SAND CONTROL FOR UNCONSOLIDATED HEAVY OIL RESERVOIRS: A LABORATORY TEST PROTOCOL AND RECENT FIELD OBSERVATIONS

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ABSTRACT

Sand production is one of the major challenges in oil and gas industry, in particular for unconsolidated heavy oil reservoirs. Achieving maximum well productivity without excessive sand production or plugging in such deposits requires new technical solutions and better understanding of reservoirs and sand control phenomena.

A laboratory protocol test has been developed for the sand control design for the heavy oil deposits located in unconsolidated reservoirs, both clastic and carbonate. The protocol allows evaluation of the different type of the sand control media (slotted liners, gravel packs, wire wrapped screens and premium screens). The protocol is used in sand control studies for thermal production operations and water disposal wells. Recent field data indicate that results of the laboratory tests are in a good agreement with field observations. The paper provides details of the laboratory test protocol and recent field data for Western Canada.

INTRODUCTION

Production of formation sand is one of the oldest problems in oil and gas industry [1]. Heavy, extra heavy oil and bitumen are often found in the unconsolidated, shallow, geologically young formations. Thermal technology based on steam injection such Cyclic Steam Stimulation (CSS) and Steam Assisted Gravity Drainage (SAGD) is effective for in situ production of heavy oil crude. As large volumes of water are utilized in such operations, disposal wells are often required. Sand control media which will allow maximum flow rates and minimal plugging or pressure build up is needed for both injection and production wells. Efficiency of sand control depends on a variety of factors such as geology, fluid type, fluid viscosity, production rates, thermal effects, etc.

Slotted liners (SL), gravel packs, wire wrapped (WWS) and premium screens are commonly used for sand control in unconsolidated heavy oil reservoirs. Straight cut (SC) and rolled top (RT) SL, standalone or with gravel packs, are commonly used in heavy oil and bitumen production operations. Pressure build up and lost production due to liner

plugging, corrosion and scale [2] are the main challenges for SL. WWS and premium screens, in particular as standalone screens, are becoming more popular due to a larger open flow area and resistance to corrosion.

Laboratory work to select sand control devices prior to well completion is required. Lost production and additional cost associated with acidizing, perforation, re-entry and side wells, etc. can be avoided with proper planning and laboratory testing.

LABORATORY TEST PROTOCOL

A laboratory protocol test has been developed for the sand control design for unconsolidated heavy oil reservoirs [3, 4]. The protocol was first used to evaluate SL for SAGD operations in unconsolidated sandstone. Later, the protocol proved to be successful in the evaluation of WWS and premium screens for both injection and production wells in thermal production operations other than SAGD, for both sandstone and carbonates, and for water disposal wells.

The protocol includes the following:

1. understanding geology of the reservoir and lithological facies, with the focus on particle size distribution;
2. obtaining typical reservoir core for each lithological facies;
3. core preparation for the study (cleaning, homogenization, etc.);
4. sand control coreflood tests; tests are conducted with a synthetic brine of the same composition as formation water, mineral oil of the same viscosity as viscosity of heavy oil/bitumen in situ under steam injection conditions in case of thermal production, laboratory test rates representing field rates;
5. analysis of produced fine solids and/or post test analysis of sand control coupons by epoxy impregnation and by means of scanning electron microscopy and X-ray energy dispersive spectrometry.

In a coreflood test, pressure differential across the sand pack, on top of the sand control media and the amount of produced fine solids versus production rates are measured. A schematic of the test apparatus is provided in Figure 1. Performance is evaluated by measuring weight of produced fines and increase in delta P. If more than 0.1 g of fines is produced or more than 5 psi delta P is developed, the sand control device is judged to be inadequate. These parameters are somewhat arbitrary and are used for the purpose to compare relative performance of different sand control devices.

Tests results provide data which allow the best possible sand control media for a particular reservoir and specific operational conditions to be determined. Such sand control media would minimize pressure build up and would provide the lowest amount of produced solids at the maximum production rates. The protocol also allows a better understanding of the sand control phenomena. The protocol has been used extensively for a variety of projects in Western Canada, California, Latin America and the Middle East.

Over 1000 tests have been conducted. In Western Canada, the protocol became an industry standard [5, 6].

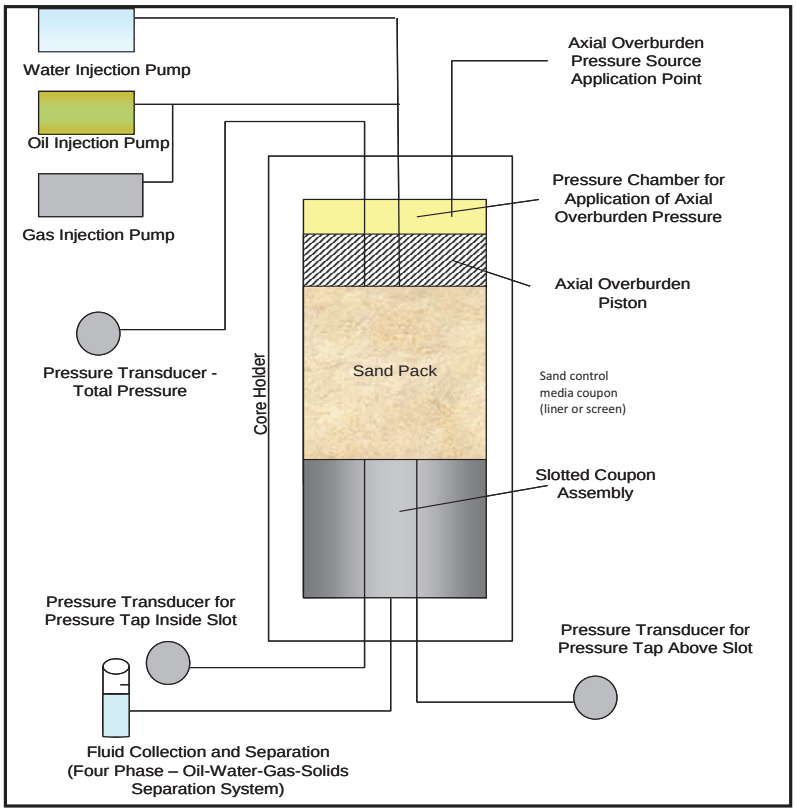

Figure 1. Schematic of sand control apparatus

TYPICAL TEST RESULTS

Formation of sand bridges on top of the sand control media and their stability under different flow conditions can be determined in the sand control experiments. Test results show that "the rules of thumb" commonly used for completion design for convention oil and gas do not apply to heavy oil. For example, instead of the rule of 2 x D10, where D10 is the grain-size diameter from the distribution scale where 10% by weight of the sand is of a larger size and 90% is of a smaller size, to determine the aperture of SC slot, one typically needs to use 1.8 x D10. This applies only to sand which has less than 5 wt% of fines, particles with less than 44 micron diameter. If sand has more than 5 wt% of fines, SL will likely fail and screens are a better option.

Typical results of sand control tests to simulate SAGD operations for unconsolidated sandstone (oil sands) from Western Canada are provided below. Delta P on top of sand control media versus different flow regime and production rates is shown in Figure 2. Amount of produced solids versus different flow regime and production rates is shown in

Figure 3. The test results presented in Figures 2 and 3 are reservoir specific and can be used as a reference only. However, the test results show a few typical trends.

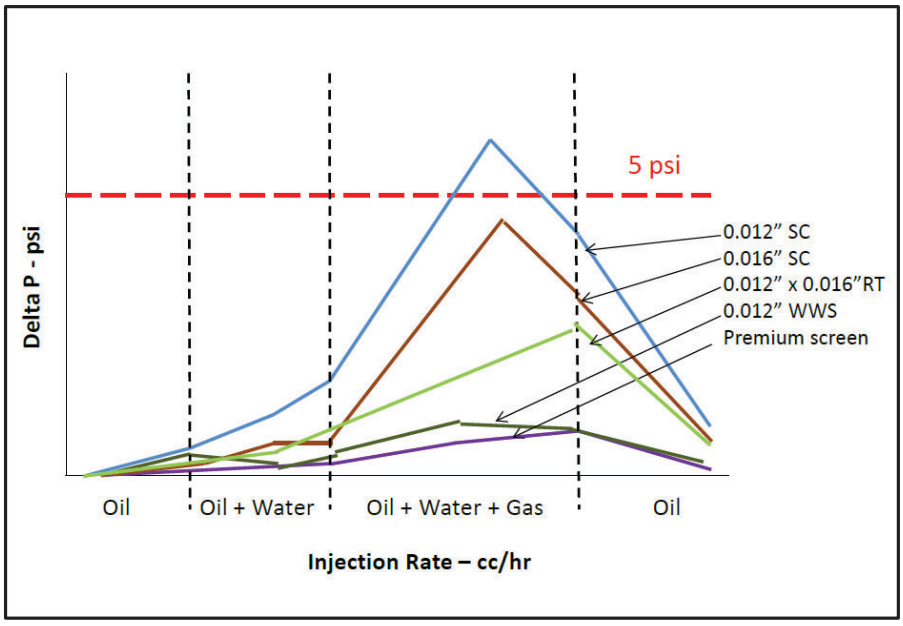

Figure 2. Delta P on top of sand control media versus different flow regime and production rates, SAGD operations, oil sands from Western Canada

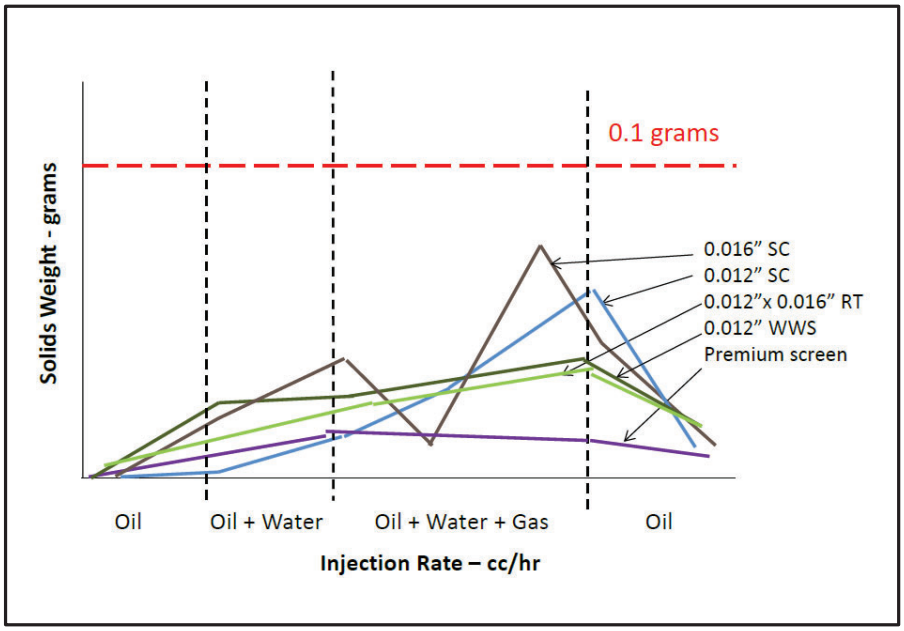

Figure 3. Produced solids versus different flow regime and production rates, SAGD operations, oil sands from Western Canada

Test results show that:

1. Type and aperture of sand control media is specific to the reservoir and operational conditions.
2. RT outperforms SC in terms of both delta P and amount of produced fine solids.
3. WWS outperforms SC and RT SL from a plugging perspective.
4. Solids production for WWS is marginally higher than for SL at the same aperture width but the aperture is chosen correctly, only colloidal size particles are produced.
5. WWS designs, even with smaller aperture width, have a lower pressure drop than SL and the smaller aperture width of the WWS results in an effective sand control design.
6. Premium screens have in general similar performance as WWS.

RECENT FIELD OBSERVATIONS

Recent field data from heavy oil projects in Canada confirm trends observed in the laboratory experiments. A good example is the Leismer SAGD Demonstration project of Statoil [5, 6]. Twenty three SAGD well pairs were completed with both liners (SC for injectors and RT for producers) and WWS. First production started in January 2011. The majority of SL producers show a gradual increasing drawdown with time which could be indicative of gradual plugging. Another example is the JACOS Hangingstone SAGD project [7]. Field data collected over the period of 15 years of production show low pressure drop for WWS and a premium screen. Nine years of production for SL show initially good sand control and good conformance but multiple liner failures and high pressure drops.

The laboratory test protocol allows determination of the type and aperture of the sand control media for a specific reservoir which would provide economical production rates without pressure build up or excessive sand production. Sand control is one of the factors which need to be taken into account for well design. Other factors such as operational practices and mechanical stresses also need to be taken into consideration. Work on the correlation of field data and lab data is ongoing.

CONCLUSIONS

1. A laboratory test protocol has been developed for sand control design for unconsolidated heavy oil deposits. The protocol allows evaluation of the different type of the sand control media with reservoir core material at test conditions simulating field conditions.
2. Test results provide recommendations for the sand control media which would be the most suitable for a particular reservoir and would provide maximum flow rates and minimal plugging or pressure build up.
3. Recent field data indicate that results of the laboratory tests are in a good agreement with field observations.

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