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STUDYING OF THE EFFECTIVE PARAMETERS ON ENHANCED HEAVY OIL RECOVERY BY STEAM INJECTION

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Abstract:
High viscosity of some crude oil makes difficult to recover with primary or secondary production methods. Therefore, thermal oil recovery techniques are recommended for the Enhanced Oil Recovery (EOR) of heavy oil. In this experimental study, steam injection was used to investigate the effectiveness parameters on heavy oil production rate. The result is shown that, by increasing pressure, steam reaches the breakthrough point sooner, but recovery decreases. If the oils are a little different in viscosity, recovery in the light oil is more than that in heavy oil. Also in the highly viscous oils and light oils, recovery in the heavy oil is much higher than in light oil.

Keywords: *heavy oil, steam injection, enhanced oil recovery*

1. Theoretical background

Heavy oils (API gravities from 10 to 20 degrees) have high viscosity and do not flow readily in conventional wells. Steam injection and steam flood are often used to produce heavy oil. Steam injection uses a well to inject steam into the heavy oil reservoir for a period of time such as two weeks. The steam heats up the heavy oil and makes it fluid. The same well is then used to pump the heated heavy oil for a similar period of time. Steam injection and pumping are alternated in this technique, called the huff and puff method. A steam flood involves injection wells that pump steam into the heavy oil reservoir. The pressure of the steam forces the heated heavy oil to a producing well between the injection wells [1,2].

Steam injection is the most advanced and most widely used EOR process. There are two versions of the process: cyclic steam injection and steam drive. In the first, high-pressure steam or steam registration and hot water is injected into a well for a period of days or weeks. The injection is stopped and the reservoir is allowed to “soak.” After a few days or weeks, the well is allowed to backflow to the surface. Pressure in the producing well is allowed to decrease and some of the water that condensed from steam during injection or that was injected as hot water then vaporizes and drives heated oil toward the producing well. When oil production has declined appreciably, the process is repeated. Because of its cyclic nature, this process is occasionally referred to as the “huff and puff” method.

The second method, steam drive or steam flooding, involves continuous injection of steam or steam and hot water in much the same way that water is injected in water flooding. A reservoir or a portion thereof is developed with interlocking patterns of injection and production wells. During this process, a series of zones develop as the fluids move from injection well to producing well. Nearest the injection well is a steam zone, ahead of this is a zone of steam condensate (water), and in front of the condensed water is a band or region of oil being moved by the water. The steam and hot water zone together remove the oil and force it ahead of the water. Cyclic steam injection is usually attempted in a reservoir before a full-scale steam drive is initiated, partially as a means of determining the technical feasibility of the process for a particular reservoir and partly to improve the efficiency of the subsequent steam drive. A steam drive, where applicable, will recover more oil than cyclic steam injection and is one of the five EOR methods used in this study of the national potential for EOR processes [3-6].

2. Set up and Experimental Method

In this study, the reservoir condition is simulated based on a sand packed model (φ (sand porosity) = 0.23, K= 300 md). Figure (1) is illustrated the experimental set-up, that included:

1. A cylinder with a height of 1.5m and diameter of 4 in, filled with sifted sand
2. A centrifuge pump, which injects cold water into the system
3. Steam injection apparatus

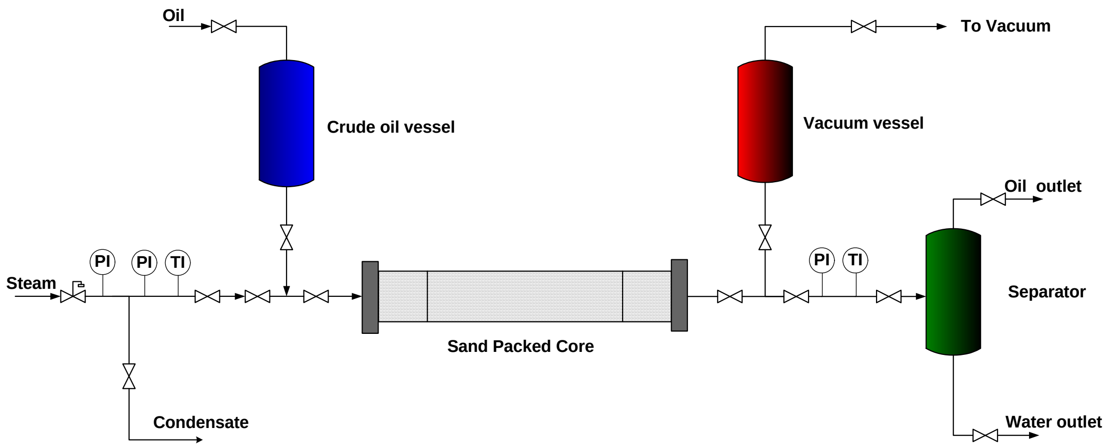

Figure (1): Steam injection set up

The first part of the device was connected to the steam injecting valve by rubber tubing and steam was injected with desired pressures. A pressure gauge and a thermometer display the input steam pressure. There was also a valve through which the oil was fed into the system until it was completely saturated. Finally a vacuum system was used to provide low pressures and a vessel for evacuating the oil and water. Table (I) is shown samples specification and experimental conditions used in this work.

Table (I): Experimental conditions in laboratory model

Experiment Type	Sample	Remarks
Steam Injection	No. 1 (API =13, Viscosity =1000 cp, Density = 980 kg/m3) No. 2 (API =17, Viscosity =700 cp, Density = 950 kg/m3)	Pressure Steam (3.2, 1.65 and 1.2 Barg)
Water Flooding	Heavy Oil (API =13, Viscosity =1000 cp, Density = 980 kg/m3)	T (°C) =14, Flow rate = 6 cc/s

Steam injection was carried out in 3.2, 1.65 and 1.2 bar_g pressures. The results obtained from steam injection recovery were compared with those from water injection under the same conditions. The amount of produced fluid was recorded in period times and it was repeated until the end of the test when steam came out of the tube. This point is called the breakthrough point. Recording was continued for a while after the breakthrough point and the level was recorded. After finishing each test, the system was saturated with oil for the next test and it was reached room temperature. It was important that the system be completely insulated. To saturate, Oil was poured from the end of the tube into the system through a case with a faucet. On the other side, in the end part of the system, the system was connected to a vacuumed case by rubber tubing and oil slowly poured through into the tube.

3. Discussion and Results

At first step, experiments are done on sample No.1 (API= 13) and steam is injected to the setup for system investigation.

The result is showed in figure (2). After a few minutes, produced fluid (oil and water) is exited and the rate of produced fluid is increased until steam reaches the end of the core (breakthrough).

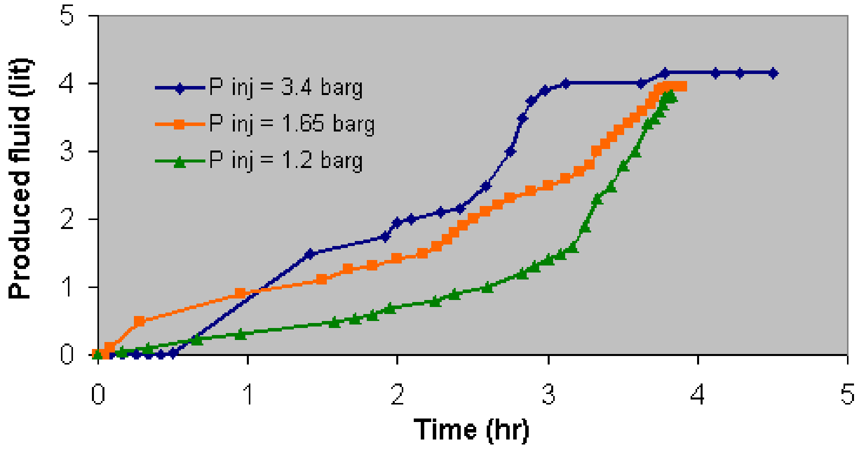

Figure (2): Produced Fluid versus Time (Sample No. =1)

Figure 2 is shown produced oil curve versus time, it indicated in 3.2 bar_g pressure steam, until 15 minutes the oil production was zero. After 20 minutes, oil production increased until 180 minutes from the beginning of the test, oil level became more than water level because the soak of temperature increased during the test. From this figure, it is observed that in the first times, the oil rate is little and after a few minutes, it increases. After 187 minutes, steam reached the breakthrough point. After the breakthrough point, oil production was approximately constant.

This experiment is done on sample 2; the same results can be seen (see fig 3,4) and by pressure decrease, recovery increases and the production of water decreases and steam reaches the breakthrough point later and oil specification is lighter and fluid produced time decreased.

With comparison of figures 2 and 4, it is obtained; Steam reaches to the breakthrough point later by decreasing API of heavy oil and steam reaches the breakthrough point later by decreasing pressure but production begins sooner and with a higher amount. On the other hand, the mount of produced water is less than in previous cases because heat loss is less.

Fluid production and recovery is a little more than that at the same pressure on the sample 1. It can be concluded that steam in the 3.2 bar_g reaches the point of breakthrough sooner than the other pressures. This means that level curve has more gradient as compared with time. On the other hand, recovery in 3.2 bar_g was less than those at 1.65 and 1.2 bar_g because as pressure goes up, the temperature of injection increases too.

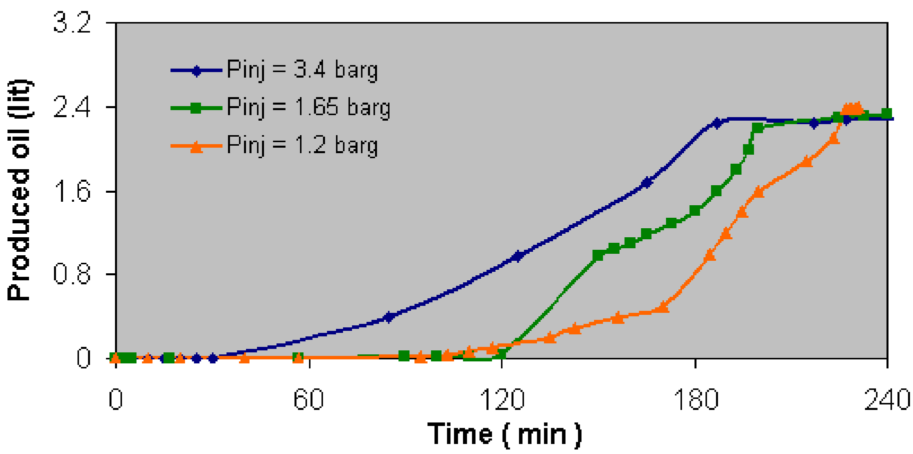

Figure (3): Produced Oil versus Time (Sample No. 1)

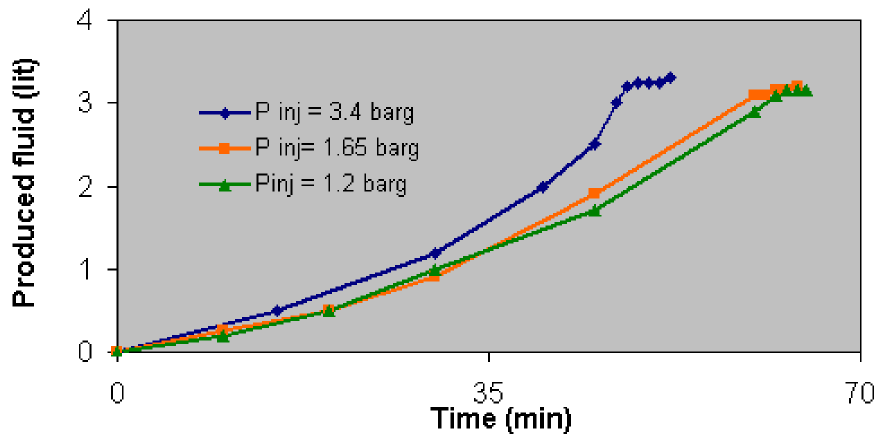

Figure (4): Produced Fluid versus Time (Sample No. =2)

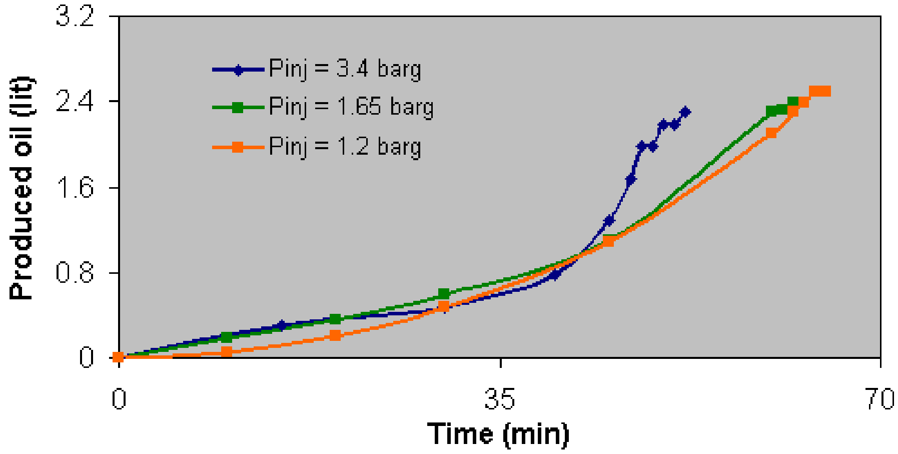

Figure (5): Produced Oil versus Time (Sample No. =2)

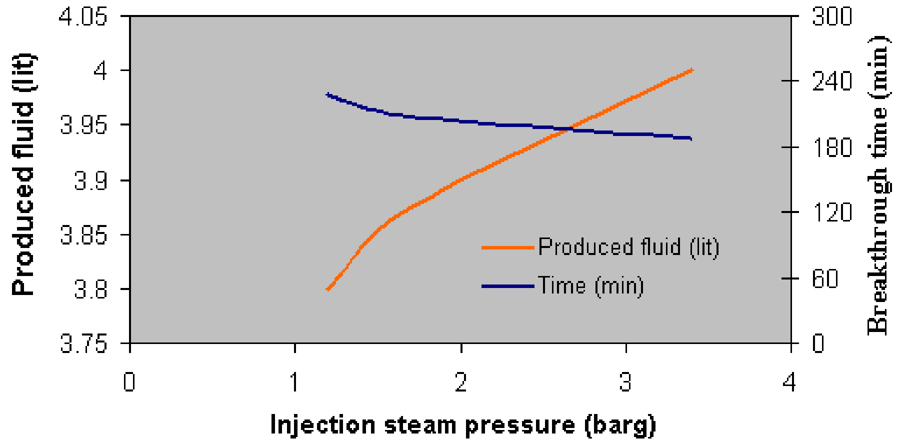

Figure (6): Breakthrough point curve (Sample No. =1)

The recovery curve as compared with produced fluid the gradient of curve in 1.2 bar_g was more than those at 1.65 and 3.2 bar_g and the level of water was less than 3.2 and 1.65 bar_g, therefore as pressure goes up steam can reach the point of breakthrough sooner but the recovery decreases. Because; as the steam pressure increase, evaporation heat decrease, therefore required steam for heating is increased.

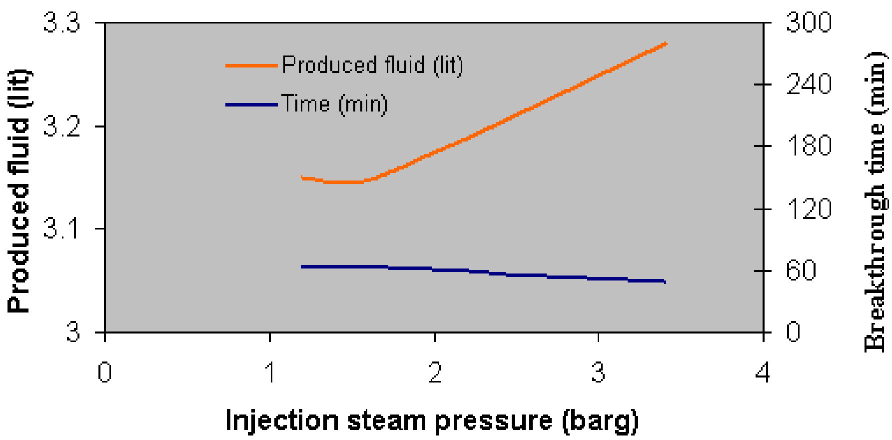

Figure (7): Breakthrough point curve (Sample No. =2)

Figure 8 indicates water flooding in sand packed core. This figure showed that recovery in water flooding was less than in steam injection because fingering effect has occurred and consequently the vertical sweep efficiency and oil production decreased.

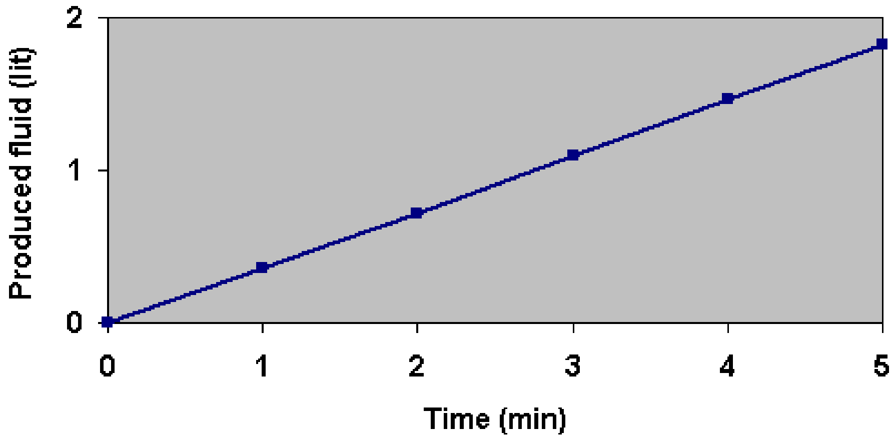

Figure (8): Produced Oil versus Time cold water injection

4. Conclusion

The result shown that, breakthrough point arises sooner in higher pressure (3.2 bar_g). But recovery in 3.2 bar_g is less than in 1.2 and 1.65 bar_g because as pressure increases, the temperature of injection increases too.

On the other hand, the temperature of condensate increases as well. This means that the heat needed for evaporation decreases and the amount of steam needed for heating the tank increases. It is observed that in the recovery curve as compared with produced fluid the gradient of curve in 1.2 bar_g is more than those in 3.2 and 1.65 bar_g. The level of water is less than 3.2 and 1.65 bar_g, so it can be conclude that as pressure goes up, steam can reach the point of breakthrough sooner and the recovery decreases as well. It is seen that cool water reaches the point of breakthrough sooner than steam and thus the recovery of cool water is lower than that of steam. In this test, fingering has occurred because $\mu_w << \mu_o$.

The steam reaches the point of breakthrough sooner than API decrease. On the other hand because the light oil contains high fractions of steam distillable components under the same pressure. If the oils are a little different in viscosity, recovery in the light oil is more than that in heavy oil. Also in the highly viscous oils and light oils, recovery in the heavy oil is much higher than in light oil. For higher recovery, first we should do steam stimulation and then steam injection.

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