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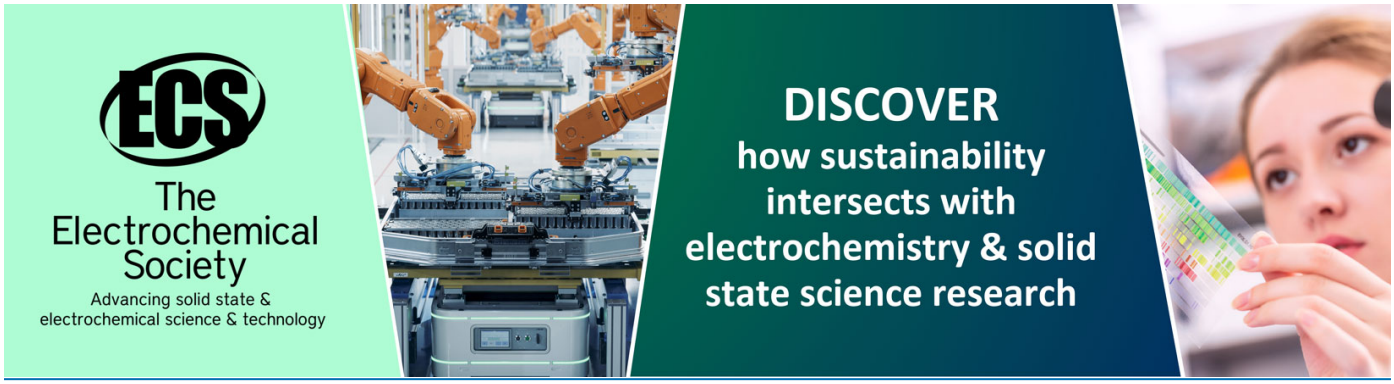

Multi-layer Fracturing Technology and the Application in CK Oilfield to Enhance the Recovery

Qiang Deng [1, *], Man Liu [2], Xiao Lu [2], Tao Yu [1], Shijun Chen [1], Gang Chen [1, 3, *]

[1.] College of Chemistry and Chemical Engineering, Shaanxi Province Key Laboratory of Environmental Pollution Control and Reservoir Protection Technology of Oilfields, Xi'an Shiyou University, Xi'an, China.
[2.] Oil Production Plant No. 11, PetroChina Changqing Oilfield Company, Xi'an, 710200, China.
[3.] State Key Laboratory of Petroleum Pollution Control, CNPC Research Institute of Safety and Environmental Technology, Beijing, China.

*Corresponding author Email: gangchen@xsyu.edu.cn

Abstract. In the operation of new well fracturing, multi-layers are opened at one time, and each layer is separately fractured by downhole fracturing tool and hydraulic fracturing method, and the fluid is discharged from each layer for production. Such fracturing technology is called a well multi-layer fracturing technology. The fracturing technology is restricted by the reservoir characteristics. The multi-layer fracturing technology of one well is an effective practical technique in the practice of fracturing and testing for the wells with the same formation and multiple layers. This technology has been applied in CK Oilfield. The daily oil production of a well with multiple fractured wells is higher than that of the combined wells. According to the data of 15 wells in a well in the CK Oilfield, the average daily oil production per well is 3.95t/d. There are 7 combined wells, and the average daily oil production per well is 1.78t/d. The average single well production multi-layer fractured well is 2.17t/d.

Keywords: Multi-layer; Fracturing Technology; Oilfield; Recovery.

1. Introduction

Multi-layer system refers to the existence of two or more layers of oil layers or oil layers in the same formation profile in one well. They were formed in the same geological age, and the characteristics of oil layers are basically similar, belonging to the same pressure system [1, 2]. In the process of oil production, they should be treated as a single layer, namely, combined production. This type of oil layer is particularly typical in Chang 6 oil reservoir of Sichuan Oilfield. In the operation of new well fracturing, multi-layers are opened at one time, and each layer is separately fractured by downhole fracturing tool and hydraulic fracturing method, and the fluid is discharged from each layer for production. Such fracturing technology is called a well multi-layer fracturing technology [3]. CK Oilfield is located in Yan'an City, Shaanxi Province. From top to bottom, there are three sets of reservoirs: Chang 4+5, Chang

6 and Chang 7. Chang 6 is the main reservoir in this area. In 1985, after a breakthrough in exploration in the area, the geological reserve was proved to be 3 x 107t in 2006. Since its establishment in 1997, different types of fracturing tests have been carried out, and mature and practical fracturing techniques have been gradually formed in this area.

2. Reservoir characteristics of CK Oilfield

The total thickness of Chang 6 reservoir in CK oilfield is about 80 meters. Most of the sandstone layers are below 20 layers. The thickness of a single layer is generally 1-3 meters. Some of the layers can be more than 5 meters. The number of layers is large, the thickness of a single layer is small, and the ratio of sand to mud is mostly between 0.5-2. Its rock type is fine grained feldspar sandstone and siltstone, cemented densely. The average compositions of quartz and feldspar are 27.31%~33.46% and 50.02%~55.0% respectively, of which plagioclase is the most; the average compositions of lithic debris are 11.67%, mainly sedimentary and volcanic rock debris; the main compositions of fillings are calcite laumontite and chlorite, and a small amount of quartz, albite and pyrite[4]. The reservoir has been studied totally, as shown in Fig. 1.

Fig. 1 The reservoir study by core analysis

Through the reservoir correlation, the reservoir in this area has the following characteristics:

(1) The reservoir formation is a set of polycyclic sedimentary assemblages, which belongs to the same pressure system. The reservoir can be contrasted in this area. The sandstone reservoir has good distribution of sand body, wide range of distribution and stable continuity. (2) The reservoir type is sandstone lens reservoir, sand body is near east-west strike, borderless water exists, and bottom water is not active. The oil-water interface of this reservoir is regular, oil-water transition zone is narrower, oil-gas interface is not obvious, and contact area is small. (3) The total thickness of the reservoir group is large, the effective reservoir thickness is medium, the single layer thickness is small, and the layer section is more. The average monolayer thickness is 2.69 m, and the thinnest is only 0.7 m. longitudinal mudstone or silty mudstone intercalation, and thickness is different (Table 1). (4) The permeability heterogeneity of the reservoir is strong in the vertical and lateral directions, ranging from 0.1 to 1.00 × 10-3um2. (5) The content of clay minerals in the rocks of Chang 6 reservoir is relatively small, mainly chlorite (content less than 2%), so there is no clay swelling and water sensitivity.

Table 1. Statistical table of reservoir and interlayer thickness in CK Oilfield

Oil layer	Equality(m)	The thickest(m)	Thinnest(m)
Total reservoir thickness	40.25	91	20
Effective reservoir	15.8	33	7.9
Effective monolayer	2.69	6.8	0.7
Sandwich layer	8.9	33	0.6

3. Principle and implementation of multi-layer fracturing technology in one well

3.1. The principle of enhancing recovery

The fracturing technology is restricted by the reservoir characteristics. The multi-layer fracturing technology of one well is an effective practical technique in the practice of fracturing and testing for the wells with the same formation and multiple layers [5]. In order to improve the production value of the whole reservoir group, the fracturing reconstruction of the multistage thin reservoir group must be carried out at the same time, so that they can contribute to the production of the oil well. If only one single layer is modified, it is difficult to increase production by a large margin because of its limited oil production potential. Only when multiple effective thin layers contribute to productivity can the effect of fracturing increase production be improved. The more the layer segment is effectively reconstructed, the greater the yield is. In a sense, each reservoir in the reservoir group is a relatively independent reservoir. Only when fractures are formed in each layer, can the oil in the reservoir establish an oil channel with the oil well. In order to achieve this goal, it is necessary to make fracturing and fracturing in order to open more than one fracture and to make fracture in oil sand layer.

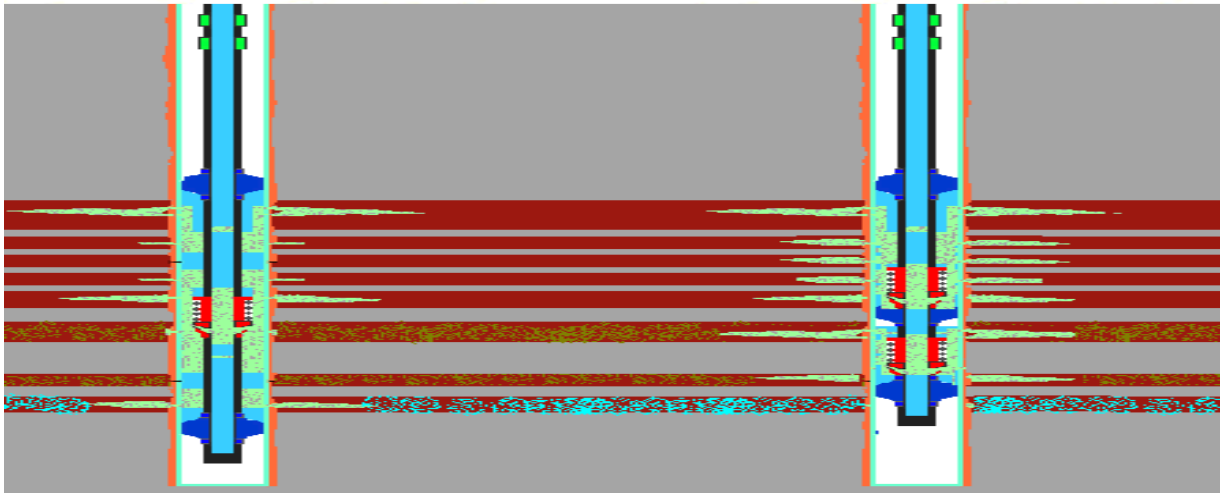

Figure 2. The multi-layer fracturing technology in one well

4. Implementation principles

4.1. Correct understanding of reservoir and selection of perforated zone

Reservoir is the foundation, only if we know the reservoir correctly, we can modify the reservoir effectively. Stratified fracturing does not mean that each small section should be pressed separately, but that it should not only increase production but also economy, but also satisfy the bearing degree of downhole tools. For the western part of CK, the secondary pressure should be based on the sedimentary cycle. The pressure can be divided three times in some cases. This is a process of reservoir analysis and correlation. Under the condition of reservoir thickness, physical property and interval, and the rationality

of construction parameters, the reservoir is reformed as fully as possible. Generally do not exceed two levels of partial pressure.

4.2. Scientific and reasonable construction parameters

The scientific and reasonable construction parameters refer to several main indexes in the construction scheme: sand quantity, discharge amount, sand concentration, and the selection of fracturing fluid, which should be adapted to the reformed reservoir. Sand quantity is the guarantee of effective length of actual fracturing, and displacement is the transmission medium of fracturing power. On the one hand, it is necessary to extend the reformed fracture mainly in the reservoir, on the other hand, to ensure that the dynamic length and width of the effective fracture reach the expected purpose. The sand concentration should be matched with the discharge of sand mixing fluid, the fracturing fluid should have compatibility with formation, low damage and meet the requirements of construction. The parameters formulated are considered to be scientific and reasonable. In the same area and different reservoir, the fracturing parameters are different, even the same reservoir group parameters are different in the same area. Therefore, there is an optimal selection process for parameter selection. The parameters of each small layer in a well with multiple layers may be different. It is thought that determining the parameters of a well and the pump group program by some way is the optimization of the parameters, in fact, it is a misunderstanding of the optimization of the fracturing parameters. Through the comprehensive optimization of fracturing parameters in CK Oilfield, a number of high-yielding industrial wells, such as Cong 624 well, Cong 712 well and Cong 713 well, are produced.

4.3. The fracture full bracing technology

The effective support technique of fracture has been used in the exploration stage of this area, and the effect is good. The key of effective fracture bracing technology lies in the choice of proppant and the laying of proppant in crack. One is to make the whole fracture surface filled with proppant, the other is to select the proppant, so that the proppant can not be broken for a long time in the fracture, the fracture is always in the state of support and has higher flow conductivity. Therefore, in the fracturing of exploration wells, the technology of full fracture support and tail-chasing ceramsite is adopted.

The usual practice after fracturing is to shut down the well for a period of time, and then open the well and let it out. In this process, the proppant in the fracture must be redistributed under the action of gravity, and the state of no proppant support in the upper part of the fracture may occur. After the fracture is closed, the fracture without proppant will gradually lose its conductivity, which affects the validity of fracturing production. If the continuous flow in the fracture is reversed after the pump is stopped, and the flow velocity after the reverse is controlled, so that it is less than the initial velocity of the movement of the proppant particles, the static pressure in the fracture can reach the closing stress of the fracture in a relatively short time, and make the fracture close. In support, the agent has been clamped by the crack wall before being redistributed, and then released.

The adoption of full fracture support technique has three functions: (1) the redistribution of proppant after fracturing is avoided, the whole fracture surface is supported by proppant, (2) the effective height after fracture closure is increased, and the effective height after fracture closure is increased, and the sand spitting after fracturing is avoided. The results are as follows: the oil production is high and the yield is good.

After sand fracturing, when the fracture is closed, the compressive stress applied by the surrounding rock on the proppant is large, which makes part of quartz sand break and reduces the conductivity of fracture. The ceramsite has certain toughness and is not easy to break, and the fracture mouth is a stress anomaly point. It can increase the conductivity of fracture and prolong the period of increasing production.

4.4. Comparison of different fracturing technology

The comprehensive data analysis shows that the Chang 6 oil layer in the CK Oilfield is significantly better than the exploration well in terms of physical properties and thickness. According to the

geological foundation of the oil layer, the effect of the split should be that the combined well is better than the exploration well, but the result is exactly the opposite. According to the statistics at the end of 2015, the output of the combined pressure wells is lower than that of the multi-layered cracked wells (Table 2). The same results were obtained in 2016 (Table 3).

Table 2. Productivity distribution of fracturing mode by 2015 in CK Oilfield

Well type	Average sand size(m^3)	Average daily oil production(t/d)	Energy distribution(t/d)		
			4—10	10—20	＞20
Multilayer fracturing	20.1	12.06	1	7	1
Combined pressure	37.9	8.61	7	1	

Table 3. Production distribution of fracturing methods for 2016

Well type	Daily oil production (t/d)	Energy distribution (t/d)		
		4-10	10-20	＞20
Multilayer fracturing	19.99	6	9	6
Combined pressure	12.68	4	3	1

The Chang 6 oil layer group of the area has geological conditions for multi-layer partial pressure transformation. The effective total thickness of the Yao 6 well reservoir is 15.9m, and the single layer is 9.7m thick. After two layers of partial pressure, the daily oil production is 10.37t. Using one well multi-fracturing technology, it becomes the first industrial oil in the region to break through 10t/d. Flow well. Yao 7, Yao 8, Yao 9, after fracturing with a multi-fracture technology, the test oil production was 18.02 t / d, 11.14 t / d, 10.37 t / d. In particular, Yao 10 well, the effective thickness of the oil layer is 15.7 m, the single layer is only 3.9 m thick, divided into three levels of fracturing, a total of 34 m^3 of sand, 10 m^3 of tail chasing ceramsite, and the tested oil production reached 20.66 t / d. In 2012, CK Oilfield did not fully count 8 wells, and the average liquid discharge output was 12.68 t/d. There are 21 partial pressure wells with an average discharge output of 19.99 t/d. According to the post-pressing drainage curve, the oil production of the multi-layered cracked well increases rapidly after fracturing, and does not decrease after reaching stability. After the fracturing, the oil production increases slowly, the time required for stabilization is long, and the oil production fluctuates greatly.

4.5. Comparison of effects during oil recovery

The daily oil production of a well with multiple fractured wells is higher than that of the combined wells. According to the data of 15 wells in a well in the CK Oilfield, the average daily oil production per well is 3.95t/d. There are 7 combined wells, and the average daily oil production per well is 1.78t/d. The average single well production multi-layer fractured well is 2.17t/d. The practicality of a technology is to be verified by the test of practice, tested in practice, and developed in practice. Although the multi-fracture technology of a well was produced and affirmed during the exploration stage, how to divide the small layers in the Chang 6 oil-bearing formation of the CK Oilfield did not form a mature technology in theory and specific operations. Therefore, it is easy to be denied. Through the fracturing practice of production and construction, the operatively strong split-fracture method with sedimentary cycles as a stratified group of fracturing is summarized, which makes the technology maturer and maturer. It enhances the practicality and economy, and also shows the scientific nature of the technology. In the CK Oilfield, a number of high-yield wells were extruded using a well multi-fracturing technology, and self-draining wells appeared. Below is an example of three typical well fracturing modifications, from which you can appreciate how to separate the fractures. Fracturing technology evaluates its pros and cons by the effect of fracturing.

Cong 624 well, electric test interpretation of the oil layer 5, according to the sedimentary cycle, we divided it into three segments, selected the above two groups to open three segments, divided twice. The upper part is sanded 10^{m3}, the displacement is 1.8m^3/min, the breaking pressure is 26MPa, the lower part

is combined, the sand is added 30m^3, the breaking pressure is 27MPa, the displacement is 2.0 m^3/min, the daily output oil is 40.9m^3, no water, the pumping depth is 530m, the input After production, the oil production has been relatively high, and the current daily oil production is above 8 tons. Cong 712 well, electric test interpretation of oil layer 9, oil and water layer 2, according to sedimentary cycle, divided into two groups, each group shot two sections, the upper group sand 30m^3, breaking pressure 30MPa, working pressure 24MPa. The next group is sanded 20m^3, the pressure is 28MPa, the working pressure is 22MPa, the row is combined, the daily oil is 30.0m^3, and the pumping depth is 540m. The cluster 713 well electrical interpretation explains the oil layer 8 segments, which can be divided into three groups according to the sedimentary cycle, but the upper two cycles are close together and are combined into one group. According to the two groups, the split-fracture scheme is considered, and each group is opened for two segments. 25 m^3sand was added each time, and the pressure is combined and discharged. The product is produced by spraying, and the oil is 43 m^3 per day.

It can be seen from the examples that the cracks was not simply split in a group of multi-layered oil layers, but also divided into two or three groups according to their geological combination characteristics, and divide the pressure 2 or 3 times, from the effect of the pressure, it is believed that the purpose of fully reforming the oil layer and pressing the multilayer is basically achieved. It avoids the blindness of large-scale fracturing. In particular, the Cong 712 well is intentionally avoided to open the oil-water layer with higher water content.

5. Conclusion

The high-volume and high-displacement fracturing technology proves that it is impossible to achieve the desire to press-open multiple layers and fully reform the oil layer through practice test, and it is not suitable for continued application in the oil field. According to the sedimentary cycle, the reasonable combination of the partial pressure intervals makes the multi-fracturing technology of the well not only effectively and fully reform the oil layer in the fracturing construction of the area, but also shows the scientific and economical technology. According to the sedimentary cycle combination method, the zone can be divided into 2-3 combinations, and the single well partial pressure is 2-3 times. In most cases, the partial pressure can be divided twice. Fracturing with a multi-fracturing technology can effectively avoid the opening of high aquifers or water layers. The daily oil production of a well with multiple fractured wells is higher than that of the combined wells. It enhances the practicality and economy, and also shows the scientific nature of the technology.

Acknowledgments

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References

[1] B.S. Aadnøy, M. Belayneh, Elasto-plastic fracturing model for wellbore stability using non-penetrating fluids, J. Petrol. Sci. Eng. 45(3): 179-192 (2004).
[2] P. Yang, Y. Jin, B. Hou, Multilayer Pressure Containment Model and its Application in Deep Well Fractured Formation, Rock Mech. Rock Eng. 46(5): 1255-1266 (2013).
[3] X.S., Zhao, H.L. Dang, Z.Y. Pang, Microscopic pore structure and seepage characteristics of different pore assemblage types in ultra low permeability reservoir: a case of Chang 6 reservoir in Tang 157 well area Ganguyi oilfield, Lithologic Reservoirs, 29(6): 9-14 (2017).
[4] Y.J. Chen, Y.M. Chen, C.B. Wang, Developing a multi-layer reference design retrieval technology for knowledge management in engineering design, Expert Syst. App. 29(4): 839-866 (2005).
[5] D. Jiang, Q. Wang, J. Tan, Application of Separated Layer Fracturing Technology with Hydraulic Jet Drive Pipe String in Horizontal Well, Well Testing, 21(6): 55-59 (2012).