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Evaluation of Foaming Agent for Oxygen-reduced Air Foam Flooding in Low Permeability Reservoir

Xinyu Zhou[1,2,*], Jia Huang[1,2], Wenli Luo[1,2], Lu Han[1,2], Wenbiao Duan[3], Zhibin Jiang[4]

[1] State Key Laboratory of Enhanced Oil Recovery, Beijing, 100083, China

[2] Research Institute of Petroleum Exploration and Development, CNPC, Beijing, 100083, China

[3] Research Institute of Petroleum Exploration and Development, Changqing Oilfield Company, CNPC, Xi'an, 710000, China

[4] Research Institute of Petroleum Exploration and Development, Xinjiang Oilfield Company, CNPC, Urumqi, 830000, China

*Corresponding Author: Zhouxinyu1982@petrochina.com.cn

Abstract

There are usually micro-fracture existed in low permeability reservoir and its physical properties are poor, therefore, the injection-production system is hard to set up. Considering the reservoir properties and development status as a whole, it is a good chance for commencing field experiment of oxygen-reduced air foam flooding. Take Wuliwan block, Wangyao block in Changqing oilfield, and Shinan21 block for example, through the evaluation of oil resistivity, adsorption resistivity, surface tension, and surface tension, and the foaming agent which is suitable for oxygen-reduced air foam flooding in low permeability reservoir with low cost is finally obtained. These works can be good support for the screening of foam stabilizer and the whole foam flooding system.

Keywords

Oxygen-reduced Air; Air Foam; Low Permeable; Performance Evaluation.

1. Introduction

Air foam flooding has the advantages of both air flooding and foam flooding: air can play an adequate role in the drive of oil[1-3], and foam can play a important role in profile control which is crucial for the stabilization of gas-oil contact[4-6]. As an new technique developed in recent years, air foam flooding has its unique advantage for the development of low permeable or extremely low permeable reservoirs[7-8]. Until now, many scholars have made lots of studies on the technical details for the air foam flooding[9-11].

In order to improve the development results of low permeable reservoir, it is necessary to start at field injection experiment from some well groups. For the purpose of successful injection experiment, full evaluation of foaming agent properties is required to finally obtain the air foam system as a whole.

Take Wuliwan block, Wangyao block in Changqing oilfield, and Shinan21 block for example, through the test of oil resistivity, adsorption resistivity, surface tension, and surface tension, the foaming agent which is suitable for oxygen-reduced air foam flooding in low permeability reservoir is thoroughly evaluated. These works can be good support for EOR technology of the air foam flooding after the water flooding period in low permeable reservoir.

2. Foaming Performance Test

Warring padding method is adopted to evaluate the foaming performance of foaming agent. Foaming agent is selected as the surface active agent ZF2201 which is self-developed. There are four kinds of water used in the experiment: 5500mg/L saline, injection water from Shinan21 block in Xinjiang oilfield, injection water from Wuliwan block, and formation water from Wangyao block in Changqing oilfield. Their salinity test results of reservoir water are shown as table 1, table 2 and table 3, and the experiment temperature is 70°C. The foaming rate and half-life of drainage which is obtained in the test are demonstrated in the form of histogram, therefore, the four conditions are convenient to be compared.

Table 1. Compositional testing result of injection water in Shinan21 block

Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	Total Salinity(mg/L)
4870.26	61.70	1928.60	98.10	9619.30	1071.40	0	92.19	17741.55

Table 2. Compositional testing result of injection water in Wuliwan block

Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	Total Salinity(mg/L)
178.37	1.87	60.43	62.81	158.29	194.12	7.32	59.28	722.49

Table 3. Compositional testing result of formation water in Wangyao block

Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	Total Salinity(mg/L)
5445	6400	2606	795	24903	40	0	377	40566

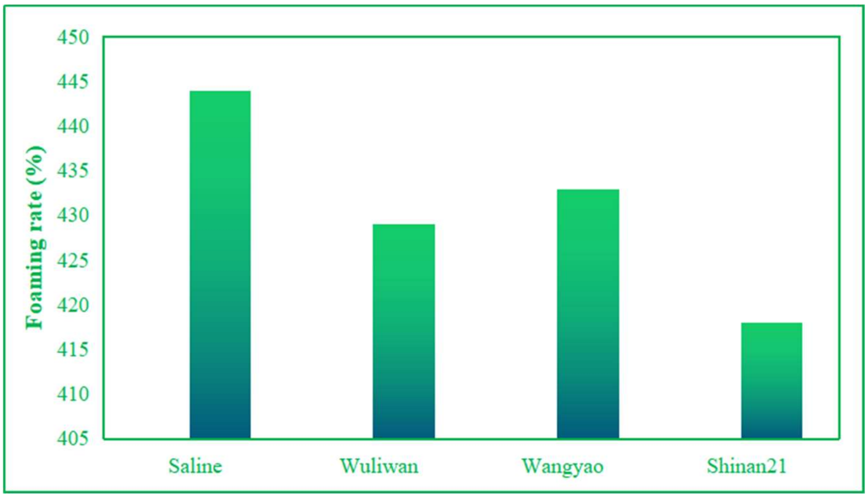

Figure 1. Foaming rate comparison

As demonstrated from figure 1, the foaming rates vary from 410% to 445% in four conditions, with relatively small distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation standard for foam agent used in foam flooding. Therefore, the foaming ability of agents are verified. Among them, the foaming rate in 5500mg/L saline is the highest and can reach 444%; the foaming rate in injection water of Shinan21 block is the lowest at only 418%. Foaming rate in injection water of Wuliwan block and formation water of Wangyao block are in the middle, and the foaming rate in formation water of Wangyao block is relatively higher between the two.

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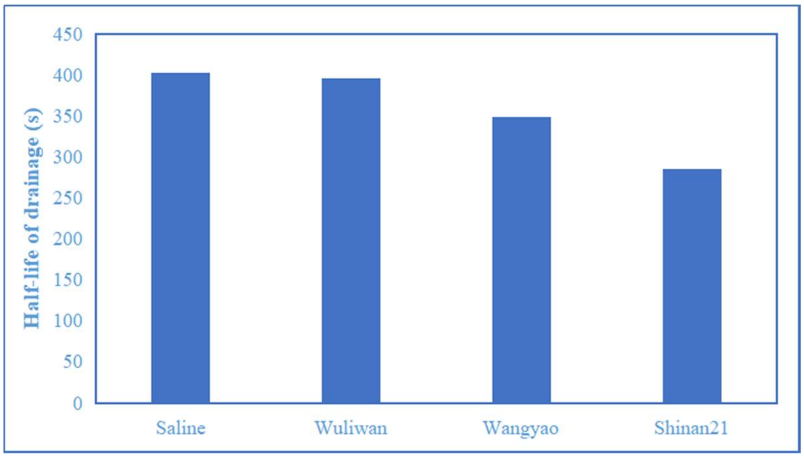

Figure 2. Comparison of half -life of drainage

Half-life of drainage is also tested to evaluate the stability of foam. As demonstrated from figure 2, the half-life of drainage vary from 280s to 410s, with relatively large distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation standard for foam agent used in foam flooding. Therefore, the foam stability is verified. Among them, the foam drainage half-life in 5500mg/L saline is the highest and can reach 430s; the foam drainage half-life in injection water of Shinan21 block is the lowest at 286s. Foam drainage half-life in injection water of Wuliwan block and formation water of Wangyao block are in the middle. Actually, foam drainage half-life in injection water of Wuliwan block and in 5500mg/L saline are generally the same with each other.

3. Evaluation of Oil Resistivity

In order to evaluate the oil resistivity of foaming agent, the same amount of oil is added to the foaming solvent with same volume. The influence of oil for foaming is tested in four conditions. The test results concerning foaming rate and drainage half-life are demonstrated as figure 3 and figure 4. The real photo of oil resistivity test is shown as figure 5.

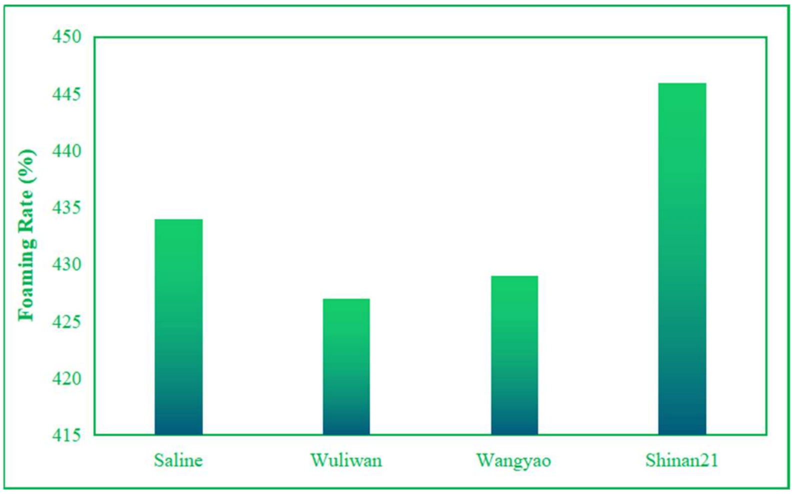

Figure 3. Foaming rate in oil resistivity test

As demonstrated from figure 3, the foaming rates vary from 425% to 450% in four conditions, with relatively small distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation standard for foam agent used in foam flooding. Therefore, the foaming ability of agents are verified. Among them, the foaming rate in injection water of Shinan21 block is the highest and can reach 446%; the foaming rate in injection water of Wuliwan block is the lowest at only 427%.

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Foaming rate in 5500mg/L saline and formation water of Wangyao block are in the middle, and the foaming rate in formation water of Wangyao block is relatively higher between the two.

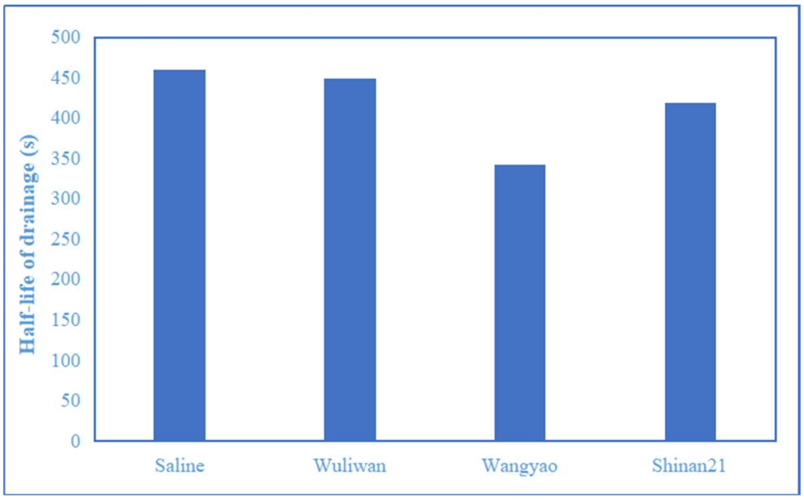

Figure 4. Half-life of drainage in oil resistivity test

Half-life of drainage is also tested to evaluate the stability of foam in oil resistivity test. As demonstrated from figure 4, the half-life of drainage vary from 340s to 460s, with relatively large distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation standard for foam agent used in foam flooding. Therefore, the foam stability is verified. Among them, the foam drainage half-life in 5500mg/L saline is the highest and can reach 460s; the foam drainage half-life in injection water of Wangyao block is the lowest at 342s. Foam drainage half-life in injection water of Wuliwan block and Shinan21 block are in the middle. Actually, foam drainage half-life in injection water of Wuliwan block and Shinan21 block are generally on the same level with each other.

Figure 5. Real photo in oil resistivity test

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4. Evaluation of Adsorption Resistivity

In actual reservoir on site, rock particles have an adsorption effect on foaming agent and this will cause negative influence towards its foaming ability. In the test, rock particles with 80 to 120 meshes are with the solvent of foaming agent, and the adsorption resistivity of foaming agent ZF2201 is evaluated. Test data are demonstrated in figure 6 and figure 7.

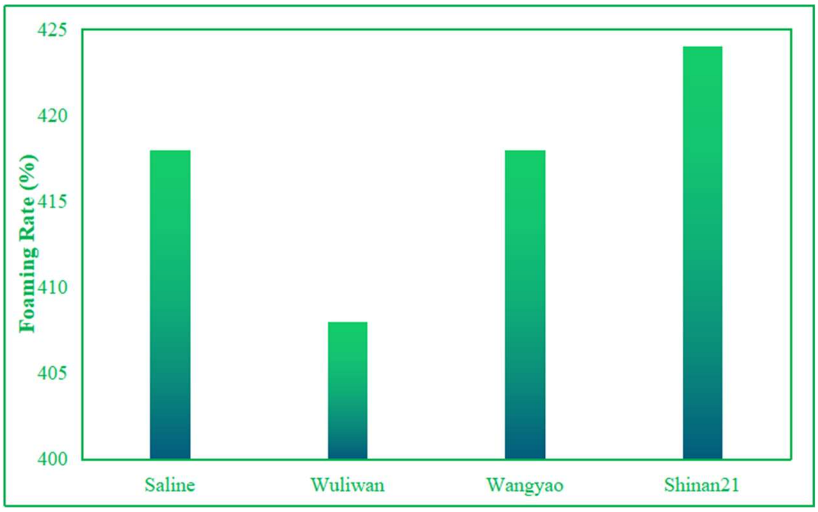

Figure 6. Foaming rate in adsorption resistivity test

As demonstrated from figure 6, the foaming rates vary from 405% to 425% in four conditions, with relatively the smallest distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation standard for foam agent used in foam flooding. Therefore, the foaming ability of agents are verified. Among them, the foaming rate in injection water of Shinan21 block is the highest and can reach 424%; the foaming rate in injection water of Wuliwan block is the lowest at only 408%. Foaming rate in 5500mg/L saline and formation water of Wangyao block are in the middle, and the foaming rate these two are the same in value.

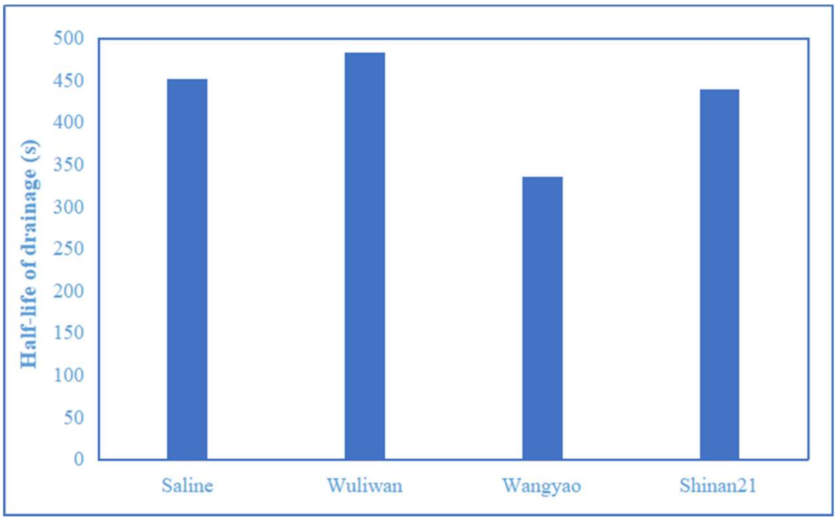

Figure 7. Half-life of drainage in adsorption resistivity test

Half-life of drainage is also tested to evaluate the stability of foam in adsorption resistivity test. As demonstrated from figure 7, the half-life of drainage vary from 330s to 490s, with relatively large distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation

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standard for foam agent used in foam flooding. Therefore, the foam stability in the condition of adsorption is verified. Among them, the foam drainage half-life in injection water of Wuliwan block is the highest and can reach 483s; the foam drainage half-life in injection water of Wangyao block is the lowest at 335s. Foam drainage half-life in injection water of Shinan21 block and 5500mg/L saline are in the middle. Actually, foam drainage half-life in injection water of Shinan21 block and 5500mg/L saline are generally on the same level with each other.

5. Surface Tension Test

Figure 8. Comparison of surface tension at four conditions

Surface tension is also tested to evaluate the property of foaming agent. As demonstrated from figure 8, the surface tensions vary from 19mN/m to 29mN/m in four conditions, with relatively large distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation standard for foam agent used in foam flooding. Therefore, the flooding ability of foaming agent is verified. Among them, the surface tension in injection water of Shinan21 block is the highest and can reach 28.48mN/m; the surface tension in 5500mg/L saline is the lowest at only 19.8mN/m. Surface tension in injection water of Wuliwan block and formation water of Wangyao block are in the middle, and the surface tension in injection water of Wuliwan block is relatively higher between the two.

6. Inter-facial Tension Test

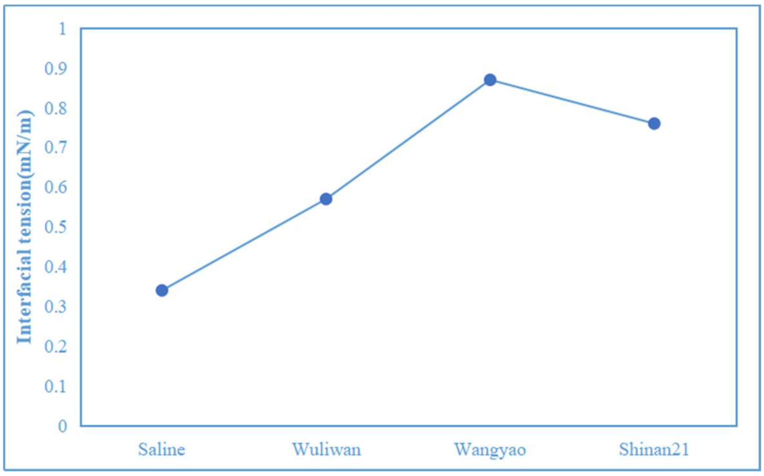

Figure 9. Comparison of inter-facial tension at four conditions

Inter-facial tension is also tested to evaluate the property of foaming agent. As demonstrated from figure 9, the inter-facial tensions vary from 0.3mN/m to 0.9mN/m in four conditions, with relatively large distribution range, and can comply with the standard Q/SY17816-2021 which is the evaluation standard for foam agent used in foam flooding. Therefore, the flooding ability of foaming agent is verified. Among them, the inter-facial tension in formation water of Wangyao block is the highest and can reach 0.87mN/m; the inter-facial tension in 5500mg/L saline is the lowest at only 0.34mN/m. Interfial tensions in injection water of Wuliwan block and Shinan21 block are in the middle, and the inter-facial tension in injection water of Shinan21 block is relatively higher between the two.

7. Conclusion

In order to commence field experiment of oxygen-reduced air foam flooding, various evaluation measures are taken including the oil resistivity test, adsorption resistivity test, surface tension test, and surface tension test, and the foaming agent ZF2201 is finally verified. Through the test with reservoir water samples from Changqing oilfield and Xinjiang oilfield, the test results can all meet the standard Q/SY17816-2021. These works set a firm foundation for the development of the whole foam system which will be used in air foam flooding.

Acknowledgments

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