Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 12	No. 2	pp. 345-348	2013

Original Research Paper

An Optimization Study on Equilibrium Development Technology of Horizontal Wells in Edge Water Reservoirs

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 20-2-2013
Accepted: 22-3-2013

Key Words:
Horizontal well
Pressure drop
Equilibrium development
Edge water reservoir
Reservoir heterogeneity

ABSTRACT

In the production process of horizontal well, a pressure drop exists in horizontal wellbore from the toe to the heel, leading to different producing pressure drops at various points of horizontal section. And the water will early breakthrough in local horizontal section, which influences on the development effect of horizontal wells. Thus, it is required to combine the pressure drop characteristics in horizontal wellbore with reservoir heterogeneity and the location of horizontal section, in order to achieve equilibrium development of horizontal wells. The edge water reservoir was taken as an example in this study, where the reservoir simulation technology was used for analysing the influences of reservoir permeability difference along the horizontal wellbore, thickness difference along the horizontal wellbore and the angle between horizontal section and oil-water interface on horizontal well development. As a result, reservoir parameters policy limits were obtained for achieving equilibrium development of horizontal wells, providing a basis for the optimal design of horizontal wells in edge water reservoirs.

INTRODUCTION

In using horizontal well technology for development of edge water fault block reservoirs, the key of efficient development of horizontal wells is to enable simultaneous water breakthrough at various points of horizontal wellbore and to extend the time of water breakthrough in horizontal wells, so as to improve oil production in water-free period. In the production process of horizontal wells, the fluids flow from the reservoirs into horizontal wellbore through various points. In the horizontal wellbore from the toe to the heel, the fluid mass flow is gradually increasing with a certain pressure drop from the toe to the heel (Novy 1995, Suwan 2000, Sun 2010).

In the horizontal wellbore, the pressure at the heel is smaller than that at the toe in horizontal section, so that the producing pressure drop at the heel is greater than that at the toe. Different producing pressure drops will influence the advance speed of edge water, resulting in water breakthrough at the heel prior to that at the toe in horizontal wells, which is not beneficial to efficient development of horizon (Dikken 1990, Penmatcha 1999). To achieve the simultaneous water breakthrough at various points in horizontal section and the equilibrium development of horizontal wells, the reservoir simulation method was applied to conduct an optimization study on equilibrium development technology of horizontal wells in edge water fault block reservoirs.

FORMATION PRESSURE AND SATURATION DISTRIBUTION

An edge-water reservoir geological model was established, where the basic parameters are given in Table 1.

Fig. 1 shows the formation pressure distribution in horizontal well production. It can be seen that considering the pressure drop in the wellbore, the pressure at the toe is higher, while that at the heel is lower.

With or without considering the pressure drop within the wellbore in homogeneous reservoirs, the calculated saturation distribution of remaining oil is shown in Fig. 2. It can be seen that considering the pressure drop in horizontal wellbore, premature water breakthrough occurs at the heel of horizontal section; without considering the pressure drop in horizontal wellbore, relatively paralleled advance occurs to oil-water interface.

The pressure drop exists objectively in the horizontal wellbore, and therefore a full use of pressure drop distribution in horizontal wellbore, reservoir heterogeneity and the location of horizontal section are required to achieve equilibrium development of horizontal wells.

THE INFLUENCE OF PERMEABILITY DIFFERENCE ON EQUILIBRIUM DEVELOPMENT OF HORIZONTAL WELLS

Along the horizontal wellbore, reservoir permeability

Table 1: The geologic parameters of the reservoir.

Parameters	Value
Average thickness (m)	6
Porosity (%)	28
Average permeability (μm^2)	0.60
Initial reservoir pressure (MPa)	18.6
Central reservoir altitude (m)	2025.5
Oil/water interface altitude (m)	2045
Formation oil density (g/cm^3)	0.826
Formation oil viscosity(mPa.s)	20
Oil formation volume factor	1.135
Stratigraphic dip (degree)	10
Wellbore relative roughness	0.0006

changes will influence the advance speed and shape of oil-water interface. In case of horizontal section parallel to original oil-water interface, the remaining oil distribution was obtained with different permeability difference i.e., the permeability difference is the ratio between the permeability at the heel and that at the toe in horizontal section. Along the horizontal section, the permeability distribution is equidifferent. In different cases, the average permeability of formation remains unchanged.

Fig. 3 shows the remaining oil distribution with the permeability difference of 0.50, 0.667, 1.0 and 1.5 respectively. It can be seen that when the permeability difference is greater than 1, i.e., the permeability at the heel is greater than that at the toe, influenced by the small flowing resistance and large producing pressure drop at the heel of horizontal well, water breakthrough occurs to the heel in horizontal section earlier. Moreover, the greater the permeability difference is, the larger the breakthrough at the heel of horizontal section will be. Therefore, the heel of horizontal well should be placed in the area with a small permeability in optimal design of horizontal wells. Calculations show that when the length of horizontal section is 300m with the permeability at the heel as 2/3 of that at the toe, relatively uniform advance occurs to oil-water interface with basically the same time of water breakthrough at various points of horizontal section, which is beneficial to equilibrium development of horizontal wells.

THE INFLUENCE OF THICKNESS DIFFERENCE ON THE DEVELOPMENT OF HORIZONTAL WELLS

With different reservoir thickness along the horizontal section, the water breakthrough time is also different at various points of horizontal wellbore. Under the condition that the horizontal section is parallel to the original oil-water interface, remaining oil distribution was calculated and analysed with different thickness difference i.e., thickness difference is the ratio between the thickness at the heel and that at the toe in horizontal section. Thickness along the horizontal section takes on equidifferent distribution. In case of different

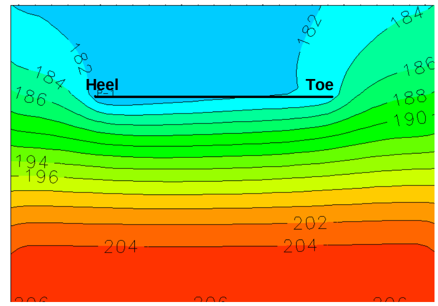
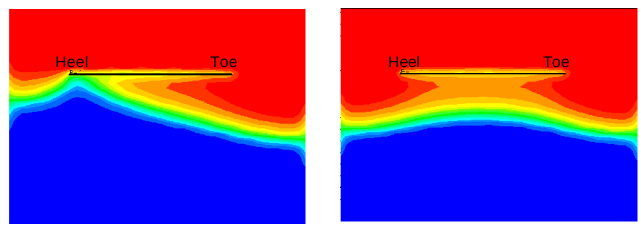


Fig. 1: The formation pressure distribution considering the pressure drop in the well bore.



A. considering the pressure drop B. without considering the pressure drop

Fig. 2: The effect of pressure drop on remaining oil distribution.

thickness difference, the average thickness of formation remains unchanged.

Fig. 4 shows the remaining oil distribution with the thickness difference of 0.33, 2.0, 3.0 and 5.0 respectively. It can be seen that when the thickness difference is less than 1, uneven advance occurs to oil-water interface, and water breakthrough occurs to the heel in horizontal well earlier. Therefore, the heel of horizontal wells shall be placed in the area with a large thickness in optimal design of horizontal wells. Calculation results show that when the horizontal section is 300m in length with the thickness at the heel as a triple of that at the toe, relatively uniform advance occurs to oil-water interface with basically the same time of water breakthrough at various points of horizontal wellbore.

THE ANGLE BETWEEN HORIZONTAL SECTION AND OIL-WATER INTERFACE

During the development of edge water reservoir with horizontal wells under the condition of homogeneous stratum, horizontal section shall not remain parallel to oil-water interface due to the influence of pressure distribution within horizontal wellbore.

Under the condition that horizontal section remains unchanged in length, different angles are set between horizontal section and original oil-water interface, as shown in Fig. 5. It can be seen that when the heel of horizontal well is close to original oil-water interface, water breakthrough

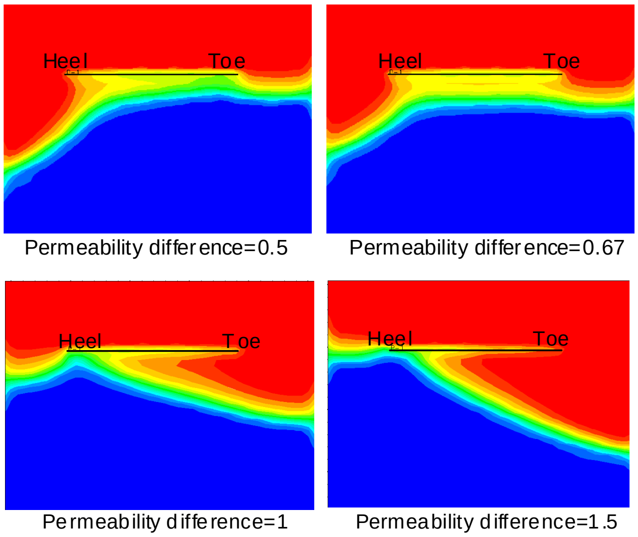


Fig. 3: The remaining oil distribution in different permeability difference.

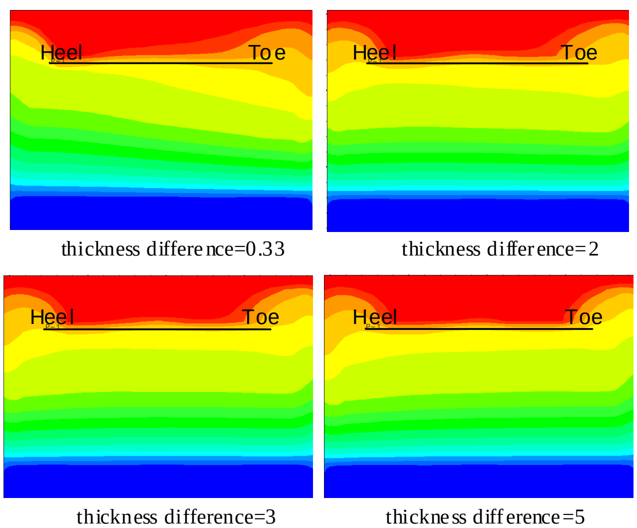


Fig. 4: The remaining oil distribution in different thickness difference.

occurs to the heel of wellbore earlier. Moreover, uneven advance occurs to oil-water interface, thus it is difficult to achieve simultaneous water breakthrough in horizontal wellbore. When the toe of horizontal section is close to original oil-water interface with an angle of about 10° between horizontal section and original oil-water interface, the advance of oil-water interface is parallel to horizontal section, thus it is able to achieve simultaneous water breakthrough in horizontal wellbore. When the angle between horizontal well and oil-water interface is greater than 10°, water breakthrough occurs to the toe of horizontal well earlier.

Therefore, during the development of edge water fault block reservoir with homogeneous stratum by horizontal well, when the toe of horizontal well is close to oil-water interface and the angle between horizontal well and oil-water interface is about 10°, the requirements of balanced development of horizontal wells can be satisfied, with a higher oil recovery and a better development effect.

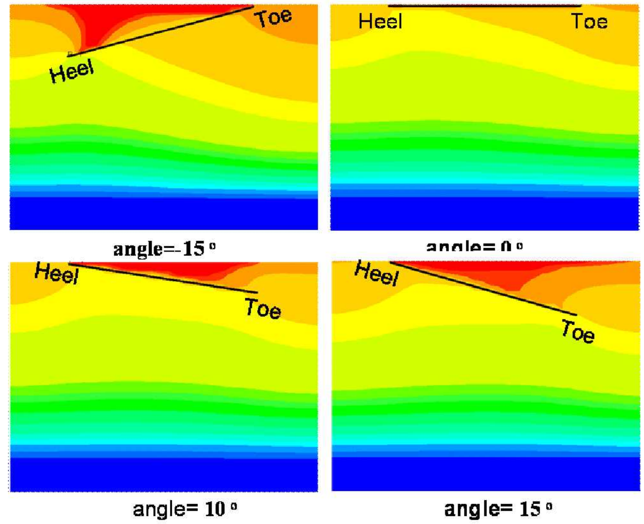


Fig. 5: The remaining oil distribution in different angle.

CONCLUSIONS

The reservoir simulation technology was used to establish the policy limits of balanced development of horizontal wells in edge water reservoirs, thus, providing a basis for an optimal design of horizontal wells.

During the deployment of horizontal wells in edge water reservoirs, the heel of horizontal section shall be placed in a zone of low-value permeability, while the toe in a zone of high-value permeability, which is beneficial to balanced development of horizontal wells. In the horizontal section with a length of 300m, uniform advance occurs to oil-water interface when the permeability difference between the heel and the toe in horizontal section is 0.67.

Under the condition that reservoir thicknesses is different, wells shall be deployed at the heel of horizontal section in a zone of high-value thickness, which is beneficial to balanced development of horizontal wells. In the horizontal section with a length of 300m, water breakthrough time at various points of horizontal section is approximately the same when the thickness difference between the heel and the toe is 3.

Under the condition of homogeneous reservoir stratum, the situation that the distance of the heel in horizontal section from oil-water interface is greater than that of the toe from oil-water interface will be beneficial to balanced development of horizontal wells. When the angle between horizontal section and oil-water interface is about 10°, advanced oil-water interface is basically parallel to horizontal section.

ACKNOWLEDGEMENT

This work was supported by China National Science and Technology Major Projects (Topic name: The technology to improve oil recovery at high water cut period in Shengli oilfield, Topic number: 2011ZX05011-03).

REFERENCES

Dikken, Ben J. 1990. Pressure drops in horizontal wells and its effect on production performance. Journal of Petroleum Technology, 42(11): 1426-1433.

Novy, R.A. 1995. Pressure drops in horizontal wells: When can they be ignored? SPE Reservoir Engineering, SPE Reservoir Engineering, 10(1):29-35.

Sun Keming, Li Kai, Tan Jian 2010. Study on fluid-solid coupling in horizontal well and pressure drop in pit shaft. Journal of Liaoning Technical University (Natural Science), 29(4): 582-585.

Suwan Umnuayponwiwat and Erdal Ozkan 2000. Water and gas coning toward finite-conductivity horizontal wells: Cone buildup and breakthrough. Paper SPE 60308-MS Presented at SPE Rocky Mountain Regional/Low-Permeability Reservoirs Symposium and Exhibition, 12-15 March, Denver, Colorado

Penmatcha, V.R., Sepehr Arbabi and Khalid Aziz 1999. Effects of pressure drop in horizontal wells and optimum well length. SPE Journal, 4(3): 215-223.