Experimental Study on Steam-Solvent Extraction of Heavy Oil in Sand-packed Model

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Abstract. The VAPEX process was first developed by Roger Butler. This technology takes the advantages of low investment and low energy requirement, which can also avoid the emission of greenhouse gases. Besides, it does some partial upgrading of bitumen and heavy oil in the formation. VAPEX has been a very promising rectory technology .In this paper, a basic tubular physical simulation experimental device was used for oil displacement experiments. It can be seen that the ultimate recovery of crude oil is 41.38% through propane flooding while the ultimate recovery of crude oil is 36.42% through steam flooding. Compared with steam flooding, the ultimate recovery of crude oil through co-injection of steam and propane increases by 32.03%.

Keywords: heavy oil, VAPEX, extraction, sand-packed model, steam flooding.

1. Introduction

VAPEX is a new method for heavy oil recovery proposed by Butler et al. from University of Calgary in 1991, which is similar to SAGD.In this method, ethane, propane or butane is injected to reservoir, then the gas chamber is formed in the reservoir. As a result, the heavy oil is recorvyed due to viscosity reduction and gravity drainage.

The advantage of this process is that natural gas is not required to produce steam thus providing a savings on energy usage. VAPEX process uses only 3% of the energy required by steam processes. In addition to its superior energy efficiency, this process has many advantages, notably the absence of costly water treatment installations; it does some partial upgrading of bitumen to oil right in the formation and a lower environmental impact. VAPEX does away with the emission of large quantities of greenhouse gases inherent in steam generation. VAPEX process produces 80% less green house gas emission than steam assisted gravity drainage process. The main drawback of VAPEX is the low drainage rates predicted for real reservoirs.compared with SAGD process. This has hampered the field implementation of the process.

The predominant mechanism for VAPEX process is the diffusion of solvent into the heavy oil and bitumen. Production rates are directly related to viscosity reduction, which in turn depends on the amount of solvent dissolved in the crude. Mixing of the solvent with heavy oil and bitumen is slow because it occurs only when solvent diffuses through the pores. Compared to SAGD, the heating of reservoirs is much faster because heat can be carried through at relatively high thermal conductivity rock as well as in the pores, this thermal diffusion is much faster than the molecular diffusion required for solvent mixing. Therefore, it is generally expected that VAPEX production rates will be much lower than those in a steam process.

2. Experiments

2.1. Experimental Materials

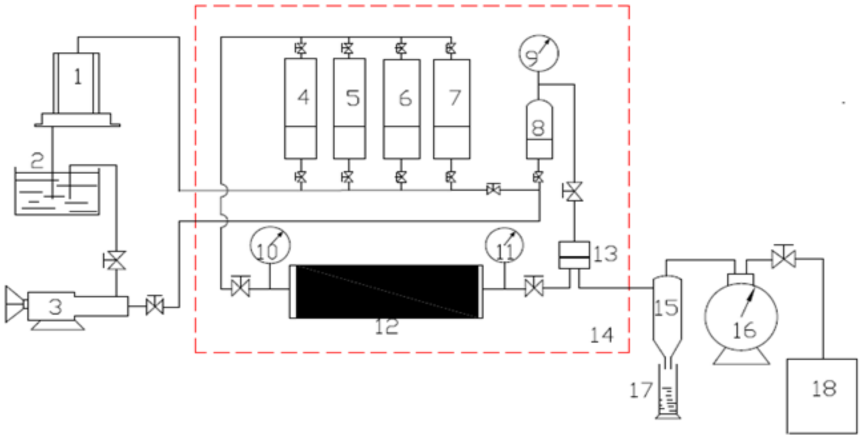
Laboratory samples were taken from the heavy oil of the degassing and dehydration of Jiang 37 block and the relationship between viscosity and temperature as well as rheological properties of the heavy oil were studied. The basic parameters of samples are shown in Table 1.

Table 1. The basic parameters of heavy oil of Jiang 37 block

Crude oil	Composition of crude oil (%)			
	Saturated hydrocarbon	Aromatic hydrocarbon	Resin	Asphaltene
Heavy oil of Jiang 37 block	52.9	27.2	17.8	2.1
Crude oil	density (g/cm^3)(20℃)	Freezing point (℃)	Average molecular weight (g/mol)	Paraffin content (%)
Heavy oil of Jiang 37 block	0.9208	11	540.8	25.3

2.2. Experimental Device

A basic tubular physical simulation experimental device was used in experiments. The device is composed of constant temperature system, model body, injection system, output system, temperature pressure measurement and control system and export liquid measurement system. Schematic diagram of the experimental device is shown in Figure 1.



1-Injection pump;2-Water storage tank;3-Manual metering pump;4,5,6-Piston container with oil,water, solvents;7-Intermediate piston container;8-Buffer tank; 9,10,11-Precision pressure gauge;12-Sand-packed Model;13-Back-pressure valve;14-Oven;15-Gas-liquid separator;16-Wet gas flow meter;17-Liquid Collector;18-Solvent recovery tank

Fig.1 Schematic diagram of experimental set-up

2.3 Experimental Procedure

Preparation of Sand-packed Model

The preparation of sand-packed model is based on the geological conditions and the physical properties of the reservoir, the length and the diameter of which is 30cm and 2.5cm, respectively.

A dry method was used to fill the model. First, the model was erected and make sure that the tightened cap was at the bottom of model. Then, according to the requirement of the experimental program, putted dry quartz sand into the model and used leather hammer to tap the wall. At last, tightened the upper end when the model was filled with sand.

Determination of Air Permeability

The length and diameter of the model were measured and then the volume was caculated. Air permeability was determined by flow tube method.

Preparation of Fluids

(1) Experimental Oil

Experimental oil was taken from production wells of the degassing crude oil in the field. First, the stainless steel mesh with 0.045mm was used to filter the oil sample, and then oil sample was dehydrated (water content less than 0.5 percent) .Finally, the treated crude oil was put into the piston apparatus.

(2) Experimental Water

According to the salinity of formation water to prepare simulated formation water and then used it for saturation of physical model and water flooding.

3. Results and Discussion

3.1 Propane Flooding

Experiments were carried out at 28℃, corresponding to reservoir temperature. First, the physical model was saturated with oil, then propane was used for oil displacement until the model reached the level of residual oil.Thus the experiment of propane flooding was studied. The basic parameters of sand-packed model are shown in Table 2. The injection rate of propane was 1.0mL/min, and the experimental results are shown in Figure 2.

Table 2. The basic parameters of sand-packed model

No.	Air permeability ($\times 10^{-3}\mu m^2$)	Porosity (%)	Oil saturation (%)	Water saturation (%)
JS-1	1143.52	38.28	90.17	9.83

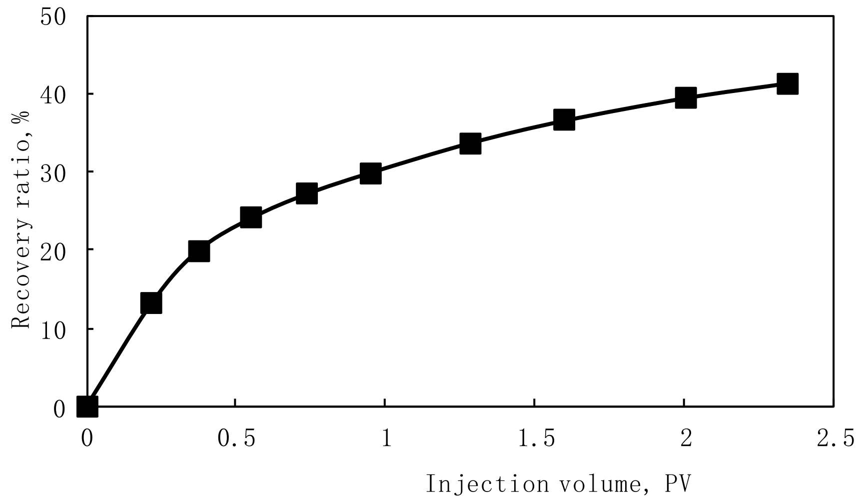


Fig.2 Effect of the pore volume injection on the recovery ratio

It can be seen from figure 2 that oil recovery increases with the increment of propane. When the amount of injected propane is less than 0.37PV, the oil recovery increases rapidly with the increase of PV while the recovery rate of increase is significantly smaller when the amount of propane is over 0.37PV.

Table 3. The basic parameters of sand-packed model

No.	Air permeability ($\times 10^{-3}\mu m^2$)	Porosity (%)	Oil saturation (%)	Water saturation (%)	Displacement method
JS-2	1140.12	36.24	90.12	9.88	Steam flooding

3.2 Steam Flooding

The temperature of steam was 200℃ in the experiment and the injection rate of steam (cold water equivalent) was 1.0mL/min. First, the physical model was saturated with oil, then steam was used for oil displacement until the model reached the level of residual oil. Thus the experiment of steam flooding was studied. The basic parameters of sand-packed model are shown in Table 3 and the experimental results are shown in Figure 3.

It can be seen from figure 3 that oil recovery increases with the increment of steam. When the amount of injected steam is less than 0.37PV, the oil recovery increases rapidly with the increase of

PV while the recovery rate of increase is significantly smaller when the amount of propane was over 0.79PV. The ultimate recovery of crude oil is 36.42% through steam flooding.

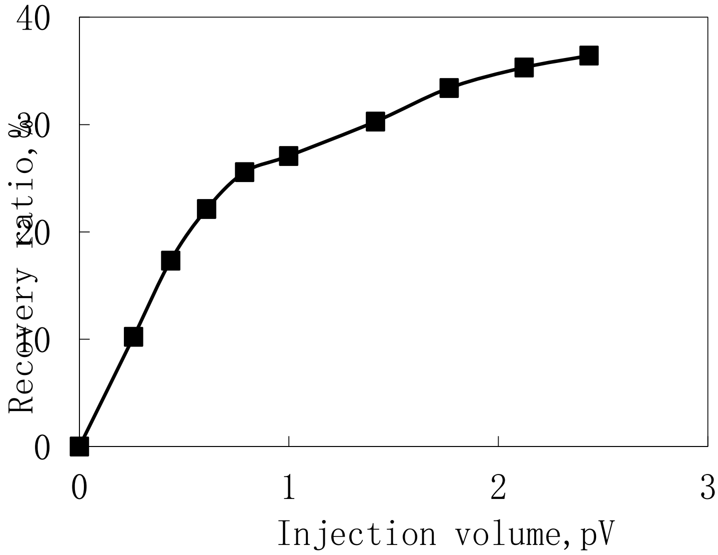


Fig.3 Effect of the pore volume injection of steam flooding on the recovery ratio

3.3 Steam-Propane Flooding

The temperature of steam was 200℃ in the experiment and the injection rate of steam (cold water equivalent) was 1.0mL/min. First, the physical model was saturated with oil, then co-injection of steam and propane was used for oil displacement until the model reached the level of residual oil. The volume fraction of propane was 8% and the volume fraction of steam was 92%. Thus the experiment of steam-propane flooding was studied. The basic parameters of sand-packed model are shown in Table 4 and the experimental results are shown in Figure 4.

Table 4. The basic parameters of sand-packed model

No.	Air permeability ($\times 10^{-3}\mu m^2$)	Porosity (%)	Oil saturation (%)	Water saturation (%)	Displacement method
JS-3	1127.22	37.43	91.34	8.66	Steam-Propane flooding

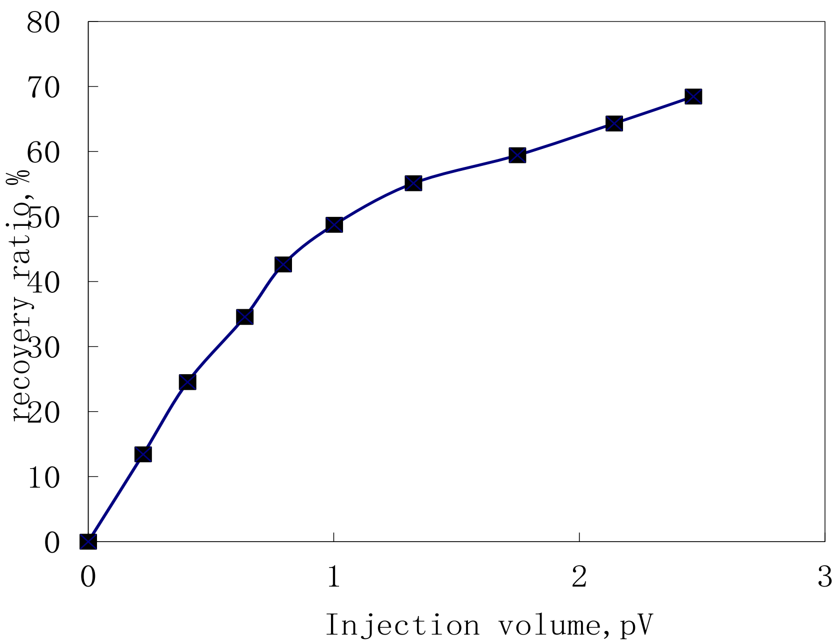


Fig.4 Effect of the pore volume injection of steam-propane flooding on the recovery ratio

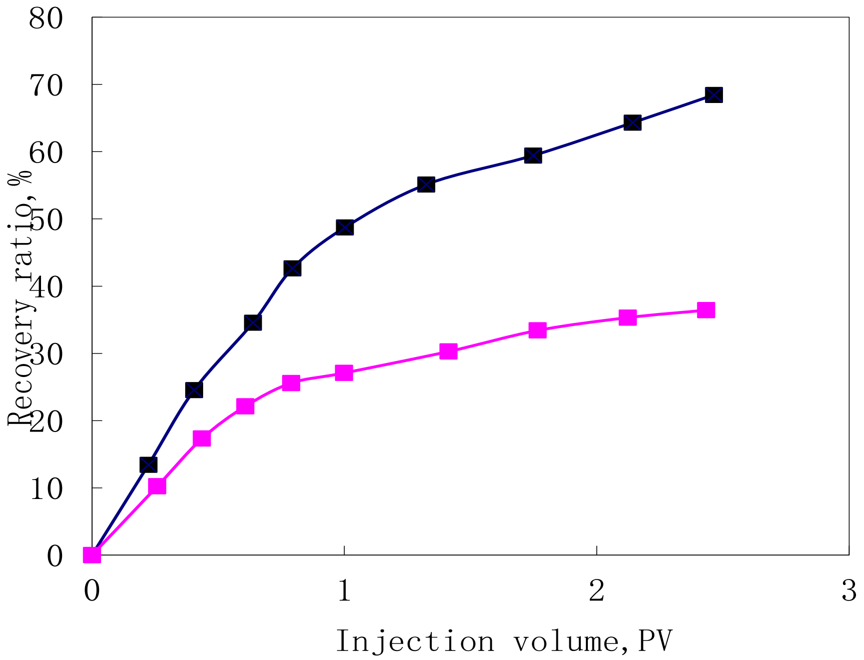


Fig.5 Experimental contrast of the steam flooding and the steam-propane flooding

Figure 4 shows the relationship between the oil recovery and the amount of steam-propane. Oil recovery increases with the increment of steam-propane. The ultimate recovery of crude oil is 68.45% through steam-propane flooding.

Figure 5 compares the steam flooding and steam-propane flooding. It can be seen from figure 5 that the final recovery of steam- propane flooding is 32.03% higher than that of steam flooding in the same amount of PV.

4. Conclusions

1. The laboratory results shows that when the propane injection amount is less than 0.37PV, the oil recovery increases rapidly with the increase of PV. The greater the amount of propane is, the more obvious the oil displacement efficiency is. When the injection amount of propane is over 0.37PV, the ultimate recovery of crude oil is 41.38% through propane flooding.

2. The oil recovery increases with the increment of steam. When the amount of injected steam is less than 0.79PV, the oil recovery increases rapidly with the increase of PV while the recovery rate of increase is significantly smaller when the amount of steam is over 0.79PV. The ultimate recovery of crude oil is 36.42 % through steam flooding.

3. The final recovery of steam-propane flooding is 32.03% higher than that of steam flooding in the same amount of PV.

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