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Experimental study on different water flooding methods for fractured-vuggy reservoir based on 3D printing

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Experimental study on different water flooding methods for fractured-vuggy reservoir based on 3D printing

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Abstract. To study the distribution of residual oil after water flooding and the effectiveness of improved water flooding, the 3D printer was used to print the 3D model to imitate the fractured-vuggy reservoir modles of Tahe Oilfield. The purpose of this paper is to quantitatively describe the distribution of the remaining oil, study the mechanism of different improved water flooding methods, and provide theoretical support and technical support for further study of oil recovery. The experimental results of the three-dimensional model show that the remaining oil in such fracture-cavity reservoirs mainly exists at the top of the structure and the corners of the cave model, as well as the injection wells and the raised centers of the model.The remaining oil at the injection well can be produced after the injection-production inversion. After gas injection, the oil at the top of the model and the raised centers can be produced, indicating that changing the water flooding method can increase the oil production of the well.

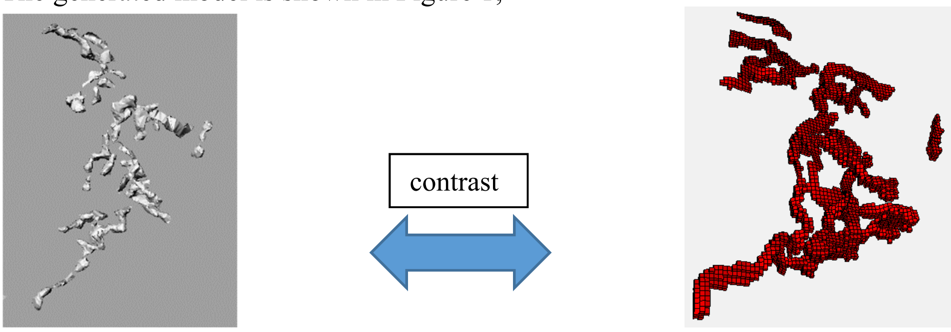
1. Introduction

Some research results of the development of carbonate fracture-cavity reservoirs at home and abroad has showed that the spatial variation of such reservoirs is large, diverse, and the filling medium is complex, which is quite different from ordinary sandstone reservoirs. The space of this kind of reservoir is mainly cracks and caves, and the matrix is basically impermeable. Its complex characteristics cause the complexity of the internal fluid flow and different water flooding methods' mechanisms. With the development of the reservoir, the energy and production of the reservoir are seriously attenuated. As a result, for the current low water flooding efficiency, it is urgent to study different water flooding methods to further improve the oil displacement effect. In order to study different water flooding methods, it is necessary to have a model similar to the actual fractured-vuggy reservoir, to observe the distribution of remaining oil, and to study the different ways of improved water flooding methods, and finally to provide theoretical and technical support for further improving reservoir recovery[1-2].3D printing technology can precisely control the size parameters of the fractures and holes, especially the three-dimensional complex shape of the fracture-cavity model. Therefore, 3D printing technology was used in this paper to make the fractured-vuggy physical model[3-4].

2. Establishment of 3D fracture cavity unit model

2.1. data modeling method to generation models

Firstly, export the geologic model network coordinates from the Petrel geological modeling software. Then, the coordinates of the surface network of the geological model are extracted by using Matlab programming to obtain the surface network model of the geological model. Finally, the coordinate points are imported into solidworks to generate the required format for 3D printing system by reverse modeling. The generated model is shown in Figure 1;



Reverse modeling to generate the required model for 3D printing

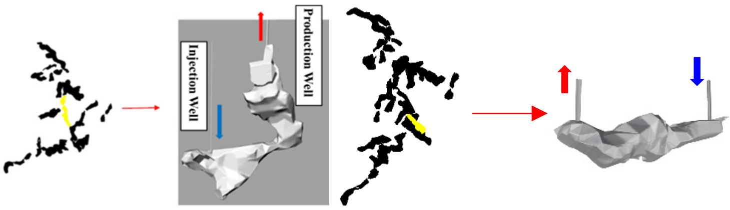
Petrel geological model

Figure 1 Data modeling method to generate 3D models

2.2. Selection and production of experimental cavity model

Firstly, the geological model is exported from the 3D modeling software to generate the required STL files for printing by reverse modeling. Secondly, the magic software is used to convert the three-dimensional structure into a slice file and the slice is converted into a track file by the rapid prototyping program and is made to athree-dimensional model based on the AFS automatic forming system. Then, using glass plate sealing the model, drilling at a specific location and sticking a plastic pipeline as injection and production wells. Finally, placing probes on the three-dimensional model for detecting oil or water saturation in the fracture and cavity.

The single-hole model, the single-hole middle bulge model and the single-hole two bulge model are selected for the experiment. Some examples of the model are shown in Figure 2:



Single-hole model Single-hole middle bulge model

Figure 2 Schematic diagram of some 3D models

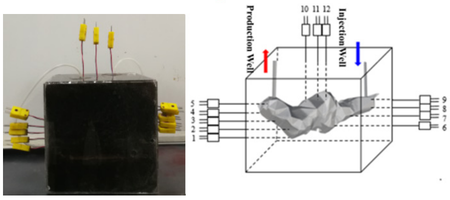


Figure 3 Complete 3D fracture-vuggy model

3. Water flooding experiments by using three-dimensional physical model

1) Experimental conditions: temperature: 25 ° C, flow rate: 20 ml / min.

2) Experimental materials: The oil was prepared according to the viscosity requirement by using pure kerosene and vacuum pump oil in a certain ratio. The density of the oil was 0.8 g/cm^3, and the viscosity was 2.745 mPa·s. In order to distinguish between water and oil easily, Sudan Red Ⅲ was added into the oil. The water was 5% NaCl solution with a density of 1.04 g/cm^3 and a viscosity of 1.14 mPa·s.

Experimental equipments: advection pump, pressure gauge, oil-water separator, stopwatch, TH2810D type LCR digital bridge.

3) Experimental steps and processes:

(1) Saturate the model with red simulated oil.

(2) Displace the oil by water on the fracture-cavity model. Record the oil production rate, water production rate, and measure the oil and water resistance value in the model in real time.

(3) Stop the experiment when the velocity of the oil drops to 0.

The flow chart is shown in Figure 4:

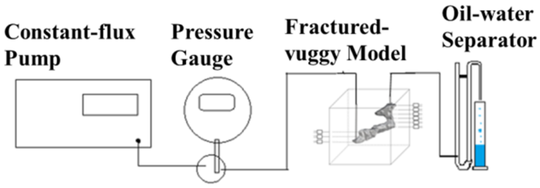


Figure 4 experimental flow chart

4. Experimental results and discussion

4.1. Single-hole model experiment results

The resistance values of the respective probes at different displacement speeds were measured, and the oil-water distribution was determined as shown in Fig. 5 according to the measured probe number measured with time.

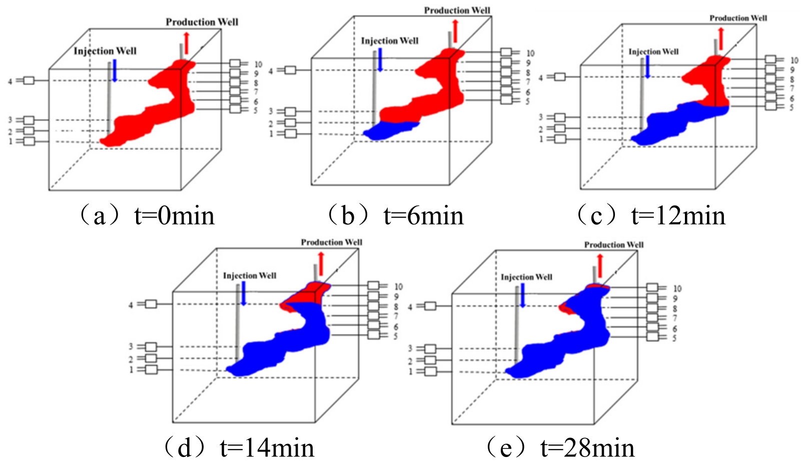


Figure 5 Distribution of oil and water at 20ml/min displacement

Fig. 6 showed the change of oil production rate and oil production during the displacement process with time.

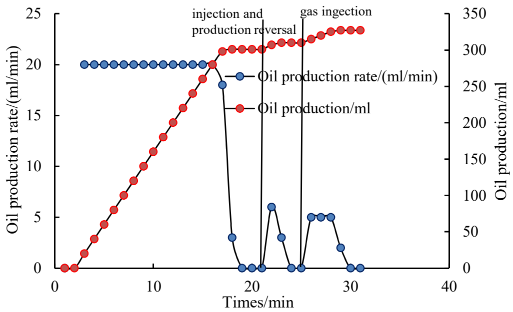


Fig.6 Curve of oil production rate and oil production during 20ml/min vs time

It can be seen from the curve that when the water cut reached 100% by water flooding with a constant speed, then change the displacement direction or inject gas in the injection well, there is more oil produced out. The result indicate that there is remaining oil in the model when the water flooding is completed with a constant speed and the oil recovery can be increased by changing the water flooding method.

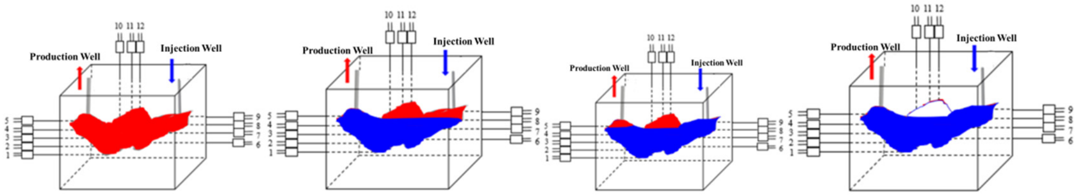
(1) It can be seen from the probe detection results that the resistance measured by the probe at the top end of the structure and the corner of the hole model is still shown as the oil phase resistance and the oil is produced out after changing the water flooding method, indicating that these places have remaining oil.

(2) There is more oil produced out by changing the water flooding method when the water cut reached 100% by water flooding with a constant speed, indicating that changing the water flooding method may increase the oil production.

(3) For such single-hole models with good connectivity and reasonable well position, water production laws would be the same with same flooding pattern. In order to increase oil production, different types of remaining oil should be driven by different water flooding methods.

4.2. Single-hole middle bulge model experiment results

The resistance values of the respective probes at different displacement speeds were measured, and the oil-water distribution was made as shown in Fig. 7 based on the measured probe number measured with time.



（a）t=0min （b）t=6min （c）t=12min （d）t=14min

Fig.7 Curve of oil production rate and oil production during 20ml/min vs time

The change of oil production rate and oil production during the displacement process is recorded in real time, and the corresponding curve is drawn in Fig. 8.

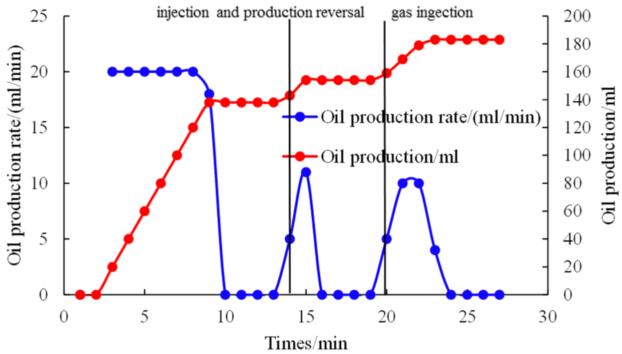


Fig.8 Curve of oil production rate and oil production during 20ml/min vs time

It can be seen from the displacement results that when the water content is displaced at a constant speed to 100%, then change the displacement direction or inject gas in the injection well, there is more oil produced out. The result indicating that there is remaining oil in the model when the water flooding is completed with a constant speed and the oil recovery can be increased by changing the water flooding method.

(1) It can be seen from the probe test results that the resistance measured by the probe at the injection well and the two bulge portions of the model still shows the oil phase resistance at the end of the positive flooding at a constant water velocity. More oil is produced with changing the flooding direction, and the resistance measured by the probe at the injection well is the water phase resistance,

indicating there is residual oil at the injection well. However, the resistance measured by the probe at the middle bulge of the model is still the oil phase resistance.

(2) There is more oil produced out by changing the water flooding method when the water cut reached 100% by water flooding with a constant speed, indicating that changing the water flooding method may increase the oil production. For such a closed model, the positive constant speed water flooding can displace the oil in the lower part of the model. After changing the derection of injection and injecting gas in the injection well, the remaining oil at the top of the model and at the injection well can be recovered.

5. Conclusion

From the above experimental results, it can be seen that the remaining oil in such fracture-cavity reservoirs mainly exists at the top of the structure and the corners of the cave model, as well as the injection wells and the raised centers of the model. The remaining oil at the injection well can be produced after the injection-production inversion. It can be produced. After gas injection, the oil at the top of the model and the raised centers middle bulge can be produced, indicating that changing the water flooding method can increase the oil production of the well.

Acknowledgments

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References

[1] Yu, M.(2016) Research on 3D printing technology of fracture-cavity reservoir and distribution law of residual oil in water flooding [D]. Shandong: China University of Petroleum.

[2] Wang, C.Q.(2017) Study on water flooding law and enhanced oil recovery in fractured vuggy reservoirs [D]. Shandong: China University of Petroleum.

[3] Liu, H.C, Mo J H, et al.(2008) Three-dimensional printing rapid prototyping technology and its application[J].Mechanical Science and Technology,27(9):1184～1186.

[4] Yang, X.L, Zhou T.R. Three-dimensional printing rapid prototyping technology and its application[J]. Journal of Zhejiang University of Science and Technology, 3: 186~189.