Applying the Fine Controlled Fracturing on Thin and Poor Reservoir

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Abstract. In Xingnan development area, the secondary and tertiary infill well mainly exploit the thin and low permeable layers, which have many characteristics, such as the layer is too much, the development is poor and thin, the layer has the small interlayer thickness, the variation range of the lithology, physical property and oil content is large, the nonuniformity is more serious. Although applying the limited entry fracturing when the wells put into production , some oil and water wells which corresponding sand body has not establish effective displacement relationship, this will lead to low producing proportion of thin and poor reservoir. To overcome the problem mentioned above, by breaking through the existing fracturing design principle, reasonably optimizing the corresponding fracturing layer, fine dividing section, personalized design of operation scale, controlling the influence factors of fracturing effect and so on, finally we establish a new reconstruction model which the single sand body apply corresponding fine control fracturing. The field test obtain a better result, it has proved the applicability of the technology.

Introduction

The development of fracturing technology for low permeability reservoirs can not only solve the contradiction between development input and production, but also meet the requirement of oil recovery speed in oilfield development and ultimately improve oil recovery [1]. However, with the development of oilfield, conventional optimization methods are difficult to adapt to further deteriorating reservoir conditions. Based on the analysis of microscopic residual oil, and further analysis of factors which affect fracturing effect, gradually formed the corresponding transformation of oil and water well sand body, individualized single sand body construction scale and targeted control are gradually formed. The field test proves that the application of the above measures can effectively guarantee and improve the fracturing effect of thin and poor formations, better meet the requirements of secondary and tertiary infill wells for stimulation and transformation, obtain greater economic benefits, and provide technical guarantees for efficient development of oilfields.

Micro Residual Oil Analysis and Key Ideas.

Thin and poor reservoirs are characterized by small single layer thickness, low permeability and complex pore structure, and their percolation characteristics and laws are extremely complex [2].

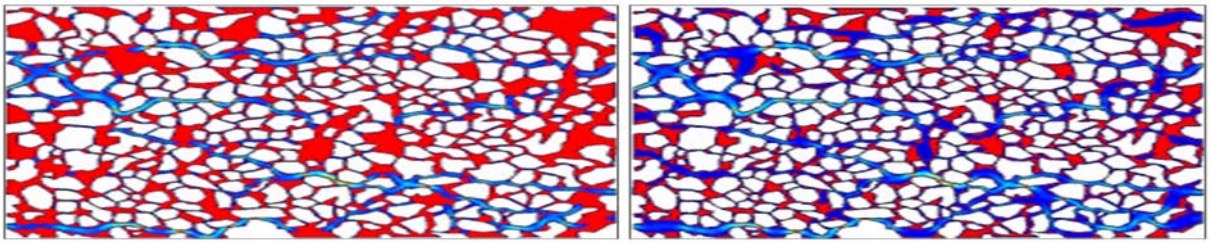

Fig.1 Microscopic remaining oil of medium and strong washing

The microscopic remaining oil of untabulated reservoir is mainly weakly washed and not washed, and its production is relatively poor. According to the results of microscopic remaining oil research, the sweep area of injected water has not been improved from medium washed to strong washed, but along the percolation path from the injection end to the production end, from the relative permeability curve, with the increase of water cut, the permeability to oil decreases sharply, while the water permeability increases slightly. It is difficult to control the decline only by enhancing liquid. At the same time, the inherent characteristic of thin and poor layer seepage exists start-up pressure gradient. Long-term studies have shown that the start-up pressure gradient mainly depends on the range of permeability，start-up pressure gradient decreases with the increase of permeability, that is, the lower the permeability, the greater the start-up pressure gradient [3]. Therefore, in order to realize the effective use of this part of reservoir, first, it is necessary to take fracturing transformation to establish an effective displacement of oil and water wells, second, by increasing the fracturing scale, increasing the area of flow leakage, lessen the filtrational resistance, and improving the degree of thin and poor layer production. Thirdly, aiming at the problem of the distance between the second and third infill wells, oil and water wells should be reformed to reduce the distance between injection and production wells indirectly and improve the relationship between injection and production.

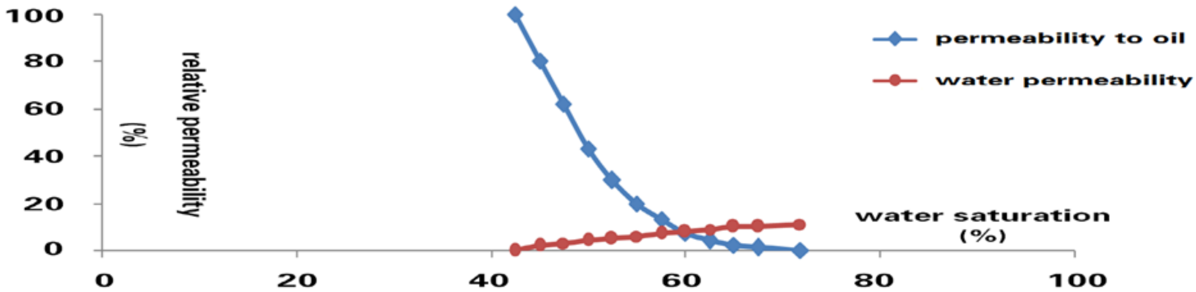

Fig.2 The change of phase permeability with water cut

At present, as many as 4-6 single layers are reformed in single-card section according to the limited entry fracturing design principle. Because of the physical property of many single layers are different, man-made fracture of all single layers can not be effectively open and some single layers have not been opened to a certain extent. At present, more than 40% of the reservoirs can not be effectively reformed by limited entry fracturing technology, which seriously affects the reservoirs producing degree[4].At the same time, because the single layer only optimizes the gravel input less than 2 cubic meters, the construction scale is low, the fracture radius is short, some layers can not establish effective displacement relationship, can not meet the needs of thin and poor layer fracturing. For this reason, the thin and poor layers in the well group are considered as a whole, and the fine subdivision and single card corresponding transformation is carried out.By reasonably optimizing the construction parameters such as liquid volume, capacity and sand volume, a fracture system with large penetration ratio is formed and the injection production relationship between thin and poor layers is improved.

General Situation of Experimental Area.

Understanding the characteristics of fracturing target zone and formulating corresponding measures are effective ways to improve the effect of fracturing reconstruction. The main targets of secondary and tertiary infill wells in the test area are thin and poor strata in the commercial reserves and untabulated reservoir, and the target strata are dispersed vertically, they have small thickness, distributed between high aquifers and the barriers is thin[5]. According to the core data of the inspection wells, the lithology, physical property and oil-bearing property of the thin and poor layer in the commercial reserves and untabulated reservoir vary widely, and the heterogeneity is serious. The lithology of thin and poor beds is mainly silty sand and fine sand, and the oil-bearing occurrence is mainly oiliness and oil immersion.

The lithology of the untabulated reservoir is mainly silty sand, the average porosity is 22.15%, the average air permeability is $30\times10^{-3}um^2$, the original oil saturation is 44.13%, and the oil bearing occurrence is mainly oil patch and oil trace. The air permeability of untabulated reservoir varies widely, and the permeability of single sands varies widely, in the range of $1.0\text{-}160.0\times10^{-3}\mu m^2$, The proportion of independent untabulated reservoir with permeability below $20\times10^{-3}\mu m^2$ is 71.43%, the proportion of thickness is 68.67%. According to logging interpretation of inspection wells, the reservoir is characterized by many layers, thin layers, dense layers and poor layers.

Analysis of Factors Affecting Fracturing Effect and Control Methods

Firstly, discovery and control measures of hard layer. The commercial reserves and untabulated reservoir in test area have the characteristics of thin oil layer thickness, thin barrier, thin sand and thin mud interbeds, and the calcium reservoirs are well developed. Because fracturing extends to the upper and lower mudstone section during fracturing, the stress gradient of mudstone barrier is large, and the fracture pressure and fracture extension pressure of construction are high [6]. For this reason, it is found in the fracturing operation that part of the fracturing interval can not be fracturing repeatedly, and this part of the layer has high breakdown pressure, which is difficult to be fractured under the existing fracturing conditions. Through the analysis of logging curves of such reservoirs, it is found that: acoustic travel time is mostly low peak fluctuation; density curve is generally high peak fluctuation; microelectrode curve is kurtosis [7]. By establishing identification method based on density and acoustic travel time, 55MPa fracturing string is adopted to reforming the hard layer, and the string is improved to ensure that the hard layer fractured, and second, because the difference of breakdown pressure for non-hard layer and hard layer is more than 20 MPa, combined fracturing is difficult to ensure that the hard layer open, this hard layer should be subdivided in the same distance, and adopt acid treatment, improve the cracking probability.

Secondly, crack interference and control measures. As there is interlayer interference in water injection and oil production, there is also interlayer interference in the formation, expansion and extension of effective fractures in fracturing operation. During construction, because of the dynamic expansion of multiple cracks, the mutual interference between cracks will be caused, which will inhibit the formation, expansion and extension of some adjacent cracks, so that some small thin layers can not form effective cracks. The interference boundaries under different crack numbers are formed through experiments. For identifying the layers with crack interference, in order to mitigate or eliminate crack interference, the layers with crack interference are subdivided into different fracturing intervals.

Thirdly, construction scale influence and control measures. Combining with theoretical research, it is the key to ensure the success of fracturing operation and obtain good fracturing effect to make full use of making cracks, preventing sand plugging and channeling. In the process of construction, the best reconstruction effect can be achieved by adjusting controllable construction parameters reasonably [8]. Statistical parameters of conventional limited entry fracturing in secondary and tertiary infill wells in test area show that average single well is 4.1 fracturing intervals, average fracturing intervals is 4.9 layers, sand addition is 8.8 cubic meters, single layer sand volume is only 1.8 cubic meters and half fracture length is only 13.8m. The actual injector producer distance in test area is more than 200 meters. Because of unreasonable injector producer distance and imperfect injection-production relationship, it causes poor water injection effect, poor recovery effect of oil wells, the formation of "incomplete injection, difficult produced", the thin and poor reservoirs can not be effectively used [9], it causes the low production in tertiary infill well. Therefore, oil and water wells should be corresponding fractured in accordance with the second and third infill wells, and large penetration ratio fractures should be formed by increasing the operation scale, indirectly reducing well spacing and establishing effective displacement pressure difference. Fracture parameter optimization is the most important link affecting the fracturing effect. In order to define the reasonable range of fracture parameter optimization, the relationship chart between reservoir permeability and limit technical well spacing under different driving pressure difference in test area is simulated. From the chart, it can be seen that the effective displacement relationship can be established only in thin and poor layers about 150 meters in test area. Therefore, the parameters of oil and water well fracture can be optimized through the specific spacing between the template and the test well group.

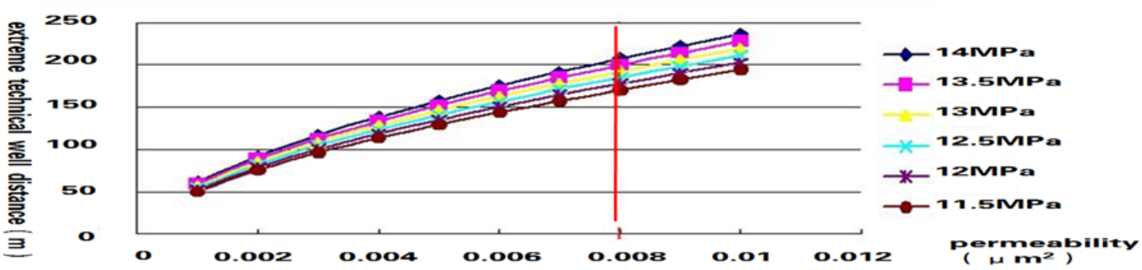

Fig.3 Relationship between permeability and limit technology well spacing under driving pressure differential

When optimizing the half fracture length, we consider the sand body distribution, sand thickness, injection-production well pattern and well spacing [10], combined with fine geological research results, the main body and non-main body in the scale optimization need to be controlled to a certain extent, for the untabulated reservoir need to increase the scale of operation, because the fracturing layers of test wells are mostly developed out of the untabulated reservoir, different optimization methods are also adopted for different distribution types of untabulated reservoir, in which the cross-distributed untabulated reservoir control scale, large area and sporadic distribution untabulated reservoir are applied on a large scale.

Considering the improvement of water flooding effect and the control of water cut in oil wells according to the above optimization scheme, the optimum template of fracture penetration ratio suitable for different development types of fracture in the experimental area was formed, which broke through the principle of conventional fracturing optimization. Individualized optimization design of single sand body is realized, the control scale of water well is 10-15% penetration ratio, and the oil well is 15- 20% penetration ratio.

Table 1 Optimization range of thin layer crack penetration ratio

classification	Penetration ratio optimization	
	Water well	Oil well
Main body	10%-11%	15%-16%
Non main body	12%-13%	17%-18%
untabulated reservoir	14%-15%	19%-20%

After the scale is determined, each layer segment is treated with acid before fracturing, and the fracture pressure is greatly reduced by reacting the acid with drilling fluid, filtrate and soluble components in formation [11]. The low damage fracturing fluid is composed of polymer, crosslinking agent and gel breaker. The polymer is a short chain compound vegetable gum [12].

Through field test, the optimization process of single sand body corresponding fine fracturing is gradually formed, mainly including the following aspects: Firstly, the corresponding relationship of sand body, production, residual oil potential analysis is carried out for the test well group, and thin and poor reservoirs with good connectivity, poor production and relatively rich residual oil are selected. Secondly, after the fracturing layers is determined, it is necessary to identify the factors affecting the fracturing effect, such as hard layer and interfracture interference, and to formulate specific control measures such as single segment and acid treatment. Third, scale optimization, this link is also more important, according to the development of different well groups and well spacing, personalized optimization of single sand construction scale, as far as possible to ensure that the sand body as a whole uniform production. After the scheme is determined, the stratified fracturing technology is selected, and the single sand body corresponding fine control fracturing is realized.

The Test of Typical Well Group and Overall Effect Analysis

According to the above method, the average single well of a test well group is finally subdivided into 11 segment, and the average number of small layers of single segment is 1.8. The fine subdivision of single sand body is realized.

In the test process, there are 9 hard layers, the thickness ratio is 14%, when it put into production without fracturing. This time take subdivision single segment and take acid treatment, the crack breaking probability is 100%. Inter-fracture interference exists in 4 segments, accounting for 26.3% of the thickness of a single well. The effect of inter-fracture interference can be effectively controlled by subdividing and reforming, there is no inter-fracture interference through the analysis of fracturing operation curve, thus controlling means ensure effective fracture extension.

After fracturing, the water well end is subdivided into 7 segments, the effect of increasing the injection volume by 50 cubic meters is obtained. At the end of the well, the initial average single well increase the amount of fluid per day by 32.5t, and the daily amount of oil increased by 7.2t, the fluid increase strength is 8.1t/d.m, which is 3.5 times of conventional fracturing. Up to now, the average production time is 735 days, the stage cumulative oil increase 1880t in single well, the input-output ratio has reached 1:5.2 and the field test achieve better economic results. According to the reservoir production after fracturing, the number of layers and the ratio of sandstone production increase by more than 40 percentage points compare with that before fracturing. Up to now, 84 wells have been tested and 157 thousand tons of oil have been accumulated.

Understanding of Field Test Results

Through analysis, we think that the main reasons for achieving better test results are as follows.

Firstly, the test well is in good condition. Through the cementing quality and dobby diameter survey before the test, the Nen 2 section has no casing damage, and the cementing quality of the reservoir section is mainly excellent, which effectively avoids the occurrence of high water cut communication caused by fracturing high pressure channeling.

Secondly, identification and transformation of the hard bed ensure the effect of single well. According to the analysis of the dynamic and static data of the test wells, the lithology of hard layer is poorly developed mudstone and calciferous sandstone in the vertical direction, and the hard layers in the horizontal distribution are outer front phase III and IV sand bodies. The distribution of the hard layer is mainly between the untabulated reservoir and pinchout area, which is locally connected or striped. In the sedimentary profile, the hard layer and the lacustrine mudstone are in the form of thin sand and mud, or intercalation, and the thickness is between 0.2-0.5 m, which can form a certain injection-production relation on the plane of this kind of layer, and has certain liquid production ability. The production capacity of this hard layer is 23.6% of the whole well. If these layers are not reformed, they will affect not only the productivity of single well, but also some of the recoverable reserves.

Thirdly, through the analysis, the test well group has large vertical perforation span, many reservoirs, which have thin thickness, plane distribution imbalance, and serious interlayer interference. The average perforation interval is 93.7 meters, and the permeability variation coefficient within the interval is 0.6-0.8. Through the fine subdivision, single segment has 1-2 layers, the thickness of the interlayer meets the effective fracture extension requirements.

Conclusion

With the development of fracturing target layer becoming worse year by year, the existing fracturing design principles can not meet the reconstruction needs of thin and poor layer, so fine fracturing is the future trend of thin and poor layer. Effective simultaneous monitoring of fracturing process can help to understand the matching degree between fracture shape and construction scale to a certain extent, which has certain guiding significance for scheme optimization. Comparing with conventional fracturing，the fracturing modification object of fine control is single sand body, it can be seen that better stimulation effect can be obtained by personalized optimization, and technical and economic analysis is feasible.

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