Research on the 3-D Oil Saturation Variation of the Oil Sand at 45° Stratigraphic Dip Angle with Hot-Water-Flooding

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ABSTRACT

Most of oil sands mineral distributed in the slope and upheaval of the basin's edge, and hot water flooding is one of EOR methods for the high-viscosity oil. In this paper the 3-D physical model for oil sands reservoir of angle 45° was studied, and the flooding way of this experiment was hot water flooding.†

KEYWORDS

Hot Water Flooding; 3-D Physical Model; Angle;

INTRODUCTION

The hot water flooding is the basic ways of thermal recovery, widely employed both home and abroad [1-2]. But there is lack of the experiments of the reservoir’s physical stimulation where dip angle is the major variable. So it is instructive to study the effect of reservoir stratigraphic dip angle on the developing of combined wells with hot water flooding the oil sand.

EXPERIMENT

The Parameter in the Experimental Condition

The oil sand used in the experiment is from Zhenlai, Jilin. The density of the

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layer’s crude oil is 0.9156g/cm³, the solidifying point is at the temperature of 20°C. Most of rocks in the oil sand ore are mainly feldspar and clast of quartz. Most of clay minerals are goeschwitzite.

**The Experimental Study of Three-Dimensional Well Pattern Model**

The water at the temperature of 70°C is used as the displacing phase in the first stage; the dip angle is 45°; the temperature of the incubator is 39.2°C; the overlying formation made by hydraulic ram is 4Mpa. The oil sands specimen is injected into the physical model’s cell. The straight well from the upper left is selected as the injection well, and the two wells which are vertical with each other are used as producing well. There are two horizontal wells. The one is paralleled to the direction of the dip angle and the other one is vertical to the dip angle. In other to record, the one paralleled to the dip angle is well I and the other one vertical to the dip angle is called well II.

When the dip angle is 45°, the breakthrough time of the well I is 0.031PV and the breakthrough time of the well is 0.192PV. The accumulative liquid producing capacity is 7972.3mL, and the crude output is 1401.0mL.

**The Variation of Oil Saturation**

When the dip angle is 45°, the distribution of the oil saturation field is shown as the Fig.1 when the pore volume is different.

The Fig.1a is the initial distribution of the oil saturation when the angle is 45°. From the picture it is learned that the sand injection is well-distributed, so the differences among the oil saturation are not very serious, which is similar to the fig.5a.

The Fig.1b is the distribution of the oil saturation field when the injection water volume is 0.124 times as much as the pore volume. This is the stage when the pressure field forms. From the picture, it is shown that the water advance front was advanced at the horizontal direction, and then it changed the direction to the 45°, because of the existence of dip angle. So the oil saturation gradually reduces at the direction of the main stream line of the straight well and the well I. Before this moment, the oil entered into the horizontal well I, and didn’t enter well II.

The Fig.1c is the distribution of the oil saturation field when the injection water volume is 0.483 times as much as the pore volume. The oil saturation of these points (1, 9), (1, 8), (1, 7), (1, 6), (1, 5) and near these points is lower and reaches 55%.

The Fig.1d is the distribution of the oil saturation field when the injection water volume is 1.076 times as much as the pore volume. From the picture it is shown that the oil saturation is partly low at the points (5, 3), (5, 1). This is because the increase of the injection time causes the increase of the bottom’s water content of the reservoir.

The Fig.1e is the distribution of the oil saturation field when the injection
water volume is 2.191 times as much as the pore volume. The oil saturation of the area near the (1, 9) and (1, 5) is low, reducing below the 43%. This is the latter stage of the development, where the oil saturation is low but keeps stable, and the developing capacity mainly concentrates on the middle low, and the oil content still keeps low and basically stable.

The Fig.1f is the distribution of the oil saturation field when the injection water volume is 3.425 times as much as the pore volume. This is the end of the experiment. From the picture, the oil saturation field of the simulation is not well-distributed. The lower left and the most of the right areas are not use to stimulate for development.

Combining Fig.1c with Fig.1d, it is shown that the oil saturation of the well I is always lower than that of the well II. The later well keeps the pressure differences all the way. So it is induced that the main stream line of the straight well to the well I, the velocity of the displacement is much higher, which is because the viscosity related to the fluid is more serious than the gravity. And the cusping happens at the water advance front, where the displacement is not stable. So at the direction of the main stream of the well I and the straight well, the velocity of the displacement is low. So the area of the water advance front is advanced at the similar speed, meanwhile the water advance front keeps stable, because of the differences of the density of the oil and the water. The water advance front is advanced steadily, finally changing to the gravity displacement.

Figure 1. Oil saturation at 45° angle.
CONCLUSIONS

Physical simulation is used in this paper, to study the oil sand experimentally with the hot water flooding using the three-dimensional well pattern model. According to the image and data analysis, when reservoir Angle 45°, the migration of water advancing front by gravity. As injection time goes by, water tongue phenomenon appears in the direction of injection well mainstream line and well I. This is why the output oil and water of well 2 are higher than that of well 1.

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