A NEW CONCEPT OF ENHANCED SAGD PROCESS BY ADDING INTERMITTENT STEAM-STIMULATION ON LOWER HORIZONTAL PRODUCTION-WELL (SAGD-ISSLW)

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Abstract. An enhanced SAGD process named SAGD-ISSLW for heavy oil recovery has been studied by experiments using 2-dimensional scaled physical-models, video and infra-red visualization techniques. In the usual SAGD process, oil production rate increases with increasing vertical well spacing between two horizontal wells, but the lead time to start oil production by gravity drainage is longer at the initial stage. The new process uses a lower horizontal well with both functions of intermittent steam-injection and continuous oil-production instead of the usual SAGD production-well. Meanwhile, like in the usual SAGD, the steam is also injected continuously through the upper well as same as the usual SAGD. The benefits of the new concept reported in the paper are quick buildup of warm steam chamber and higher oil production rate as compared to the usual SAGD process. The process also has advantages for setting longer vertical well spacing and keeping temperature of flowing heavy-oil in the surface-drilled SAGD wells by the single well configuration.

INTRODUCTION

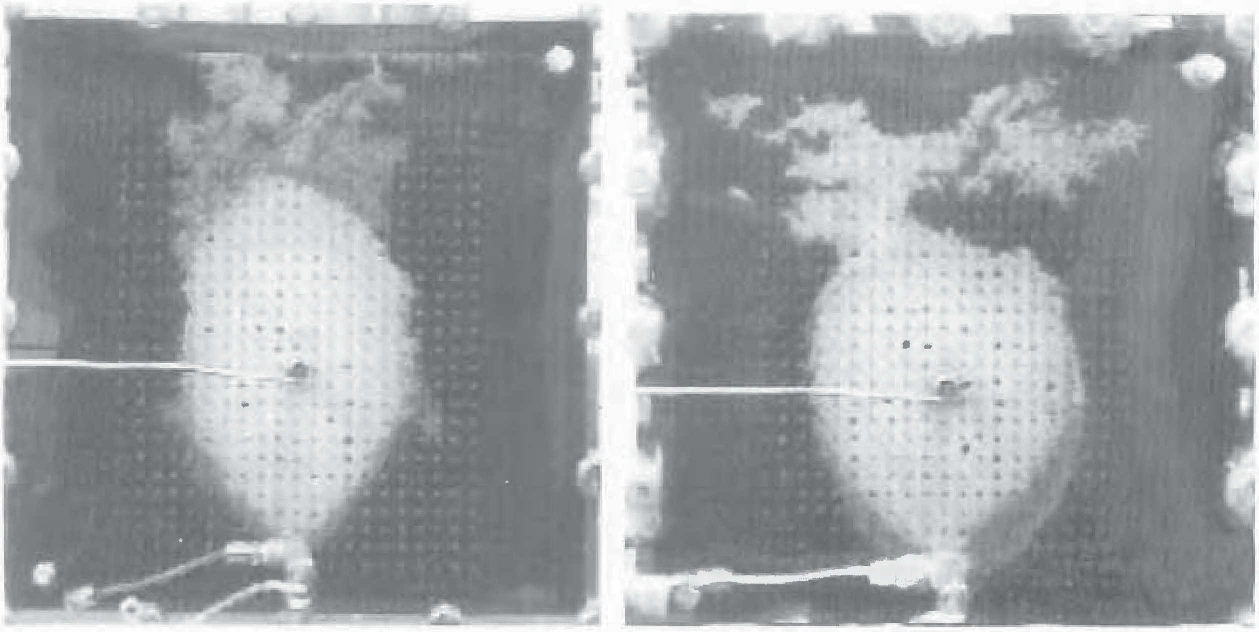
It is not easy to produce heavy oil efficiently and economically. However, as shown in the reports of the UTF projects (phase A and B) in Canada, the steam assisted gravity drainage, SAGD, process has proven to be very superior process for the recovery of the bitumen due to its high recovery factor. The process has been developed by Butler and his co-workers. Their ideas was to overcome the problems associated with the highly viscous bitumen by gravity drainage in steam chambers generated by displacement of heavy oil. Recently, the surface-drilled SAGD process has been tested as more economical one. The SAGD process operated by steam injection from upper well and production from lower well like that of UTF project, is hereinafter referred as 'usual SAGD'.

A problem of the usual SAGD process for oilsands reservoirs is the lead time required to generate a steam chamber in near break-through condition between two wells before the rising chamber stage. The more economical SAGD process should be achieved by an enhanced process to shorten the period of initial stage with effective usage of boilers and production facilities.

In this study, expanding or rising process of steam chamber and drainage mechanism along the chamber interface at the initial stage have been investigated by video-pictures and temperature distributions visualized using thermal-video system. The scaled physical reservoir models (200 × 200 mm and 300 × 300 mm, thickness = 4.5 or 9.6 mm) with tightly packed glass-beads (diameter = 0.18 – 0.25 mm, porosity = 38%, permeability = 115×10^{-12} m^2) were used. For each test, the model was saturated with heavy-oil (molecular-weight = 490 g/g-mole, density = 998 kg/m^3, viscosity = 0.12 Pa·s at 106 °C) using a vacuum pump. In most experiments, steam of 106 °C was injected under the constant steam pressure of 20 kPa to suppress the pushing effect by steam. The range of the dimensionless factor, B_3, defined by Butler (1985) is 7.6 to 10.4 for present experiments. After near break-through between two wells, oil production was controlled successfully to keep the temperature of production fluids mixture (oil and condensate) under the set temperature of 70 to 95 °C. The rates of oil production and expanding area of the steam chamber were measured and analyzed. Furthermore, temperature distributions using infra-red thermal video system were compared with visualized video-pictures. The heat losses from the reservoir models have been estimated at 60 to 75% of total injected heat for the amount of condensed water flowed down on the transparent acrylic-plates. The net steam/oil ratio (SOR) has been evaluated as 1.2 ± 0.3 based on emulsified water/oil volume ratio.

On the basis of the experimental results for the usual SAGD, a similarity of production rate for different vertical spacing between two wells has been investigated. The oil production rate increases with increasing vertical well spacing between two wells within half of the reservoir thickness, but the lead time to start oil production by gravity drainage becomes longer. Furthermore, the SAGD process using a single horizontal well for both functions of steam injection and oil-production proposed by D. Liderth (1995), referred as single well SAGD, has been investigated by the experiments using scaled models. For the case of the single well SAGD, its oil recovery was limited and production rate was much less than that obtained in the usual one. However, quick generation of a small steam chamber and oil production were observed in the single well SAGD process.

A new SAGD process named SAGD-ISSLW has been developed to shorten the lead time, set a longer vertical spacing between two horizontal wells and enhance oil production rate after steam break-through. The process uses the lower horizontal well with the dual functions of intermittent steam-injection and continuous oil-production, rather than for oil production only. Meanwhile, the steam is also injected continuously through the upper well like the usual one. From the results of the experiments for the new process, the break-through at the single well was observed at $t = 7$ to 10 minutes from the start of steam injection, and the lead time to generate near breakthrough condition between two wells was shortened 20%, and oil production rate was enhanced 16% compared to that of usual SAGD process at $t = 9$ hours (see Figs 1 and 2). The intermittent steam injection from lower well accelerated instability of the interface near the ceiling leading to fingering areas. This enhanced the expanding rate of the chamber area was enhanced 43% compared to the usual SAGD process. It is expected that the steam can be injected earlier due to the quick generation of the steam chamber around the lower well, thus pre-heating of reservoir around the wells can be shortened and it will help set longer vertical spacing between the two wells. Furthermore, it will be easier to control expanding rate of the steam chamber after breakthrough by changing rate and interval of the intermittent steam injection from the



Usual SAGD SAGD-ISSLW

Fig. 1. Comparison of steam chambers of usual SAGD and SAGD-ISSLW. (Reservoir model: 300 × 300 mm, 4.5 mm thickness, $t = 9$ hours).

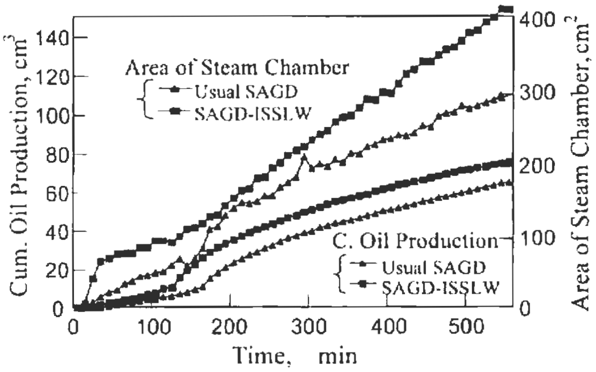


Fig. 2. Cumulative oil production and steam chamber area *vs.* time (Reservoir model: 300 × 300 mm, 4.5 mm thickness).

lower well.

This new process using the single-well configuration that allows steam injection through the tubing offers an advantage for the case of the surface-drilled SAGD has been field-tested in Canada, because it helps maintain the temperature of the mobile heavy-oil during production.

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