Numerical Simulation on displacement mechanism of fracture-cave reservoir surfactant-Assisted N_2 huff and puff in Tahe Oilfield

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Keywords: surfactant；N_2 huff and puff；numerical simulation；fracture-cave；enhanced oil recovery；

Abstract. Some fracture-cave units controlled by single well in fractured-vuggy carbonate reservoirs lack natural energy, which leads to rapid decline of production and recovery. Having applied the N_2 huff and puff, Tahe Oilfield has improved their exploitation. However, the effect of N_2 injection weakens in the production process. So it is necessary to seek new method for exploitation of fractured-vuggy reservoirs. Combing with the numerical simulation, then analyzing the qualitative and quantitative influences of injection rate, injection concentration of surfactant on the recovery efficiency of isolated fracture-cave units, this paper focuses on the problem of the fractured-vuggy carbonate oil reservoir's low recovery, and also forecasts the effect of the different surfactant-Assisted N_2 huff and puff scheme, then presents the best plan in this reservoir condition and acquires the main control factors of the surfactant - assisted N_2 huff and puff.

Introduction

Tahe Oilfield is the largest marine carbonated oil and gas field discovered and developed in China, where the Ordovician carbonate fracture-cave formation is currently the largest carbonate reservoir in China [1]. The Ordovician carbonate fracture-cave formations in Tahe Oilfield are characterized by strong heterogeneity, large natural decline rate and low recovery. Water injection is currently one of the main method to enhanced oil recovery in reservoirs [2-3]. However, with the development of oil fields, water injection wells increased year by year, more and more wells are out of work, the effect of water injection are gradually worse. In the face of these difficulties, gas injection is currently proposed as a replacement technology [4-9]. In May 2012, Tahe Oilfield carried out some gas injection enhanced recovery tests, and achieved a good increased effect at the site [10]. In order to further understand the displacement mechanism and related parameters of single well gas huff and puff, it is necessary to carry out the research on relevant oil and gas reservoir. This thesis takes carbonate fracture-cave formation of the Ordovician, the 6th District of Tahe Oilfield as an example, combing with the numerical simulation, establishing a surfactant-assisted N_2 huff and puff model, then optimizing the parameters to ensure the accuracy of the surfactant-assisted N_2 huff and puff model. On this basis, the injection parameters are adjusted. This research helps to further understand the migration and distribution of surfactant-assisted N_2 huff and puff in the macroscopic fluid field, which has realistic guiding significance for oil field production.

Laboratory experiments show that there are three exploitation mechanisms for N_2 huff and puff.

(1) The injection of N_2 can effectively supplement the formation energy and maintain the pressure of the reservoir, forming a huge elastic energy. Because N_2 has a large Z-factor, it has good compressibility and expansibility, making N_2 a huge elastic energy in the oil replacement process.

(2) N_2 is insoluble in water, less soluble in oil, and can be injected in the form of an immiscible evaporative gas drive to extract crude oil. Although the solubility of N_2 in oil is very low, it can extract (vaporize) the light hydrocarbons and intermediate hydrocarbon components in the oil, allowing it to

be enriched, driving the immobile oil into a mobile oil, finally increasing oil flow. Nitrogen can enter low-permeability reservoirs where water cannot enter, and can "carry" crude oil in the low-permeability zone in a immobile state.

(3) N_2 has a low density and can displace oil in a gravity-differentiation manner.

Surfactants can wash oil, emulsify oil, reduce the viscosity of oil. In particular, after the N_2 injection, the thickening of crude oil due to the deposition of organic matter has been improved, thereby improving the N_2 huff and puff effect.

Reservoir and fluid properties

The Ordovician carbonate formation in the 6th District of Tahe Oilfield is an ancient weathering crust-karst fracture-cavity formation with fractured cave as the main reservoir space. Reservoir depth is 5400-5600m. Pressure coefficient is generally 1.08~1.10. Formation temperature gradient is 2.2~2.3°C/100m. Formation temperature is about 129.4°C. Permeability is 0.001~5052mD. Matrix permeability is low ($0.018\times10^{-3}\mu m^2$) and matrix porosity is low (0.04～5.24%). Matrix reservoir is no storage capacity. The storage capacity and permeability of the formation is determined by fracture-cave and large emposieu. The reservoir with "show of oil and gas during logging" is classified as a type II reservoir, which the fracture porosity is 0.3% and the oil saturation is 90%. The reservoir in the "unload and leak interval" is designated as a type I reservoir, which the vug porosity is 9%, and the fracture porosity is 0.4%. Oil saturation takes an average of 69% interpretation with logging data in this area. Permeability is 4.95-40.5mD and take 40mD. The basic reservoir property and fluid property are listed respectively in table 1 and table 2.

Table 1 Reservoir basic data

leve number	Interval [m]	Thickness [m]	Porosity [%]	Water saturation [%]	Interpretation result
1	5563.0~5569.5	6.5	2-4	20	type I reservoir
2	5569.5~5579.0	9.5	2	30	type II reservoir
3	5624.0~5579.0	8	1	40	type IIIreservoir

Table 2 Fluid physical data

Reservoir pressure [MPa]	59.71
Saturation pressure [Mpa]	12.90
Formation crude viscosity [mPa.s]	18.052
Formation crude density [Kg/m^3]	885.30
Gas / Oil ratio [m^3/m^3]	38.83
Dead oil density [20^{O}C][Kg/m^3]	957.30
Oil volume factor [m^3/m^3]	1.12

Reservoir geological model

In order to characterize the actual reservoir of the fracture-cave body as much as possible, this study first established a conceptual geological model. Then, the seismic inversion, ant and FMI imaging logging data are used to establish a large-scale fracture-cave unit geological model by Petrel software. Finally, a small geologic model is taken in the large fracture-cave unit model to characterize the single fracture-cave geological model controlled by a single well.

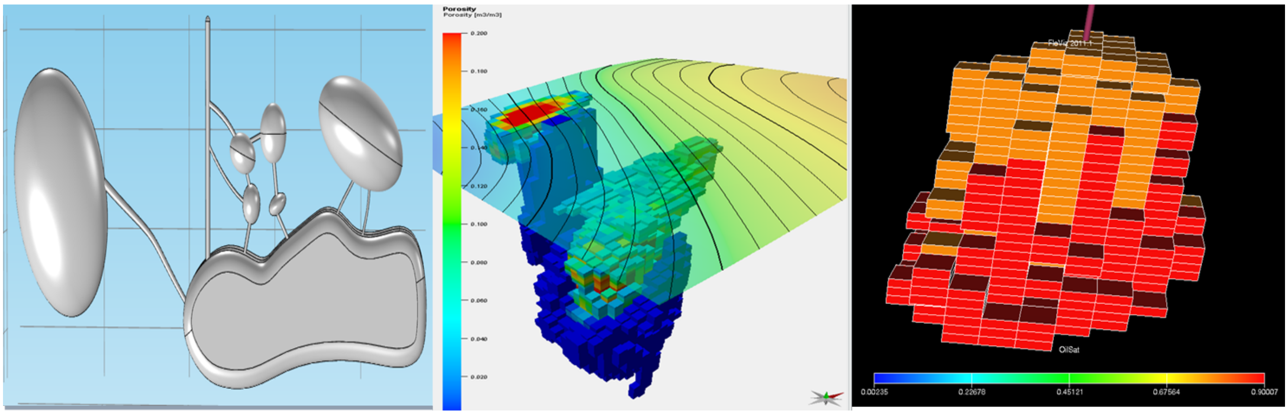

Figure 1 Reservoir models at each stages

Sensitive Analysis of Surfactant-Assisted N_2 huff and puff Injection Parameters

In order to study the effect of surfactant-assisted N_2 huff and puff on the recovery, it is necessary to first study the production performance and recovery of the reservoir depletion development without external energy supplementation. Then the decline stage time point serves as the initial time for the surfactant–assisted N_2 huff and puff. Finally, the sensitivity analysis of the surfactant-assisted N_2 huff and puff is performed under the same production system and the same production time.

Reservoir depletion development analysis

By averaging the initial production liquid in the carbonate reservoir in the 6th District of Tahe Oilfield, it is determined that the initial production of single well depletion development is 10 m^3/d, 20 m^3/d, and 30 m^3/d. Does not control the minimum bottom hole pressure in production wells. According to the actual conditions of performance, the predication time of depletion development is set to 7 years, 4 years and 2 years respectively. Comparing the performance curve, there will be gas breakout in the later period of production, which will cause the water production to rise dramatically and the oil production will decline rapidly (Figure 2). This is due to the fact that the isolated caves have no energy to be replenished in time, and carbonate reservoirs have caves, holes, and fractures that are highly heterogeneous. Reservoir pressure decline sharply, which in turn significantly reduces recovery (Figure 3).

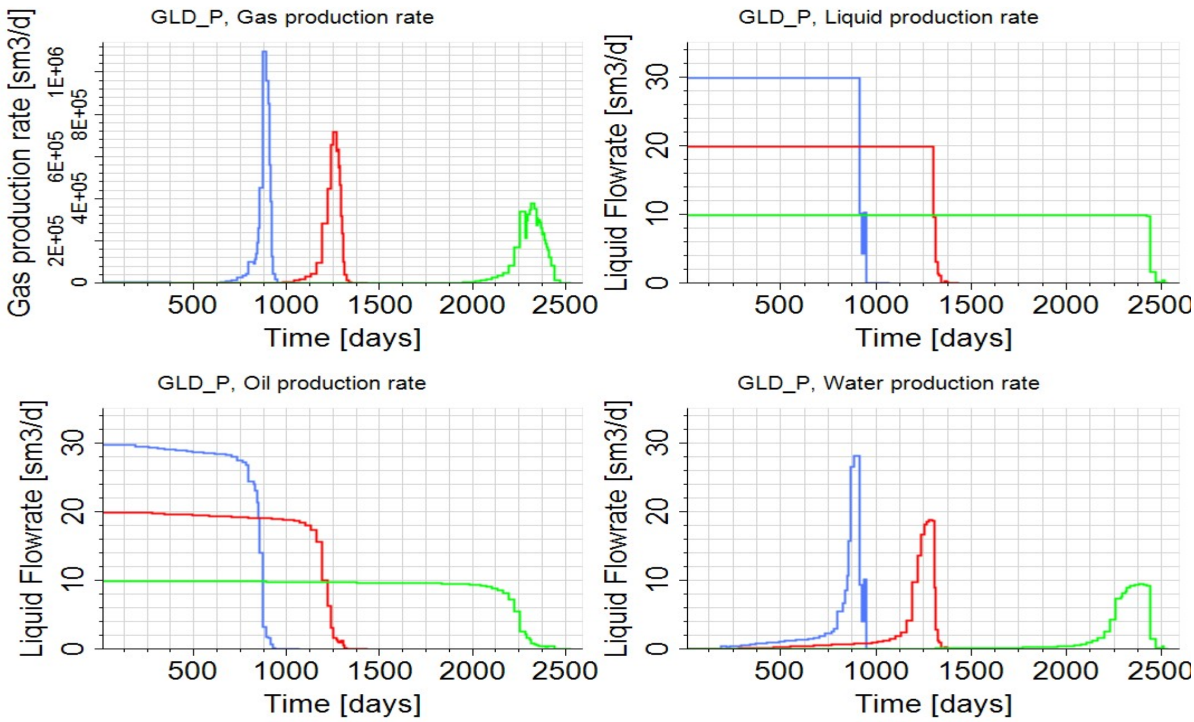

Figure 2 Depletion performance curve of reservoir

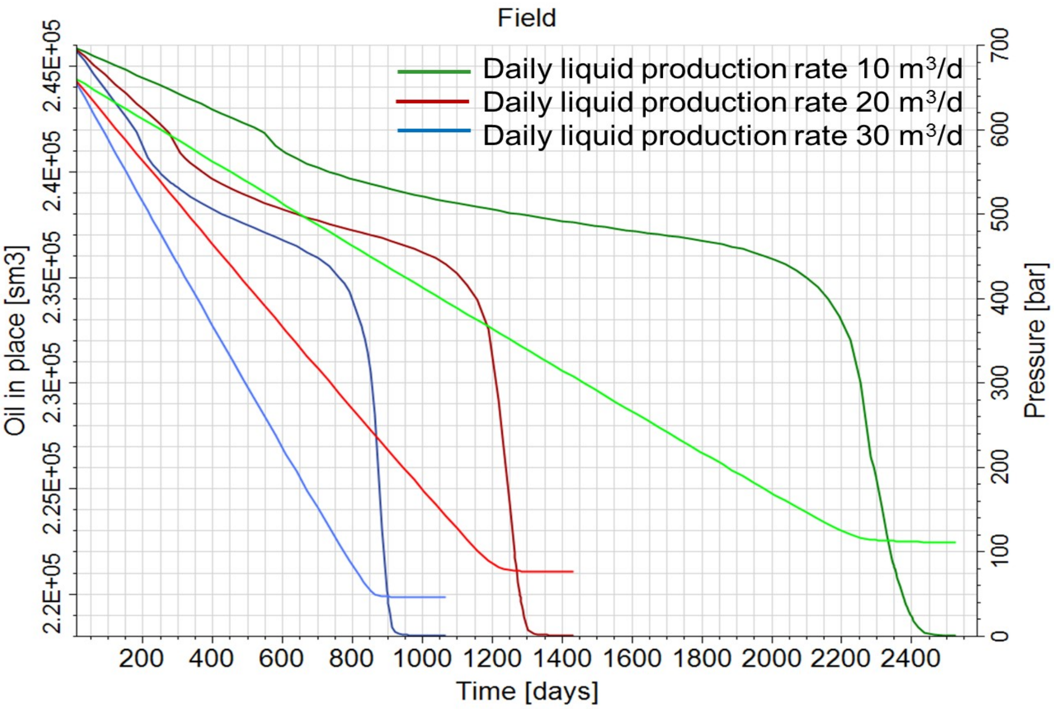

Figure3 Degree of reserve recovery and reservoir pressure at depletion stage

Sensitive Analysis of Surfactant concentration

When depleted production reaches the 1215th day, the daily production liquid rate is 10m^3/d, the N_2 injection rate is 115200 m^3/d, surfactant injection rate set 346 m^3/d, and the injection time is 4 days, a sensitivity analysis of the surfactant concentration is performed and the prediction time is 6 months. The surfactant concentrations are set to 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, respectively. The above parameters are used to study the effect of varying surfactant concentration on recovery (Figure 4).

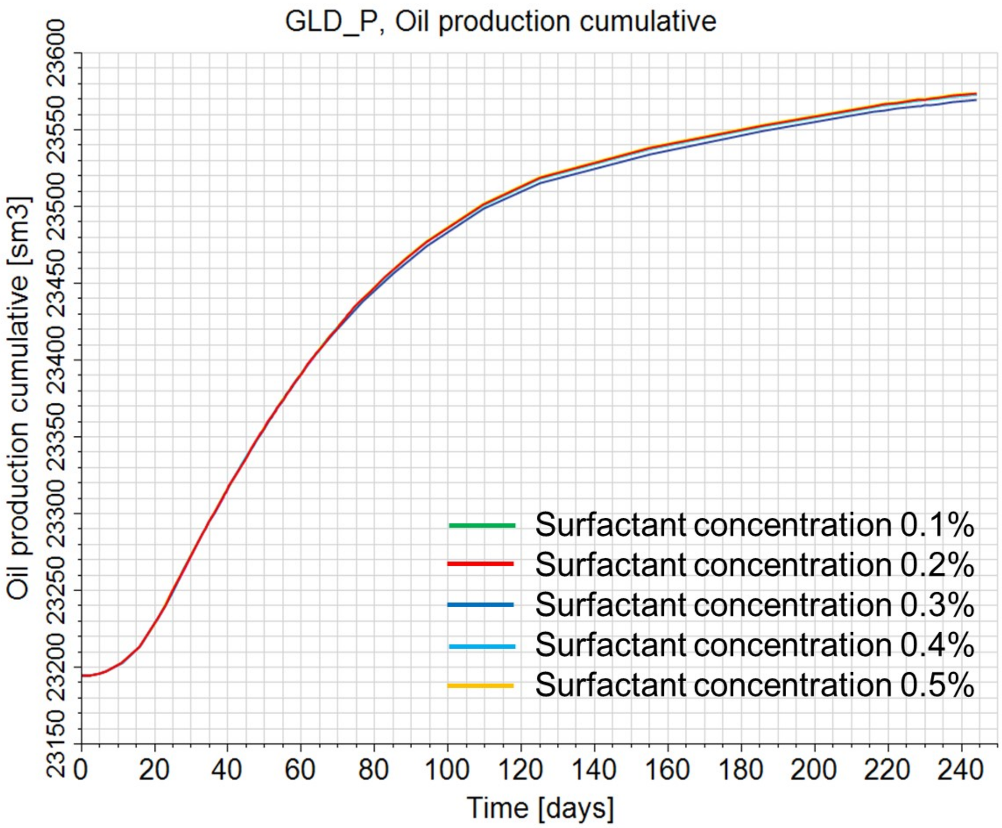

Figure 4 Oil production cumulative of different Surfactant concentration

Table 3 Recovery of different Surfactant concentration

Surfactant concentration [%]	Recovery [%]	Enhance oil recovery [%]
0.1	9.6615	0.07687
0.2	9.6611	0.07646
0.3	9.6611	0.07646
0.4	9.6615	0.07687
0.5	9.6611	0.07646

From Figure 4 and Table 3, it is shown that within a certain range, the recovery does not change significantly with the increase of surfactant concentration. This is mainly due to the highly permeability of caves, holes and fractures in the reservoir.

Sensitive Analysis of injection rate

In the case of a certain injection-production ratio, the reservoir injection rate will be affected by the liquid supply capacity of the reservoir, reflecting the strength of the surfactant injection and the flow of the fluid in the reservoir. It is an important factor affecting the migration of surfactants. Therefore, studying the recovery rate under different injection rates has guiding significance for the development of reservoir production. In this study, the depletion production is selected to be the 1215th day, the daily production liquid is 10 m^3/d, the N_2 injection volume is 0.5×10^6 m^3 and the surfactant injection volume is 1.5×10^3 m^3, surfactant injection concentrations are 0.2% and 0.4% respectively.

When the injection surfactant concentration is 0.2% and the injection rate are 259 m^3/d, 346 m^3/d, and 432 m^3/d, the effect of the change on the recovery are studied (Figure 5).

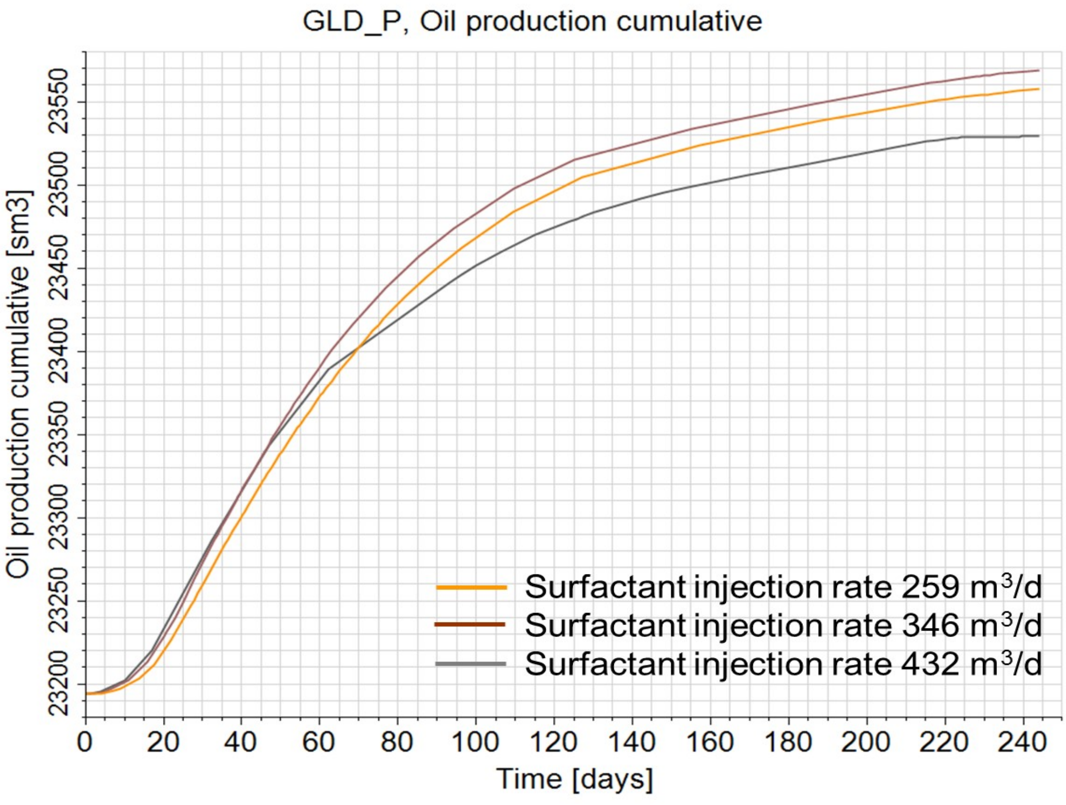

Figure 5 Recovery of different injection rate with 0.2% surfactant concentration

When the injection surfactant concentration is 0.4% and the injection rate are 259 m^3/d, 346 m^3/d, and 432 m^3/d, the effect of the change on the recovery are studied (Figure 6).

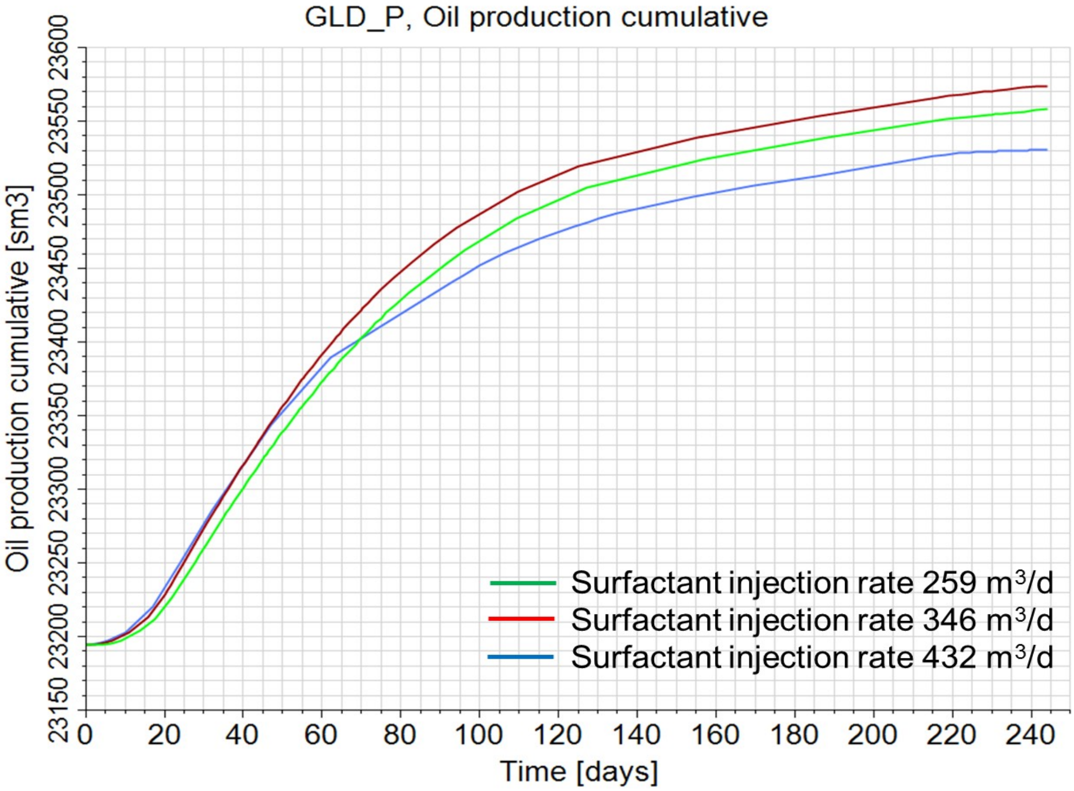

Figure 6 Recovery of different injection rate with 0.4% surfactant concentration

Table 4 Recovery of the two different combinations

Surfactant concentration [%]	Surfactant injection rate [m3/d]	Recovery [%]		Surfactant concentration [%]	Surfactant injection rate [m3/d]	Recovery [%]
0.2	259	9.6549		0.4	259	9.6549
0.2	346	9.6594		0.4	346	9.6615
0.2	432	9.6430		0.4	432	9.6439

From Fig. 5, Fig. 6 and Table 4, it can be shown that when the injection surfactant concentration is 0.2% and the injection rate is increased from 259 m^3/d to 432 m^3/d, the recovery of the isolated cave is increased by 0.0703 %, 0.0748 % and 0.0584 % respectively. When the surfactant concentration is 0.4% and the injection rate increased from 259 m^3/d to 432 m^3/d, the recovery of the isolated cave increased by 0.0703 %, 0.0769 % and 0.0592 %. This shows that the injection rate is one of the main controlling factors for enhanced oil recovery in this isolated cave.

Conclusion

(1) Surfactant-assisted N_2 huff and puff can enhance oil recovery. The best production plan for the optimal surfactant-assisted N_2 huff and puff of the single well in the isolated cave is the N_2 injection rate of 115200 m^3/d, the surfactant injection rate of 346 m^3/d and the surfactant concentration of 0.3%.

(2) The effect of surfactant concentration and injection rate on the recovery of Ordovician carbonate fracture-cave reservoirs in the 6th District of Tahe Oilfield is analyzed using numerical simulation techniques. The change of surfactant concentration has no obvious effect on enhanced oil recovery.Injection rate is one of the main controlling factors for enhanced oil recovery. As the injection rate increases, the recovery increases. When the injection rate exceeds 346m^3/d, the rate continues to increase, the oil displacement effect is not significant.

References

[1] Fangzheng. Jiao, Zhiling. Dou, Mingxi. Zhang et al. China oil gas field development journal [M]. Petroleum Industry Press, 2011

[2] Aifeng. Li, Dong. Zhang. Chenghai. Gao et al. Law of water injection and oil recovery for closed-volume seam-cavity unit [J] Petrolum Geology and Recovery Efficiency ,2012,19(3):94-97.

[3] Yuanshuai. Rong, Xinhua. Li, Xueli. Liu et al. Water injection development model of multi-well seam-hole unit in carbonate fractured reservoir in Tahe oilfield [J] Petrolum Geology and Recovery Efficiency , 2013,20(2):58-61.

[4] Qingshan. Zuo, Hongbing. Wen, Weiguo. Lu et al. Study and practice of nitrogen injection in fault-block oilfield [J].Drill & production technology, 2007,30(5);42-43.

[5] Jian. Hui,Xueli.Liu, Yang. Wang, et al. Study on gas injection mechanism in fractured-cavern reservoir of Tahe Oilfield [J].Drill & production technology, 2013,36(2):8-9.

[6] FengHan. Bai,Youqing. Zhong, Qingchun,Meng, et al Reservoir engineering the Nitrogen injection pilot in YanLing Oilfield [J] ACTA PETROLEI SINICA ,1998,4(19):61-67.

[7]Yanhui. Zhang, CaiLi. Dai, Xinguang. Xu, et al Study and application of nitrogen foam flooding technology in Henan oilfield [J] Fault-block oil & gas field,2013,20(1):129-132.

[8]Xiudong. Guo, Haiyang. Zhao, GuoLiang. Hu,et al Ultra-deep wells in fractured-vuggy reservoir nitrogen injection EOR technology [J] Oil drill & production technology, 2013,35(6):98-101.

[9] Jingyi.Li, Hanqiao. Jiang, Junjian.Li, et al Feasibility study on nitrogen injection in fractured carbonate reservoir [J] Inner Mongolia Petrochemical Industry, 2008,34(23):84-87.

[10] Jian.Hui, Xueli.Liu, Yang.Wang, et al Study on gas injection mechanism in fractured-cavern reservoir of Tahe Oilfield [J]. Drill & production technology, 2013, 02:55-57+8-9.