Enhanced Heavy oil Recovery Using Steam Injection

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Abstract

Summary

The cold oil in a reservoir is very viscous and does not flow easily, therefore thermal oil recovery techniques are recommended for the EOR of heavy oil. In this study, steam injection is used on the laboratory models to investigate the effects of temperature rise on viscosity reduction of heavy oil and consequently the production rate. Several parameters such as porosity, permeability, sand size and temperature of injecting steam are studied and a mathematical model is developed to predict the temperature profile during steam injection. The temperature profile predicted from the theoretical model agreed in some extent with the experimental results.

Introduction

All thermal methods tend to reduce the flow resistance by reducing the viscosity of the fluid [1].Of all these processes, steam assisted gravity drainage (SAGD) is an effective method of producing heavy oil and bitumen. In a typical SAGD approach, steam is injected into a horizontal well located directly above a horizontal producer. A steam chamber grows around the injection well and helps displace heated oil toward the production well [2], as shown in figure 1. SAGD maximize the role of gravity forces during steam flooding of heavy oils. Heat is transferred by conduction, convection, and latent heat of the steam. By injecting steam, figure 1, a steam chamber forms directly above the production well. At the steam chamber boundary, steam condenses to water as heat is transferred to the oil. Condensed water and hot oil flow along the steam chamber to the production well [3].Willman et al. (1961) reported experimental studies on the effect of some steamflood mechanisms, such as viscosity reduction, thermal expansion and steam distillation, on the oil recovery [4].A method for producing the bitumen drainage from around a spreading steam chamber above a horizontal well was described by Butler (1985) [5].

This study consists of oil displacements by hot water and steam in unconsolidated porous media under isothermal conditions at different temperatures. Experimental results showed that the oil recovery by steam injection is significantly higher than by hot water injection. It is concluded that the effect of steam distillation, gas-drive and solvent extraction contributed to more oil recovery during steam injection.

Experimental set up & procedure

Unconsolidated clean calibrated silica sands were packed into the tube models, and were saturated with water to determine pore volume, porosity and absolute permeability of the model [6].Then the oil was injected at the bottom of the column. Water was displaced by oil until the irreducible water saturation was reached. The connate water saturation and the oil saturation in the porous medium were determined by material balance. To establish the waterflood residual oil conditions, water was injected from the bottom of the column and the amount of residual oil determined. The laboratory steam assisted gravity drainage test was performed by injecting the steam at the top of the column. The oil bank formed as the oil in the steam invaded zone accumulates on the top of water zone at a relatively low production rate. Figure 2; shows a schematic diagram of the experimental set up. The physical properties of oil and laboratory models are known in each experiment.

Results and Discussion

In experiment no. 1, hot-water flooding is used after cold-water flooding and at the last step; steam is injected into the model. The experimental results of all experiments are summarized in table 1. As can be seen in figure 3, the experimental investigation of both hot water and steam flooding processes, for the recovery of residual oil resulted in higher oil recovery than for an ordinary water flooding. The results of these experiments exist and can be shown in figures.

Theoretical Model

An analytical model of steam assisted gravity drainage represented by Butler (1985) was modified to study the laboratory model; some assumption was made to develop a new analytical model [5].In the first part of the modeling, the mathematical equations were developed for a small part of the interface. The temperature distribution would correspond to the steady state beyond an interface advancing at a constant unspecified velocity U is given by equation 1, (is the direction of flow and is contact angle).

(1)

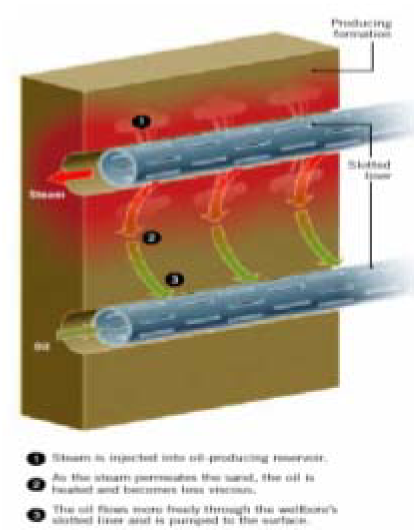
In the treatment which followed by Butler the temperature gradient term, for general cases, is approximated by a function which is exact for two limiting cases (the steady state case and the case of a stationary interface with T equal to when t equals zero) [5].The solution of Fourier's equation for a front which advances steadily from t=0 with a constant temperature Ts, given by Carslaw and Jaeger as equation (2):

(2)

Where

In this study, as shown in figure 4, because of vertically setup of our model, is used instead of , and angle is equal to 90 and results . Some parameters in Equation (2) were unknown, so one should use relations to estimate required parameter to calculate K, , ,…[7] [8]. The data, which has been used in our temperature distribution of experiments, could be shown in some tables.

Figure 5 represents the temperature profile for the laboratory model, during steam injection, plotted by MATLAB program. A comparison between this analytical model and the experimental data was done, for example at t=54 min, as illustrated in figure 6. These results show an overall agreement between experimental and analytical curves. The results of the temperature profile obtained in this work confirm the previous ones obtained by Jabbour et al. [9].



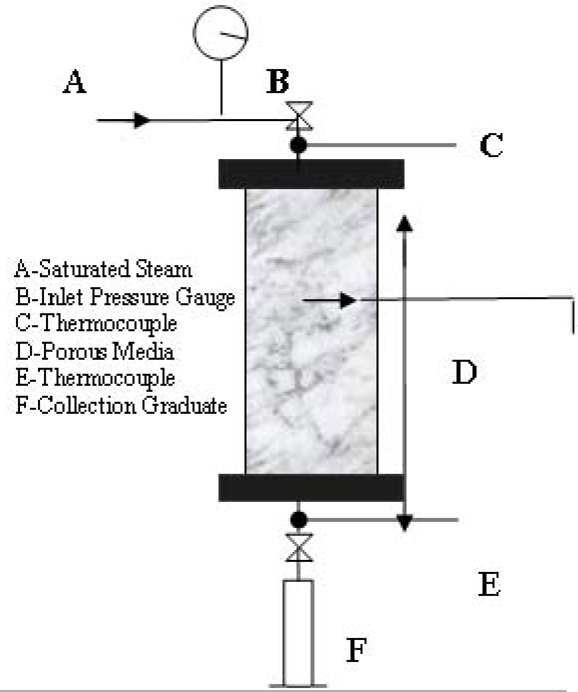


Figure 1- Sketch of SAGD process.

Figure 2- Schematic diagram of the experimental set up.

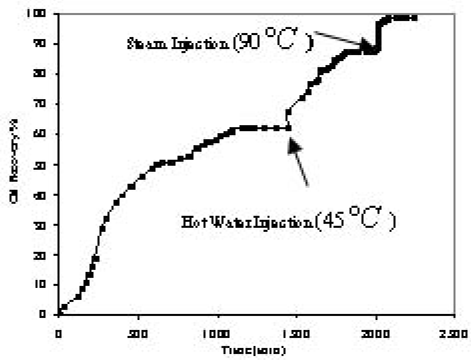


Figure 3- Oil recovery percent vs. time during cold and hot water followed by steam flooding.

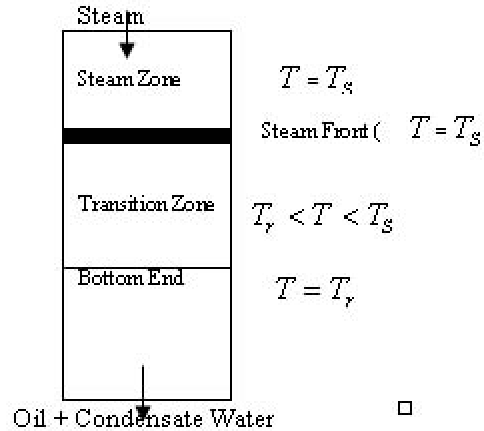


Figure 4- Schematic of laboratory model used for analytical simulation.

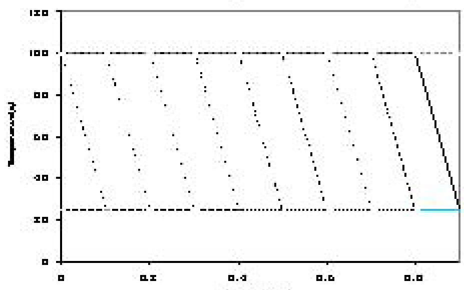


Figure 5- Temperature distribution vs. length during steam injection

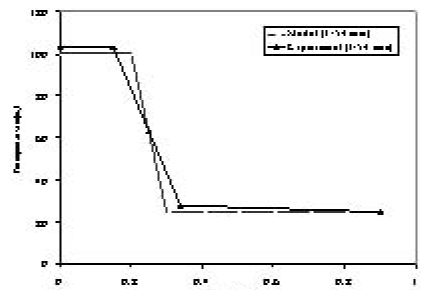


Figure 6- Comparison between analytical model and experimental results during

steamflooding (at t=54 min).

Table 1- Experimental results in laboratory models

Experiment No.	Drainage Type	Oil Recovery (%)	Residual Oil Saturation (%)	Recovery Duration (hr)
1-a	Cold Water Flooding	62	31	24
1-b	Hot Water Flooding	87	10	8.3
1-c	Steam Injection	98	1.1	4.9
2-a	Cold Water Flooding	54	39	13.7
2-b	Steam Injection	98	1	2.8
3	Steam Injection	98	1.2	3

List of Symbols

C_p Specific heat capacity $(\frac{j}{Kg^\circ C})$

K_{eff} Effective thermal conductivity $(\frac{w}{m^\circ C})$

T Temperature $(^\circ C)$

T_r Reservoir temperature $(^\circ C)$

T_s Steam temperature $(^\circ C)$

t Time(sec)

U Steam front velocity $(\frac{m}{sec})$

θ Contact angle(dimensionless)

α Thermal diffusivity $(\frac{m^2}{sec})$

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