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Steam Injection in A Waterflooding, Light Oil Reservoir

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Abstract

Steam injection, one of commercial technologies widely used to develop heavy oil reservoir, has brought reservoir engineer's attention to improve performance of waterflooding, light oil reservoir and enhance its oil recovery. Sarto reservoir, located at the transitional belt in Daqing Oil Field, is the case of steam injection utilized. It is a typical multi-layer sandstone fluvial and deltaic deposit with depth of 1000~1200m, permeability of 500~2000md and porosity of 20~30%, surface oil viscosity of 50~100cp @ 50°C, wax content of 25~30% and freezing point of 30~35 °C.

The reservoir came into development in 1989 with line drive water injection with line space of 250~270m. Water injection has good response at the early stage and several years' later water cut increased rapidly. In 2005, water cut increased to 90%. However, oil recovery was only 14%, lots of oil has been left in the reservoir. Measurements such as water plugging, profile modification and layered water injection show good but unexcited response. In 2005, steam injection was utilized to improve the performance and enhance the oil recovery.

The paper will firstly discuss mechanisms, strategies as well as barriers and difficulties to high recovery of steam injection in such waterflooding, light oil Sarto reservoir. It will also detail reservoir engineering study, such as well pattern suitable to steam injection, development manner, injection and production system, and its pilot test plan. Finally, the paper will introduce production history of steam injection and analyze its performance and influence factors. The pilot shows us that steam injection has great potential in improving injection and production profiles, increasing productivity, decreasing water cut and enhancing oil recovery.

Introduction

Steam injection, one of commercial technologies widely used to develop heavy oil reservoir, has brought reservoir engineers 'attention to improve performance of waterflooding, light oil reservoir and enhance its oil recovery. There are several successful pilot tests of steam injection in the waterflooding reservoir[1] such as Wilmington oil field[2] (1981), Brea field (1973)[3], Elk Hill (1987)[4], Ruhlermoor (1987)[1], Minas (1997) [1].

Sarto reservoir, located at the 4th transitional belt in Daqing Oil Field, is developed by nearly 20-year's waterflooding with 14% oil recovery but 90% water-cut. It is a typical multi-layer sandstone fluvial and deltaic deposit with depth of 1000~1200m, permeability of 500~2000md and porosity of 20~30%, surface oil viscosity of 50~100cp @ 50°C, wax content of 25~30% and freezing point of 30~35 °C. How to rejuvenate such mature reservoir with 'secondary water body' and water channel formed during long-time water flooding? The answer is steam injection. This paper will introduce lab experiments and numerical simulation to study the steam injection in the mature water flooding reservoir such as its mechanisms, its key influence factors and its strategies as well as the pilot test performance.

Development History of Water flooding

The 4th belt, located at north of Sarto oil field, is a heterogeneous multi-zone river-delta deposit with the dip of 2° and the depth of 1000~1200m. The deposit thickness is about 50~60m with the permeability of 50~800 mD and average porosity of 24% and initial oil saturation of 70%. The reservoir has two pay zones which are S-1 and S-2, is a typical waterflooding reservoir but with high oil viscosity of 108mPa.s in 4th belt and high wax content of 25~30% and freezing point of 30~35 °C

The 4th belt reservoir came into development in 1989 with line water flooding with line space of 250~270m (see Fig. 1) and the targeted zone is S-1 and S-2. Water injection has good response at the early stage with oil production per well of 20~40t/d and low water cut about 5~10%. After 13 years' water injection, the water cut increased rapidly to 80%. In 2005, water cut increased to 90%, the oil production was about 2~5t/d and oil recovery was only 14%. Lots of oil has been left in the reservoir. How to improve the oil recovery became a challenge faced to reservoir engineers. Measurements such as water