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EFFECT OF WELL DESIGN AND GEOLOGICAL FEATURES ON «FISHBONE» WELL PERFORMANCE (FIELD X CASE STUDY)

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Fields with low porosity and permeability values, complex geological structure and high degree of uncertainty are the main share of all discovered reserves. Such field could be successfully developed only with implementation of modern techniques and non-standard methods.

These methods include the use of multilateral wells with long horizontal sections. They allow to increase the oil saturated area which is involved into development process. One of such design which consists of main horizontal wellbore and a few sidetracks is called «Fishbone» wells. Such constructions are used in situations when long horizontal sections with following multistage hydraulic fracturing are not applicable (risks of water coning or breakthrough of gas). There are lot of design factors which controls «Fishbone» well performance – length of horizontal section and sidetracks, angle between them, spacing between sidetracks.

The other significant role in field development planning geological features and sedimentary environment play. The value of average Net-to-Gross ratio (NTG), type of sand bodies, their scale, space distribution and connectivity have to be taken into account before production starts.

In the frames of this work performance of «Fishbone» well for different designs will be assessed in the reservoir with high degree of heterogeneity (with using synthetical model of a Field X). Effectivity of «Fishbone» construction will be compared with multilateral assemblies and base horizontal wells. Impact of each design features and reservoir characteristics will be evaluated and some recommendations about «Fishbone» design applicability could be formulated.

«Fishbone» well consists of one main wellbore and a few sidetracks. Such design requires less volume of drilling operations in comparison with drilling separate horizontal wells, allow to increase conformance of oil saturated rocks. According to reviewed resources, growth of drilling cost in value by 130 percent gives extra production up to 200–300 % [3].

The common design of «Fishbone» well is presented on Figure 1.

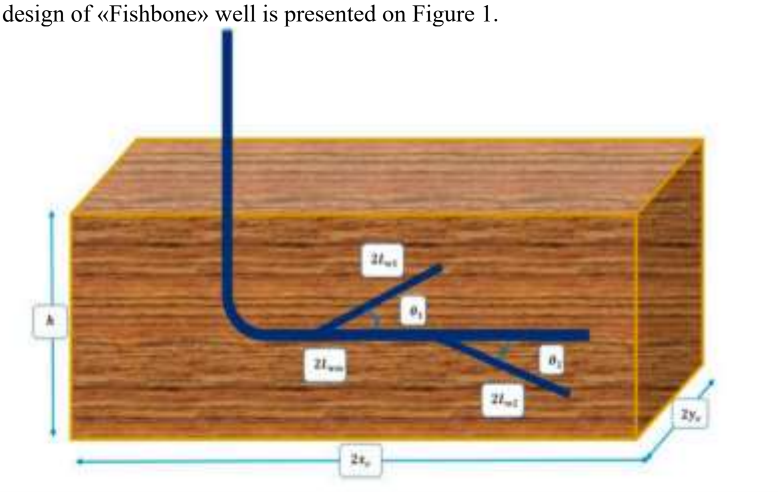

Fig. 1. «Fishbone» well [1]

Such configuration allows to achieve the following goals and tasks:

- Decrease drilling. It happens due to lower time required for tripping and drilling operations.
- Provide a way to involve isolated and unprofitable reservoir bodies into production.
- Produce oil from parts of reservoir with low poroperm properties and high degree of compartmentalization.
- Same production level can be achieved at lower drawdown due to higher Productivity Index (avoid/decrease possibility of development troubles such as water coning).

Distribution of sand bodies plays a crucial impact on each well design performance.

Reservoir conductivity describes connection of sand bodies with each other and with production/injection wells. If high connectivity is achieved with lower NTG value (plot of Connectivity as a function of NTG) – bigger part of reserves is involved in water flooding and development process, more reservoir bodies are connected and can transmit fluid (Fig. 2).

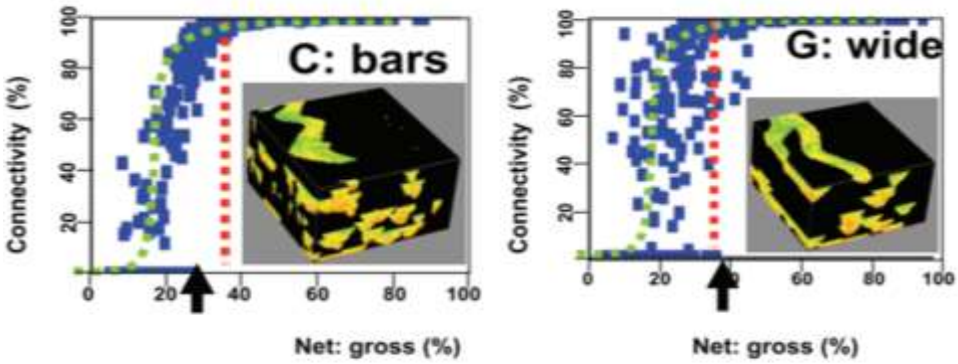

Fig. 2. Results of 1000 simulation NTG distribution in dependence on shape of sand bodies (bars–left, wide channels–right) [2]

Well design also influences a connectivity characteristic. It can be said, that «Fishbone» wells involve a certain area into development, they have higher possibility of drilling through sand bodies in comparison with simple horizontal well. In the frames of the study two types of bodies will be used for stochastic modeling-channels and bars.

After modeling process, following results were obtained.

1. Impact of main hole direction (azimuth) and sandbody type. Fishbone well is much more effective than horizontal well if it is drilled perpendicularly to direction of sand bodies elongation (more sand lenses are connected to well, some sidetracks are fully drilled through an isolate bodies). If «Fishbone» wells is drilled along bodies, it also has higher production, but less than in previous case.
2. Impact of lateral length / sidetracks number.

According to the revied studies it can be said that longer laterals obviously allow to achieve higher production. Consequently, in order to estimate optimal design, it was decided to evaluate «Fishbone» and its alternative case – multilateral wells according its total drilling length $L_{footage\ total}$:

$$L_{footage\ total} = L_{MW} + N * L_{ST} \quad (1)$$

where L_{MW} – length of main wellbore horizontal section, m; L_{ST} – length of sidetrack, m; N – number of sidetracks.
The most optimum design of multilateral well from the side of total drilled footage length (the highest production per meter of well) under uncertainty is «Fishbone» well with bigger number of shorter sidetracks. Production from many short sidetracks is higher than from a few long branches. It can be explained by more uniform reservoir penetration around main wellbore (more sand lens are drilled through and involved in production).

1. Impact of sidetrack angle.

The more angle, the higher square of reservoir is involved in production. The magnitude of angle is limited by available technology of drilling. According to the reviewed literature articles it can be said that angle varies from 10 to 45 degree. Consequently, that values were used in simulation (Table).

Table

Well performance data with different angle between main wellbore and sidetracks

Main wellbore and sidetrack angle	**Starting liquid flow rate, stm^3/d**
Base (horizontal)	67.7
10	82.3
15	103.5
20	118.8
25	128.8
30	157.9
35	166.7
40	167.5
45	165.4

The optimum angle between main wellbore and sidetrack from the drill safety and production gain aspects is 20–30°.

2. Impact of geological parameters (NTG/Sandbody type)

«Fishbone» wells are more effective if NTG is low (20–40 %) (Fig. 3).

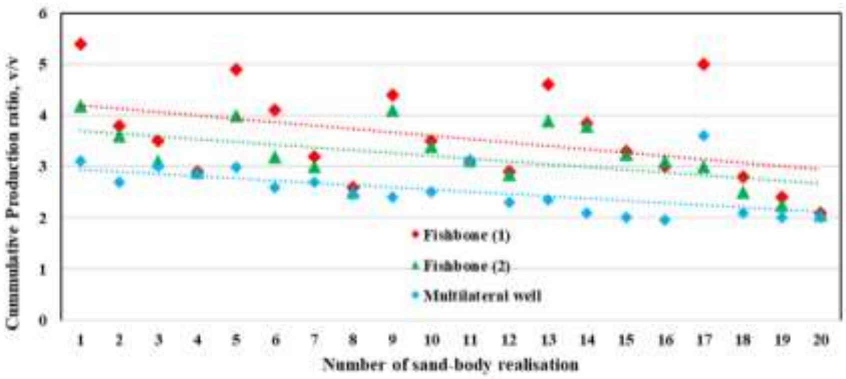

Fig. 3. Magnitude of cumulative oil production multiplication factor (in comparison with horizontal base case). Average NTG – 30 %

If NTG is in range from 60 to 70 – it still produces more than base horizontal case, but due to higher sand bodies connectivity value multilateral well could be more effective due to equal/higher production and simpler drilling process (fewer tripping operations). Sand bodies with great sizes (more than 600 m major and 6 m minor) is more effective to develop with multilateral well (Fig. 4).

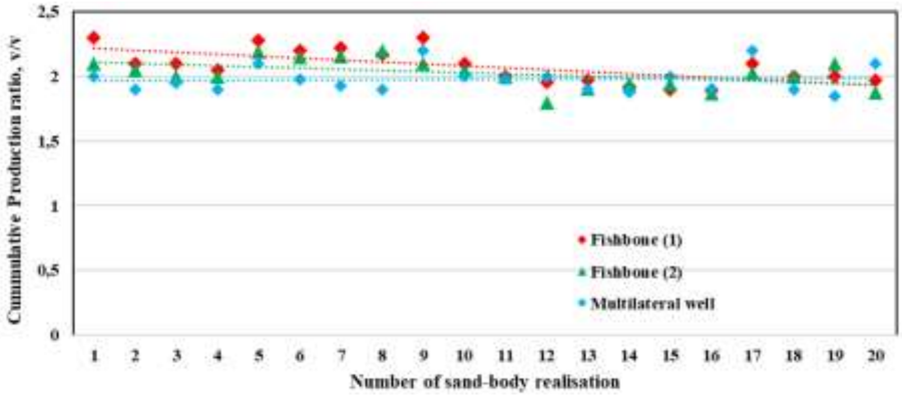

Fig. 4. Magnitude of cumulative oil production multiplication factor (in comparison with horizontal base case). Average NTG – 70 %

This work could be a start for the unified approach of well optimization model. Using laws and common factors, determined in the frames of this study, algorithm will analyze geological information (type of reservoir bodies, their ranges, thickness and orientation) and give the most optimal production well stock (horizontal, multilateral and «Fishbone» wells of particular design) for achieving higher NPV and recovery. This algorithm can also be presented by some Artificial Intelligence or machine learning model.

Also, one of possible direction of this study development is to use geomechanical model for calculation of maximum length of horizontal section and sidetracks in the frame of optimization process.

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