoir management, especially for long extended reach of multilateral wells. Rock formation damage and permeability reduction induced during drilling may greatly affect well completion and future production. Also, reservoir pressure depletion and the increase in effective stresses around the wells are well-known to be the prime culprit behind sanding/solid production and utility damages. This work illustrates these points by reviewing one such case in the Khuff-C reservoir, Ghawar field, Saudi Arabia. The configuration of the mother and lateral wellbores, i.e., borehole sizes and well trajectories,