

Optimization of Toe-up SAGD Well Trajectory Considering Vertical Location and Size of Shale Barrier in Oil Sands Reservoir

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Summary

The performance of steam-assisted gravity drainage (SAGD) is influenced by shale barrier, which impedes steam flow and thermal communication in oil sands reservoir (Kim and Shin, 2020; Kumar and Hassanzadeh, 2021; Shin, 2008; Venegas Prada and Cunha, 2008). Therefore, drilling SAGD well-pair above the shale barrier can be considered to avoid the impact of shale barrier. However, it results in leaving significant bitumen unrecovered below the producer, ultimately reducing recoverable bitumen amount.

This study suggests an optimization method for SAGD well trajectory, considering the vertical location and size of the shale barrier within the oil sands reservoir. Toe-up SAGD, where the toe of horizontal well is partially located above the shale barrier, was designed to avoid shale barrier impact and secure more production zones. Additionally, a preheating operation was designed to deal with thermal communication issues arising from uneven injector/producer (I/P) spacing. Reservoir modeling and simulation were performed with various SAGD well trajectory scenarios based on the characteristics of shale barrier. Lastly, the performance of each scenarios was analyzed in terms of performance indicators.

The optimal SAGD well trajectory was determined based on the maximum net present value (NPV) from the examined scenarios. The results showed that toe-up SAGD can improve the performance with maximum 25% of NPV when the shale barrier had shorter length and lower vertical heights.

Method

A 3-D reservoir model that includes one shale barrier was constructed using a symmetrical approach to reduce computational costs with model complexity. The properties of reservoir and shale barrier were derived from a commercial SAGD project in Athabasca, Canada. The parameters of the shale barrier were defined with lengths of 200, 400, 600 m and heights of 5, 10, 15 m, while the thickness and width were fixed based on literature reviews (Kim and Shin, 2020).

Various reservoir models, representing different characteristics of the shale barrier based on its length and height, were simulated in three well trajectory scenarios: conventional, toe-up parallel, and toe-up producer (Fig. 1). Each scenario reflects how the shale barrier influences the reservoir model with the implemented well trajectories. Toe-up parallel SAGD positions both the injector and producer above the shale barrier with uniform spacing. In contrast, toe-up producer SAGD allows only the toe of the producer to extend above the shale barrier, resulting in uneven I/P spacing.

For the same preheating conditions prior to bitumen production, an optimal preheating strategy was determined only for the toe-up SAGD scenarios. The concepts of steam circulation and cyclic

steam stimulation (CSS) were utilized to address the thermal communication challenges associated with uneven I/P spacing (Coskuner, 2009). The CSS cycle lasted approximately two months, including phases for steam injection, soaking, and production. The number of cycles increased as the shale height increased.

The performance evaluation of the different SAGD scenarios was conducted by analyzing performance indicators such as NPV, steam-to-oil ratio (SOR), cumulative oil production (COP), effective recovery factor (eff_RF), and calendar day oil rate (CDOR). Additionally, performance indicators were measured when the NPV was maximized, with production periods of five and ten years, respectively (Fig. 2).

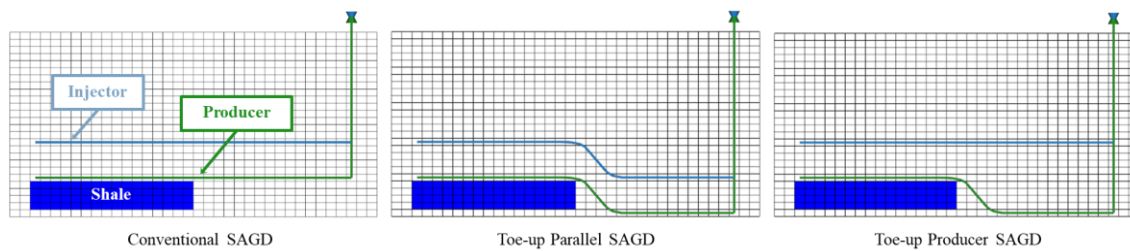


Fig. 1 Three scenarios of SAGD well trajectory considering shale barrier

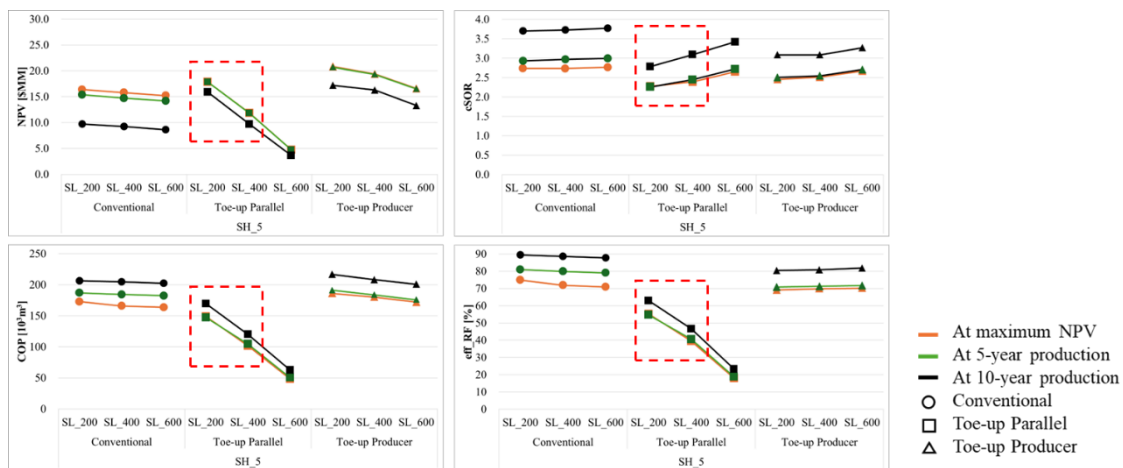


Fig. 2 Comparisons of SAGD scenarios productivity indicators on 5 m shale height

Conclusions

The results demonstrated that optimization with toe-up SAGD significantly enhanced production performance compared to conventional SAGD, especially as the height of the shale barrier decreases to 5 m. All the examined scenarios achieved superior NPVs for shorter shale barriers, resulting in higher performance compared to traditional methods. Economic evaluations reinforced these findings, showing that toe-up SAGD produces favorable economic results, particularly for shorter shale lengths. However, as the dimensions of the shale barrier increased, toe-up SAGD performance began to decline, especially when its height surpassed 10 m. These

findings indicate that the optimal well trajectory for SAGD is influenced by the characteristics of the shale barrier. Moreover, simulation results over ten years showed significant performance differences between toe-up producer and toe-up parallel designs, especially showing the superior NPV of toe-up producer under optimal well trajectory conditions. This indicates that the long-term operation of toe-up producer is more advantageous for SAGD production. This study ultimately demonstrates that aligning targeted drilling strategies with geological conditions has significant potential for maximizing recovery and enhancing the return on investment.

Acknowledgements

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