Influence of orientation of vertical crack of hydraulic fracturing treatment on the efficiency of reserve recovery

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Abstract. The article presents the study results of the influence of the orientation of a vertical crack from hydraulic fracturing treatment on the efficiency of oil reserve recovery, indicating the crack propagation direction. It was found that the increase in initial recoverable reserves is the greater, the longer the crack length is, and if the crack is oriented parallel and perpendicular to the filtration flow down to the permeable zone in the stagnant or deadlock zone, then the perpendicular connecting current lines from the injection well to the recovery well is most effective. The presented results show that HFT significantly changes the conditions for the oil reserve recovery in general in the reservoir area. Therefore, it is relevant to assess the contribution of a single HFT to the oil recovery factor of the reservoir area, as well as its effect on the wells density grid.

1. Introduction
The influence of the crack propagation direction of HFT on the efficiency of reserve recovery was considered in works [1, 2]. At the same time, interactions of wells pairs - injection and recovery with HFT were investigated. As was shown in works [3-6], HFT on one well significantly affects the operation of the surrounding wells. Consider how the crack orientation of HFT affects the reserve recovery in the whole area.

2. Materials and methods
As a research tool, we use the Tempest-More hydrodynamic simulation package (manufactured by Roxar / Smedvig).

3. Results and discussions
Figure 1 shows a model permeability field with an indication of the crack direction, corresponding to one of the considered options.

Consider the development options of the reservoir with the use of HFT, while the HFT will be oriented along the axis 0Y.

Let HFT be conducted in a low permeability area in the well area WPRD4.
The calculation results showed the following.

In Figure 2a the extrusion characteristic, corresponding to the third variant with the maximum crack length, is located below the curves of the other considered variants. This third option is characterized by the lowest efficiency because, despite the largest cumulative oil uptake, this option produces the maximum amount of water. The cumulative effect on reaching the water cut of the plot of more than 60% begins to decline sharply (Figure 2b). At the same time, for a certain period (with a water cut of 70 to 84%), the accumulated indicators of oil production in this variant are less than in the base case, which is associated with a sharp drop in oil production rate. However, then the flow rate on the base case decreases faster than for the version with HFT. With a water cut of 98%, the accumulated effect was: according to the first variant - 4.1 thousand m$^3$, according to the second variant - 6.5 thousand m$^3$, according to the third variant - 10.0 thousand m$^3$. Volumes of additionally produced associated water: variant 1 - 264 thousand m$^3$, variant 2 - 509 thousand m$^3$, variant 3 - 1064 thousand m$^3$.

Let us compare the obtained results with similar ones for a different orientation of the HFT crack. Figure 3 shows a comparison of IRR increments for cracks of different lengths and orientations. Here, the term “parallel” refers to the orientation of the fracture parallel to the rows of wells, the term “perpendicular” means the orientation of the fracture perpendicular to the direction of the rows of wells.

The picture shows unexpected results. It would seem that the crack direction along the rows of wells should have a greater effect in the reserve recovery because allows you to cover the impact of a larger volume of the reservoir [2]. The crack orientation along the straight line connecting the injection and the first recovery rows of wells leads to fast watering and less water flood coverage, which was also shown in [2]. In terms of the accumulated additional water productions, the results correspond to the accepted concepts: when the crack is oriented along the straight line connecting the injection and recovery well, more water is produced than with the “parallel” crack orientation. But at the same time, more oil is produced! The apparent contradiction is easily explained by the conditions in the problem formulation. In work [2] is considered, only a pair of wells— recovery and injection. Here is also considered an element of a development system consisting of a larger number of wells. Figure 4 shows that a crack with a “parallel” orientation is a kind of barrier to the front of the invading water, where is formed behind the crack a “shadow region” of larger dimensions than with a “perpendicular” crack orientation.
Figure 2. Comparison results of the development parameters of the site as a whole for variants for using HFT at the WPRD4 well: a – desaturation characteristics, b - dependence of the effect on the current water cut extracted product of the wells at the site, c - accumulated incremental oil production dynamics due to the use of HFT site, d - the dynamics of the accumulated incremental water production due to the use of HFT in the whole site.
Figure 3. Dependence of the IRR increment on the length and orientation of the crack during HFT at the well WPRD4.

Thus, the crack orientation relative to the location of the wells in the development system affects the efficiency of the reserve recovery. If the low-permeability zone is located close to injection wells, the implementation of the HFT crack oriented along the line of recovery wells leads to the formation of immovable oil reserves in the “shadow” zone behind the HFT well. At the same time, the technological efficiency of the reserve recovery of the site as a whole becomes lower than when the crack is oriented along a straight line connecting the rows of recovery and injection wells.

Consider the simulation results of oil reserve recovery for the case when the low-permeability zone of the reservoir is located far from a number of injection wells (well WPRD2) (Figure 5).
Figure 5. Comparison results of the development parameters of the site as a whole for variants for using HFT at the WPRD4 well: a – desaturation characteristics, b - dependence of the effect on the current water cut extracted product of the wells at the site, c - accumulated incremental oil production dynamics due to the use of HFT site, d - the dynamics of the accumulated incremental water production due to the use of HFT in the whole site.

Figure 5a shows that the desaturation characteristic, corresponding to the third variant with the maximum crack length, oriented parallel to a number of recovery wells, is higher than the curves of the other options considered, which corresponds to the greatest efficiency in the oil reserve recovery of the site as a whole. The cumulative effect increases smoothly, reaching a maximum when the water cut of wells in the area is 90%. With a water cut of more than 92-93%, the effect of the use of HFT begins to decline sharply (Figure 5b). With a water cut of 98%, the accumulated effect was: according to the first variant - 14.8 thousand m$^3$, according to the second variant - 23.1 thousand m$^3$, according to the third
variant - 29.8 thousand m$^3$. Volumes of additionally produced associated water: variant 1 - 96 thousand m$^3$, variant 2 - 226 thousand m$^3$, variant 3 - 344 thousand m$^3$.

Let us compare the increase in the IRR with variants with different crack lengths with its different orientations relative to the rows of wells (Figure 6).

![Figure 6](image_url)

**Figure 6.** The dependence of the increase in the IRR of the site on the length and orientation of the crack when conducting HFT on the well WPRD2.

As can be seen in the figure, in contrast to the previous case, the “parallel” crack orientation will increase the efficiency of the development of the deposit area. At the same time, the volumes of additionally produced water are reduced, which means the economic efficiency of the technology increases.

4. Findings

Thus, at the location of the low-permeability zone away from the injection wells in the stagnant or dead-end region of the reservoir, the crack of the greatest (of the considered values) length with an orientation perpendicular to the direct connecting injection and recovery wells has maximum efficiency.

5. Conclusions

The results presented above show that HFT changes the conditions for the oil reserve recovery in general in the reservoir area. Therefore, it is relevant to assess the contribution of a single HFT unit to the oil recovery factor of the reservoir area, as well as its effect on the wells density grid [7 – 10].

References

[1] Kanevskaya R D, Diyashev R D and Nekipelov Yu V 2002 The use of hydraulic fracturing for production stimulation and enhanced oil recovery *Oil Industry* [in Russian – Neftyanoye Khozyaystvo] 5 96-100

[2] Kanevskaya R D and Kats R M 1998 Evaluation of the effectiveness of hydraulic fracturing, production and injection wells under different systems of water-flooding reservoir *Oil Industry* [in Russian – Neftyanoye Khozyaystvo] 6 34-37
[3] Shakurova Al F and Shakurova Ay F 2018 The influence of hydraulic fracturing on the estimated ultimate recovery *IOP C. Ser.: Earth Env.* 194(8) 082039

[4] Vladimir I V, Manapov T F, Shakurova A F and Arzhilovsky A V 2012 Some specific features of modeling of a formation hydraulic fracture *Oilfield Engineering* [in Russian - Neftepromyslovoe Delo] 1 59-60

[5] Almukhametova E M, Fattakhov D I, Zakirov A I and Safiullina A R 2018 The analysis of the hydraulic fracturing efficiency at the Potochnoe field facility *AV* 194(8) 082004

[6] Almukhametova E M, Fattakhov D I and Zakirov A I 2018 The efficiency analysis of applying hydraulic fracturing of formation at *AB* 194(8) 082002

[7] Blanco E R 1990 Hydraulic fracturing requires extensive disciplinary interaction *Oil and Gas J.* 12 112-118

[8] Economides M J and Nolte K G 1989 *Reservoir Stimulation* (Prentice Hall, Eglewood Cliffs, New Jersey) p 430

[9] Sadvakasov A A, Shamsutdinova G F, Almukhametova E M and Gabdrakhmanov N Kh 2018 Modeling of Karachaganak field development *J. Phys. Conf. Ser.* 1015(3) 032007

[10] Almukhametova E M, Shamsutdinova G F, Sadvakasov A A, Tyncherov K T, Petrova L V and Stepanova R R 2018 Modeling development of Fyodorovsky deposit *IOP Conf. Ser.: Mat. Sci.* 327(4) 042100