NAME: AFABOR MICHAEL ONAFOME

MAT NO: 15/ENGO7/001

COURSE: PTE512

BRIEFLY DISCUSS THE FOLLOWING THERMAL ENHANCED OIL RECOVERY METHODS

1. STEAM ASSISTED GRAVITY DRAINAGE (SAGD)

Steam-assisted gravity drainage (SAGD) is a promising approach for recovering heavy and viscous oil resources. In SAGD, two closely-spaced horizontal wells, one above the other, form a steam-injector and producer pair. The reservoir oil is heated by the injected steam and drains to the producer under the effect of gravity. The success of steam-assisted gravity drainage has been demonstrated by both field and laboratory studies mostly based on homogeneous reservoirs and reservoir models. A comprehensive understanding of the effects of reservoir heterogeneities on SAGD performance, however, is required for wider and more successful implementation. This dissertation presents an investigation of the effects of reservoir heterogeneities on SAGD. In addition, two potential methods, hydraulic fracturing and mobility control using foamed steam, are proposed and reported here to enhance SAGD performance, especially for heterogeneous reservoirs.

The main feature of SAGD depends on introducing steam into a reservoir to form a steam chamber and producing heated oil using two horizontal wells by gravity. Since the oil production is mainly from the chamber/heated-oil interface, the steam chamber growth is responsible for oil production. In practice, the SAGD process is normally initiated with a preheating period to overcome the difficulty of steam injection due to extremely unfavorable mobility ratio (Saltuklaroglu et al., 2000). During the preheating period, steam is circulated in the tubing and out of the annulus for both horizontal wells, thus heating the surrounding oil by conduction. Once thermal communication is established between wells and the oil in the inter-well region becomes mobile, steam is injected into the reservoir to develop a chamber above the wells. An idealized steam chamber in a homogeneous reservoir is shown schematically in Figure 1. The development of this inverse-triangularly-shaped steam chamber involves complicated steam condensate flows and thermal processes. Injected steam rises within the chamber under buoyancy forces and flows continuously to the perimeter of the chamber, where it condenses and releases a large amount of latent heat. The heat is transferred, by both conduction and convection, first to the condensate that flows inside the steam chamber, and then the adjoining oil (Farouq-Ali, 1997; Ito and Suzuki, 1999). The mobilized oil and the condensate drain by gravity along the steam chamber toward the production well. As the oil is removed and more steam is injected, the boundary of the steam chamber expands upwards and sideways.

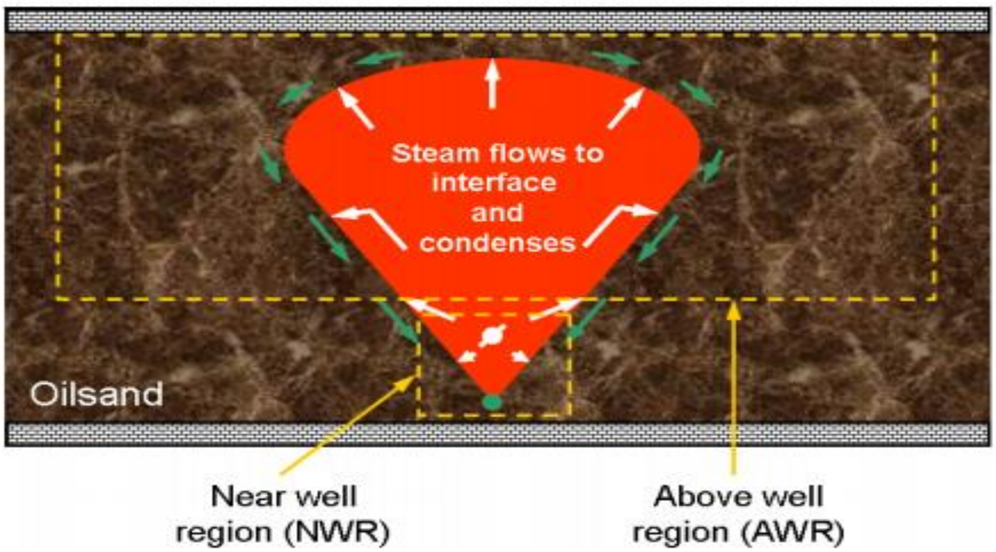
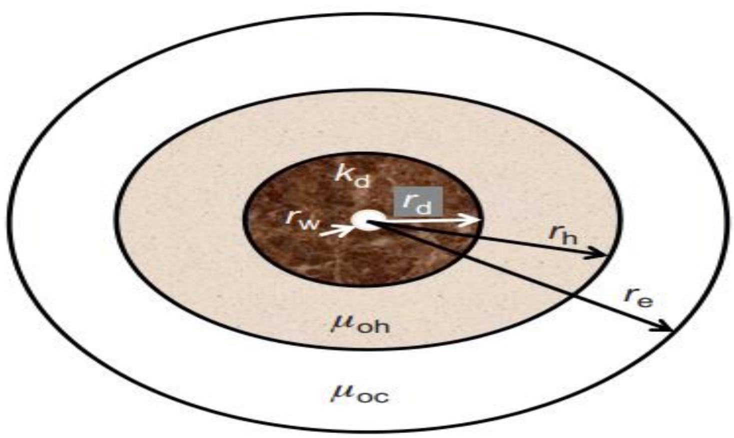


Figure 1: Schematic steam chamber growth in a SAGD process. Boxes drawn with dashed lines indicate the near well region (NWR) and the above well region (AWR).

2 CYLIC STEAM STIMULATION

In cyclic steam stimulation (CSS), steam is injected into a production well for a period. Then the well is shut in and allowed to soak by steam for some period before it returns to production. The initial oil rate is high because of high initial oil saturation, high increased reservoir pressure, and lowered oil viscosity. As the oil saturation becomes lower, the reservoir pressure becomes lower and the oil viscosity becomes higher due to heat losses to the surrounding rock and fluids, oil rate declines. At some point, another cycle of steam injection is initiated. Such cycle may be repeated several times or many times. The terms of steam soak and steam huff-and-puff (huff-n-puff, huff ‘n’ puff) are also used to describe CSS.

The first mechanism of CSS is the reduced oil viscosity owing to the steam injection. Steam injection increased the reservoir pressure. Thus the pressure drop is high. According to the Darcy equation, the oil rate is increased.



Schematic of a radial flow model after steam stimulation.

Fig.2 schematic of a radial flow model after steam stimulation

The diagram above is a schematic of a radial flow model after steam stimulation. Let us use the steady-state Darcy flow equation. The production rate at the downhole conditions after steam stimulation, qoh, is

$$q_{\mathrm{oh}} = \frac{2\pi h(p_{\mathrm{e}} - p_{\mathrm{w}})}{\frac{\mu_{\mathrm{oc}}\ln(r_{\mathrm{e}}/r_{\mathrm{h}})}{k} + \frac{\mu_{\mathrm{oh}}\ln(r_{\mathrm{h}}/r_{\mathrm{d}})}{k} + \frac{\mu_{\mathrm{oh}}\ln(r_{\mathrm{d}}/r_{\mathrm{w}})}{k_{\mathrm{d}}}}$$

$$= \frac{2\pi k k_{\mathrm{d}} h(p_{\mathrm{e}} - p_{\mathrm{w}})}{k_{\mathrm{d}}\mu_{\mathrm{oc}}\ln(r_{\mathrm{e}}/r_{\mathrm{h}}) + k_{\mathrm{d}}\mu_{\mathrm{oh}}\ln(r_{\mathrm{h}}/r_{\mathrm{d}}) + k\mu_{\mathrm{oh}}\ln(r_{\mathrm{d}}/r_{\mathrm{w}})}$$

3 HOT WATER FLOOD

Hot water-flooding is the most common thermal method of enhanced oil recovery used in the CIS. Hot water-flooding is particularly effective in the development of fields of highviscosity oils which contain large quantities of paraffins and resinous asphaltene substances, and which exhibit anomalous (non-Newtonian) properties as they flow through porous media. Hot-water flooding is considered as an effective EOR technique for heavy oil after steam injection.

It can not only continue to heat the reservoir, but also make use of the residual heat of steam. Compared with other thermal recovery methods, the sweep area in the hot-water flooding process mainly locates in the bottom of the reservoir, in spite of the permeability of the upper layer being higher than that of the bottom.

The EOR mechanisms of hot-water flooding include

(1) Heating and viscosity reduction—heavy oil viscosity reduces dramatically with the increase of temperature, which decreases viscosity fingering and then improves areal sweep efficiency.

(2) Pressure maintenance—similar to conventional water flooding, hot-water flooding can maintain reservoir pressure and supplement displacement energy.

(3) Mobility ratio reduction—as oil viscosity is decreased, the mobility ratio between oil and water also decreases so much that oil-flow ability increases.

(4) Sweep efficiency improvement—the injected steam usually flows to the upper layer of the reservoir preferentially due to its lower density, while the injected hot-water can carry the retained heat of steam to the bottom region under the action of gravity because of its higher density, thus improving the vertical sweep efficiency of the reservoir.

Diaz-Munoz and Farouq Ali pointed out that HWF could provide larger displacement drive than steam flooding because water had a much greater viscosity than steam (Diaz-Munoz and Farouq Ali 1975). The heat loss to the overburden and understrata during HWF process is much smaller than that in a SF process due to the lower injection temperature. Furthermore, HWF can make use of much higher injecting pressure than steam-flooding at a given temperature.

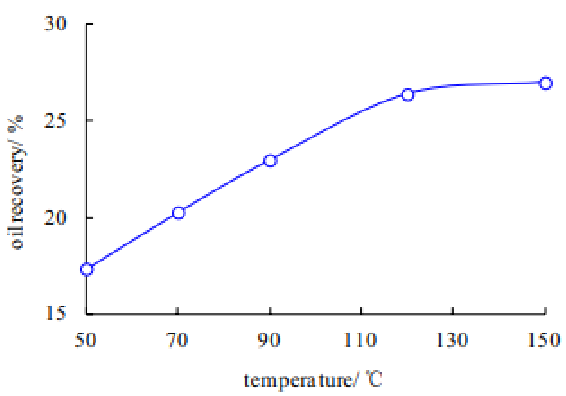


Fig.3 Oil recovery at different temperatures

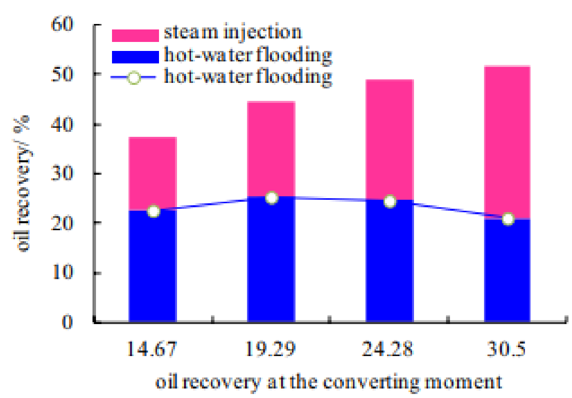


Fig. 4 Comparison of oil recovery different converting moment