In Situ Recovery Methods for Heavy Oil and Bitumen

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Introduction

The production of heavy oil and bitumen is becoming increasingly important in Canada. It comprises approximately 60% of current Canadian crude oil production, with volumes of nearly 240,000 m^3/day [1]. Of this amount, slightly more than 140,000 m^3/day is recovered from *in situ* operations, with the remainder coming from surface mining operations [1].

The *in situ* production of heavy oil and bitumen from the enormous resources contained in the Western Canada Sedimentary Basin (WCSB) is expected to accelerate, as a result of the potential of new recovery technologiies developed specifically for these challenging resources [2]. Key examples of these new recovery technologies include: thermal gravity processes; solvent- assisted gravity processes, cold production (primary production involving the aggressive production of sand); and, cyclic solvent stimulation for enhanced recovery following cold production [3].

In Situ Recovery Methods

The most promising thermal recovery technology for Canadian bitumen resources is the steam-assisted gravity drainage (SAGD) process. In this process, two horizontal wells aligned in a vertical plane are drilled near the bottom of the reservoir. The top horizontal well is used to inject steam, while the bottom well is used to collect the produced liquids (oil, condensed steam, formation water). The steam injected from the top well rises into the formation, forming a large steam chamber above the well. The rising steam condenses on the boundary of the chamber, heating the oil and allowing it to drain to the production well. The process leads to high oil rates and a high recovery of the original oil in place (OOIP) at economic oil-to-steam ratios.

The first successful field demonstration of the SAGD process occurred during the late 1980s at the Underground Test Facility (UTF) near Fort McMurray, Alberta. This facility was constructed and operated by the Alberta Oil Sands Technology and Research Authority (AOSTRA) to test the SAGD concept for the Athabasca oil sands. Its success stimulated producers to develop a number of additional SAGD pilots in heavy oil and bitumen reservoirs in Alberta and Saskatchewan during the 1990s. More recently, several commercial SAGD projects have been initiated in Athabasca reservoirs and planning for futher commercial projects in Alberta is underway.

The SAGD process is energy intensive. For some reservoirs, the vapour extraction (VAPEX) process may have more potential. It is an analogue to SAGD, involving the injection of vapourized solvents (e.g. ethane, propane, butane) or solvent/gas mixtures rather than steam. This process results in the formation of a vapour chamber rather than a steam chamber, but with a similar reduction in oil viscosity at the chamber boundary that allows the oil to drain to the production well. Although VAPEX is less energy intensive than SAGD, production rates are also lower. A pilot for testing the VAPEX concept has been established by a consortium of producers and government in Athabasca. In addition, hybrid steam/solvent processes are currently under development for reservoirs in which steam or solvent processes alone are not suitable.

Cold production has emerged over the past decade as a viable commercial technology for recovering heavy oil from the very thin reservoirs (e.g. 2 m to 7 m net pay) that are predominant in the area surrounding Lloydminster. It is a primary (non-thermal) recovery process in which sand is produced aggressively along with oil (and water and gas). The cold production process improves oil production rates substantially by creating regions of increased permeability – wormholes. The process keys on the formation and flow of foamy oil (generated by solution gas drive) into wormholes, as they grow into the reservoir. The wormholes provide improved access to the reservoir.

Ultimate recoveries for the cold production process are relatively low, in the range of 5% to 15% of OOIP. Thus, significant volumes of oil remain in the reservoir for further exploitation. This oil is trapped, by the free gas that breaks out of the live (gas-saturated) heavy oil as the pressure is depleted during cold production. In order to produce more oil from a depleted reservoir, the mobility of some of the remaining oil must be improved. Cyclic solvent stimulation processes appear to offer the best potential for accomplishing this. With reservoir access provided by wormhole networks created during cold production, the injection of solvent/gas mixtures could reduce oil viscosity within the reservoir, allowing redistribution of the oil phase to occur by means of gravity and capillary forces. Then, the re-mobilized oil could be stripped from the reservoir by turning the injection well into a producer. It is anticipated that this injection/production cycle could be repeated several times.

Seismic Monitoring

The heavy oil and bitumen recovery technologies discussed above share a common characteristic. As each process evolves, a depleted zone from which oil has been produced grows outward from the production well. Production rates tend to be controlled by drainage from a transition zone separating the depleted zone from the virgin (undepleted) reservoir. This transition zone is relatively narrow, as a consequence of the high viscosities of heavy oil and bitumen resources in the WCSB.

The economic success of projects employing these recovery methods is predicated on optimal production strategies and effective reservoir conformance (fairly uniform recovery of oil from the depleted zone). Current standard industry practices for designing production strategies and monitoring reservoir conformance are based on reservoir engineering tools, such as material balance methods and numerical simulation of reservoir performance. These tools only allow problems with production strategies, such as slow depleted zone growth, or with reservoir conformance, such as by-passed sections of the reservoir or unwanted channelling of injected steam or solvent, to be uncovered indirectly.

Seismic technologies offer a complementary approach that could be integrated with reservoir engineering tools to monitor *in situ* performance of heavy oil and bitumen recovery technologies more effectively. Time-lapse seismic imaging would enable fluid behaviour to be tracked within the reservoir, by detecting changes between seismic surveys directly and inferring current *in situ* conditions from these changes. This could allow problems with production strategies or with reservoir conformance to be identified more readily, and provide more detailed reservoir information for determining remediation tactics.

References

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