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Steam Circulation Strategies for SAGD wells after Geomechanical Dilation Start-up

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Abstract

Dilation start-up has been widely used in Petro-China's Xinjiang oil field as a means of reducing start-up time and enhancing production from its "super" heavy oil reservoirs through the Steam-Assisted Gravity Drainage (SAGD) process. SAGD dilation start-up employs geomechanical dilation mechanisms to achieve these preferred results. Using a short-period of small-volume and high-pressure fluid injection, the dilation start-up facilitates the development of a dilated zone that vertically connects the SAGD well pair and is laterally uniform along the length of the well. This zone allows for more effective heat transfer to the inter-well area through convection than what is achieved through simple conduction during the conventional SAGD steam circulation start-up. In Petro-China's Xinjiang oil field, conventional SAGD start-up requires 10 to 12 months of non-productive steam circulation before oil production can begin. Wells treated with the SAGD dilation start-up can be converted to production after only 2 to 3 months of steam circulation.

This paper presents optimized steam circulation strategies which can be used with the dilation start-up treated SAGD well pairs. Numerical simulations are effectively integrated with field trials to derive best practices for steam circulation after the dilation start-up. The objectives are to get earlier and increased SAGD production as well as enhanced horizontal steam conformance. Operating parameters such as steam injection pressure, rate and pressure difference between the SAGD well pair were found to influence these objectives.

Introduction

The SAGD recovery method has become a mainstream thermal production process for heavy oil/oilsands reservoirs. It involves a pair of horizontal wells. The upper well (injector) serves as a conduit for continuous steam injection while the lower one (producer) serves for continuous oil production. This injection-production system requires communication between the wells before it can be used efficiently. Uniform communication is needed for higher production rates and improved steam stimulation efficiency. Conventional start-up processes circulate steam through both upper and lower horizontal wells to achieve the desired communication between the well-pair. The thermal energy imparted during the steam circulation diffuses into the reservoir, including the inter-well area, mainly via thermal conduction. Eventually, the bitumen viscosity between the wells is reduced to the point where it can be produced. Consequently, the communication between the well-pair is established and the SAGD start-up period is completed.

Conventional circulation start-up through thermal conduction has several disadvantages which are particularly significant in low quality reservoirs such as the “super” heavy oil reservoir in the Xinjiang oil field. Thermal transport via conduction is slow compared to thermal convection. As a result, the conventional SAGD start-up period normally lasts for 3 to 6 months in a typical Athabasca oilsands reservoir in Alberta, Canada. It can take up to 12 months in Xinjiang, China where the heavy oil viscosity can be up to one order of magnitude higher and reservoir permeability can be one order lower than their Canadian counterparts. Secondly and perhaps more detrimentally, thermal conduction is subject to further reduction in efficiency where geological in-homogeneities are present. Mudstone stringers, which are less bitumen-saturated and less permeable, can easily hinder the gravity-driven oil to drain down. Thus, non-uniform communication results horizontally along the length of the well. The oilsands reservoir in Xinjiang belongs to the continental deposit type where mudstone stringers are prevalent. Thus, non-uniform start-up along the SAGD well length also poses as a significant challenge. The current practice calls for placing the SAGD wells in the upper cleaner section of the reservoir and drilling shorter horizontal wells, e.g. 400 m long. This practice reduces the stringer’s impact but at a significant loss to exploitable reservoir area.

Geomechanical dilation start-up can overcome the above disadvantages by utilizing a short-period of high-pressure injection which creates a high porosity zone between the well pair. These newly formed micro-cracks serve as a conduit for the initial steam to travel through. Therefore, the more efficient convective thermal heat transport becomes active between the wells allowing for earlier inter-well communication. Another benefit is seen when the dilation start-up modifies the in-situ stress condition between the well pair. This helps counteract the impact of the geological in-homogeneities along the well length by promoting in-situ stress conditions favourable to break through mud stringers both near the SAGD wells and between the SAGD well pair. Hence, uniform dilation and consequently uniform communication along the horizontal well length is achieved.

The research on dilation start-up began in 2002. It was successfully field-tested in 2010 on two SAGD well pairs in the Athabasca oilsands area, Alberta, Canada. Application of the dilation start-up process in Xinjiang began in 2013 and has since been expanded to include all SAGD wells in 2015. The field results have demonstrated a much earlier start to SAGD production and an improved early production rate, which translates to a greatly reduced steam-oil ratio. Annual performance reviews filed by Cenovus Energy Inc. summarized the field performance of the dilation start-up, e.g., Cenovus (2012). A paper by Yuan et al. (2013) also described the earlier field results in Xinjiang.

Delicate fluid injection control is critical to activating the dilation start-up process. The medium used to raise the pore pressure is not particularly relevant and thus, either steam or water can be injected. Steam, solvent and water were used by Cenovus. Produced hot water is injected in the Xinjiang oil field. When water is used, steam circulation is still needed in order to reduce the bitumen viscosity. Therefore, the optimization of the steam circulation after the dilation start-up becomes an important issue. Are conventional steam circulation strategies still preferred or are novel ones, better suited to exploiting the modified in-situ conditions like the newly formed high mobility zone between the SAGD well pair, now available? This paper will address this question by examining the impact of after-dilation steam circulation parameters on production like injection rate, pressure and pressure difference Numerical simulations are effectively integrated with field trials to derive field-pr steam circulation after the dilation start-up.