E3S Web of Conferences **375**, 01028 (2023) https://doi.org/10.1051/e3sconf/202337501028
ESAT 2023

Application of close cut volume fracturing in tight oil horizontal Wells

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Abstract. S tight reservoir is rich in oil and gas and has good development potential. However, the reservoir lacks good physical property, strong heterogeneity, tight lithology and complex reservoir formation conditions, and the fracturing operation is characterized by lack of good fracture complexity and difficulty in initiation. For the geological characteristics of the reservoir and the difficulties of reconstruction, we actively follow the principle of fracture-controlled reserves, broaden the understanding of unconventional volume fracturing, and integrate cutting fracturing technology in the long-term practice process. The combination of cluster perforation, plug segmentation, reverse mixed injection and other methods can fully improve the fracture initiation and extension effect of multiple clusters. The combination of sand addition technology and smooth water to replace guar gum, promote the laying quality of fracture proppant to be fully improved, promote the formation to further achieve the energy storage and increase goal, tight oil layer to achieve the volume transformation goal, and promote the long-term, stable effect of fracturing reconstruction.

Key words: Close cutting; Volume fracturing; Horizontal well.

1. Introduction

In order to make full contribution to the stability and efficiency of tight oil formation development, different technologies should be used together. For tight oil horizontal Wells, preparatory treatment should be carried out before formal production, and volume fracturing is a key step. This work covers cutting and fracture-net fracturing modes. The fracture-net fracturing technology has a good application effect in the large brittle reservoir, and the cutting volume pressure has a good application effect in the small brittle reservoir, while the tight oil reservoir is less brittle, so the cutting pressure technology can be adopted [1].

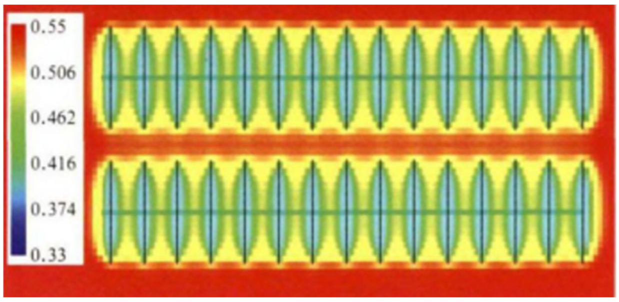
2. Specific application of medium volume pressure technology in horizontal well

2.1 Specific application of subdivision cutting technology in horizontal well medium volume pressure technology

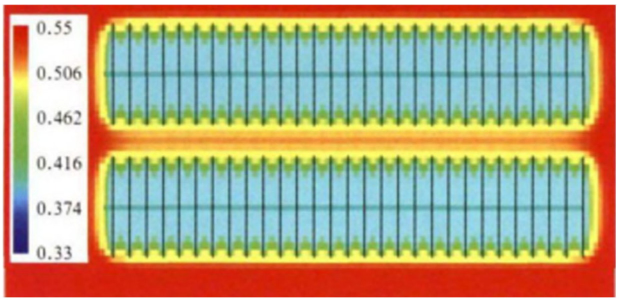
The S reservoir is an extremely low and low-porosity permeability reservoir with starting pressure in the range of 0.017MPa/m -- 0.14MPa/m, which is higher than other reservoirs of the same type. As starting pressure increases, oil flow decreases and the reservoir is highly dependent on fractures. The S reservoir mainly adopts the form of two wing fractures. Based on increasing the number of artificial fractures per unit volume, the flow distance between bottom fluid and fractures can be shortened by subdividing and cutting the reservoir, which can fully increase the production volume of the reservoir and increase the production of a single well.

In addition, the starting pressure of BKQ formation on the north slope of S reservoir is 0.14MPa/m, and that of BKQ Formation on the west slope is 0.017MPa/m, and there is an order of magnitude difference between them. Therefore, the Arctic slope BKQ reservoir should have a denser cut density, and the distance between artificial fractures in the horizontal section should be smaller than that in the western slope BKQ reservoir, so the fracturing process should be designed in a differentiated way [2].

The oil saturation of the north slope BKQ reservoir is simulated under different conditions of 1000m horizontal interval, 300m distance of well development and fracture spacing. See the picture below.



A: 70m fracture spacing oil saturation



B: 70m fracture spacing oil saturation

Figure 1 Oil saturation at various fracture distances after 3 years

It can be found from the figure above that the effective control area is located around the main peak when the spacing is 70m, and there is a lack of good effective mobilization between different fractures. When the fracture distance is 35m, the fracture control area is expanded, the overall oil saturation in the reservoir is reduced, and the operation of jointing is controlled. Through production simulation, it is found that when the starting pressure is not taken into account, the production of a single well can be effectively increased when different fractures change from 70m to 35m.

Therefore, it was determined to use the cementing bridge cluster perforation and pressure division technique. The number of perforations in the interval was 2 to 3 clusters, and the fracture distance in the north slope BKQ reservoir was shortened from 70m to 30m, and the fracture distance in the west slope BKQ reservoir was shortened to 40m. The microseismic survey showed that the fracture morphology is mainly banded, and the sweep bandwidth can fully cover the fractured well interval, so as to fully improve the fracture complexity target and volume reconstruction target.

2.2 Large displacement reverse mixed joint making process

(1) Fracturing pumping technology. The fractures in S reservoir have large roughness, and the fracture extension path is tortuous, and the proppant movement in the fracture lacks good regularity, so it is difficult to simply introduce the "slippery water + sand" technology. According to the physical simulation data of S reservoir, in the fracture initiation stage and the initial propagation stage, gravel will have an influence, and the viscosity of slippery water is low. Therefore, the pre-fracture formation with large displacement can further improve the fracture complexity in the well zone. Therefore, the complex fracturing technology of "guar gum + slippery water" was selected in the initial stage of horizontal well S development to construct fractures with good complexity and further enhance the reconstruction effect. According to the field practice, frequent overpressure and high pressure can not effectively improve the construction displacement in the process of joint construction with slippery water, which will not only affect the construction process, but also affect the actual cracking effect of artificial cracks. The main reason is that the leakage of slippery water is large and the viscosity is low, and the fractures in the well zone of conglomerate formation are narrow. In addition, the physical simulation found that the cluster perforation and shallow deep hole may lead to the increase of fluid friction, while the liquid in conglomerate has a circumferential flow phenomenon, which promotes the complexity of fractures near the wellbore. Through the combined action of the two factors, the construction process always maintains a high pressure, unable to raise the displacement smoothly, and thus difficult to fully extend the artificial cracks.

Therefore, combined with the advantages of various fracturing fluids, 200mPa·s cross-linked Guar gum was selected to effectively improve the cracking effect and efficiency of the main joint by taking advantage of the low filtration loss and high viscosity of Guar gum during the fracture initiation period. At the same time, it was combined with slug treatment to build a good seam width and reduce the construction pressure. After the construction displacement meets the requirements, 5.5mPa·s slippery water is selected for joint construction. The reverse mixing technology of "Guar gum sand carrying + smooth water seam making + Guar gum seam making" can not only effectively extend the main crack, but also effectively connect the pore space of the main crack wave. According to the field practice results, the fracturing displacement of guar gum and smooth water can exceed $8m^3$/min and $9.8m^3$/min by using the above technology, which fully reduces the construction difficulty, improves the fracture initiation and extension effect, and further improves the contact area between reservoir and fracture. In 2018, the construction displacement was continued to increase, and the displacement reached $12m^3$/min under the condition of 5000m horizontal Wells and 3 clusters of perforation, realizing the limit of wellbore construction [3].

(2) continuous + slug combination sand adding technology. With the increase of grain size fluctuation and content of gravel in conglomerate formation, the roughness of fracture surface also increases, which makes the placement of proppant more complicated than that of shale formation. In addition, the Young's modulus of S reservoir is in the range of 20GPa -- 25GPa, Poisson's ratio is in the range of 0.22 -- 0.25, and the formation is soft, resulting in proppant embedment, which has a certain impact on the conductivity level of artificial fractures. Therefore, this kind of reservoir needs to lay proppant strictly.

In S reservoir, there are depressions, and some fan bodies are developed. Due to certain differences in reservoir formation mechanism, reservoir characteristics and reservoir characteristics of different slopes are also quite different. The BKQ reservoir in West Slope 18 is dominated by mudstone with small sand span, which enables effective placement of proppant in the reservoir. The sand body of the second member of BKQ in the back slope 131 well area has a large span. The first member of Baier Member of the upper part of the sand body is an oil reservoir, while the second member of the middle and lower part of the sand body is a tight non-oil reservoir. There is no significant difference in lithology between the two layers, and there is no stress or lithology between each layer. With conventional fracturing techniques, the longitudinal extension of the artificial fracture is not controlled, which can affect effective propping during proppant settlement.

To solve the above problems, with the help of sand carrying performance test analysis, the proppant settlement law of various sand carrying liquids and the settlement law of various injection methods were revealed, and then with the help of sand adding process optimization, proppant placement was effectively optimized to provide a good guarantee for placement concentration.

First, the law of proppant settlement under various sand carrying liquid conditions. For low-viscosity liquids, dynamic sand processing is generally carried out with the help of the turbulent action of fracturing fluid to simulate the displacement condition of $4m^3/min$. When injected into sub-fractures, the proppant will settle in fractures. Only after the displacement is adjusted to $8m^3/min$ can the settlement be effectively alleviated. Compared with low viscosity liquid, high viscosity liquid has more prominent sand carrying capacity, and will not easily appear settlement based on low displacement conditions.

Second, settlement law based on different injection mode conditions. Analysis of proppant deposition of low viscosity fluid based on various injection conditions. In the case of continuous injection, the proppant rapidly settles and becomes a berm that cannot be fully injected into the distal fracture. The slug injection method is selected. After the front slug completes the injection operation and becomes a sand bank, the rear slug will gradually advance the injection [4].

Under the condition that there is no stress shielding at the bottom of the reservoir and the lithology is not obvious, the method of "slug carrying sand + slippery water" is selected in the pre-forming link of the reservoir to construct the shielding layer at the bottom to avoid the fracture derivatives.

In the phenomenon of proppant embedment, the high sand ratio of ggel was selected for continuous sand addition to fully strengthen the proppant distal injection level, increase the proppant placement thickness per unit area, and fully improve the fracture conductivity level.

Therefore, the organic combination of sand addition technology and large-displacement reverse-mixed fracturing technology can fully improve the fracture-forming effect of conglomerate formation. When guar gum is selected, the crack initiation effect can be fully improved. After meeting the design displacement requirements, smooth water is selected to increase sand concentration according to the step mode for sand addition treatment. When the slug sand content is 25%, the high sand ratio of ggel is selected to carry out continuous sand addition operation. The application of this technology in field practice can not only have outstanding adaptability, but also can carry out construction activities smoothly.

3. Field application status

After 2016, 86 secondary volume fracturing processes were applied in the S reservoir. Selecting the cementing plug cluster perforation process not only ensured that the requirements of horizontal well reconstruction in the 6000m and 2000m horizontal sections were fully met, but also ensured that the maximum length of the horizontal section was 2022m, the maximum depth was 6008m, and the distance between fractures was shortened from 70m to 30m, further improving the effect of reservoir reconstruction. The proportion of slackwater was increased to 70%, and a large amount of liquid was injected into the formation to ensure that the formation energy was maintained. The maximum fracturing volume and support dose reached more than $4000m^3$ and $2400m^3$ [5].

On this basis, the production of horizontal Wells in tight reservoirs has been effectively broken through after reconstruction treatment, and the stable production capacity has been continuously improved. At present, the cumulative production of horizontal Wells in S formation has reached 86, all of which are capable of self-injection production. The daily oil production of more than 86% of the peak well is more than 40t and the maximum oil production is 117.7t, and the cumulative oil production of a single well exceeds 8589t in 300d and 28500t in 800d, reflecting stable and sustainable production capacity. See table below.

Table 1 Peak daily oil production of horizontal Wells in S reservoir

Oil production	proportion
≤10t	14%
40—60t	60%
60—80t	14%
80—100t	2%
100—120t	10%

Table 2 300d oil production of horizontal Wells in S reservoir

300d Oil production	Distribution ratio
$0.2—0.4*10^4t$	3%
$0.4—0.6*10^4t$	27%
$0.6—0.8*10^4t$	24%
$0.8—1.4*10^4t$	35%
$1.4—2.0*10^4t$	11%

4. Conclusion

In summary, for the reconstruction work of S conglomerate reservoir, combined with the concept of "fracture-controlled reserves", cutting volume pressure and reverse mixed fracture-building technology are proposed to fully improve the operation effect of tight reservoir horizontal Wells. This technology is highly targeted and operable. Volume fracturing + level and technology can fully improve the development quality of tight reservoir. It is also necessary to combine the theoretical research of reducing cost, increasing benefit subjects, improving nonlinear seepage flow and conglomerate fracture expansion mechanism, continuously optimize the fracturing scale and fracturing materials, and fully strengthen the production efficiency of horizontal Wells in tight oil reservoirs.

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