ASPECTS OF SIMULATION OF THE COMPARATIVE CALCULATIONS BETWEEN THE HORIZONTAL PROBE PRODUCTIVITY AND THE PRODUCTIVITY OF THE VERTICAL WELLS THAT PRODUCE FROM THE SAME PRODUCTIVE FORMATION

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Abstract

The paper analyzes the case of a group of wells from the continental shelf that produce from the same productive formation. According to the information on the nature and physical parameters of the collector rock, the productive formation presents a high degree of unevenness (heterogeneity and anisotropy). In the immediate vicinity of the horizontal probe, the flow is radial in a plane perpendicular to its axis, and in the rest of the layer the flow occurs in a horizontal plan.

In order to be able to determine the advantages of the horizontal probes relative to the vertical probes, a productivity analysis has been carried out. The anisotropy influence is taken into account through Muskat anisotropy coefficient and the effective permeability of the deposit. For example, the liquid flow equation of the horizontal wells for homogeneous and anisotropic deposits established by Joshi was used.

Keywords: *horizontal and vertical probes, anisotropy coefficient, productivity index, productivity ratio.*

1. Introduction

In the current context of the oil extraction industry, there is a particular interest in the drilling of horizontal wells. The main advantage is the openings of the productive layer over several times the vertical probes.

This advantage has increased the flow of the horizontal probes compared to the vertical ones due to the increase of the flow area.

In the case of flowing fluids to a vertical probe there is a symmetrical planar flow around it, which can be analyzed in a two-dimensional or one-dimensional system, compared to the horizontal probes where the analysis is made in a three-dimensional system (figure 1).

In the stationary flow through the homogeneous and isotropic fields it is considered that the surface of the horizontal probe drainage is ellipsoidal.

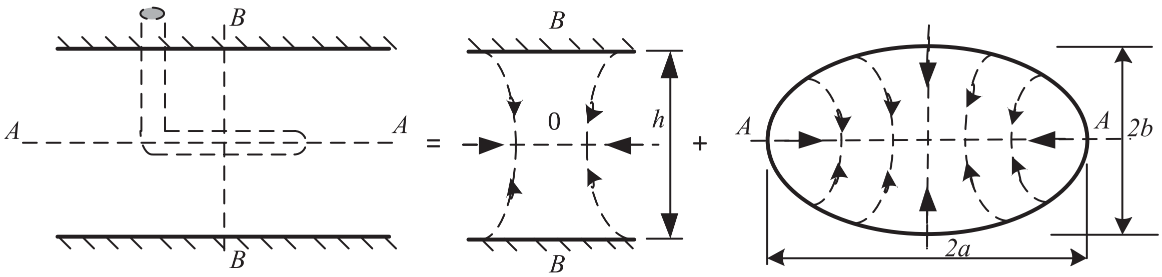

Fig.1. *Three-dimensional flow in two-dimensional system*

If the two flow effects are combined, the flow rate of a horizontal probe Q_h can be expressed with Joshi's relationship, valid for L> h and l/2 < 0,9 $r_{ch.}$

$$O_h = \frac{2\pi k_h h \Delta p}{\mu b \left[\ln \dfrac{a + \sqrt{a^2 - \left(\dfrac{L}{2}\right)^2}}{\dfrac{L}{2}} + \dfrac{h}{L} \ln \dfrac{h}{2 r_{sh}} \right]} \tag{1}$$

where:

k_h - permeability of the layer in the horizontal direction

h -layer thickness

Δp - Total pressure drop

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b - volume of crude oil
μ - the dynamic viscosity of crude oil
L - the length of the horizontal trajectory of the probe
a - Large ellipse semi-axis
r_{sh} - Radius of the horizontal probe
r_{ch} - Drainage chute for horizontal probes;

$$a = (L/2)\left\{0,5 + \left[0,25 + \left(\frac{r_{ch}}{L/2}\right)^4\right]^{0,5}\right\}^{0,5} \tag{2}$$

2. Theoretical and experimental aspects

The work is based on data from a group of soloists on the continental shelf. The probes produce from the same productive formation. The structure is represented by an elevation of the anticline and faulted shape.

The system of faults is complex, due to the geological evolution of the Cretaceous - Eocene sediments, during the deposition of the Oligocene formations.

The upper Cretaceous oil is contained into a structural trap.

From the lithological point of view, the shop rock is represented by a white, compact, compact, gaseous, limestone alloy alternation, conglomerates with limestone matrix and limestone sandstone, in which the presence of a system of vertically and obliquely oriented oblique microchips is filled with clay . According to the information on the nature and physical parameters of the collector rock, the productive formation presents a high degree of unevenness (heterogeneity and anisotropy).

One of the most important factors in ensuring the success of a horizontal probe is the completion of the well (well completion).

In determining the optimal variant, the implications of drilling and exploitation as well as the necessity of carrying out some operational interventions or probe stimulations should be taken into account.

The probes analyzed are free-hole type, equipped with slit lines and perforated. In this variant, the probe is not equipped in the productive horizontal zone, producing it through the natural wall, and in the horizontal tract area the probe is equipped with a production liner made of surface slopes.

In order to determine the advantages of the horizontal probes relative to the vertical probes, a productivity analysis has been performed.

Pseudo-stationary flow is recommended for the comparison of well productivity over a long period of time. In the immediate vicinity of the horizontal probe bore the flow is radial in a plane perpendicular to its axis, and in the rest of the layer the flow is horizontal.

For many deposits the permeability ratio (k_h / k_v) is greater than l and often close to 10. The anisotropy influence is taken into account $\sqrt{k_h k_v}$.

$$\beta = \sqrt{k_h / k_V} \tag{3}$$

The equation of liquid flow of the horizontal probes for homogeneous and anisotropic deposits set by Joshi is:

$$q = \frac{2\pi k_h h \Delta p}{\mu b \left[\ln \dfrac{a + \sqrt{a^2 - \left(\dfrac{L}{2}\right)^2}}{\dfrac{L}{2}} + \dfrac{\beta h}{L} \ln \dfrac{\beta h}{2 r_s}\right]} \tag{4}$$

Equation (4) applies to ellipsoidal drainage surfaces and can be used to obtain variance in the ratio of productivity indices q/Δp when comparing a horizontal probe with a vertical probe that produces the same field. The flow of a vertical probe is given by the formula:

$$q_V = \frac{2\pi k_h h \Delta p}{\mu b \ln\left(r_{ch} / r_s\right)}. \tag{5}$$

Starting from known field parameters, analyzes will be made on the productivity index of a horizontal probe and a vertical probe.

Table 1. *Field parameter values*

Nr. crt.	Field parameters	Stock parameters
1	Radius of drainage of the well r_c	225 [m]
2	The area of drainage A_d	15,9 [ha]
3	Anisotropy coefficient β is considered for three different situations	β = 2.5 anisotropy frequently encountered
		β = 1 total isotropy, $k_h = k_v$
		β = 0,25 large anisotropy on the vertical
4	Track length of horizontal probe L	60... 600 [m]

The calculations were made for three layers of layer thickness h = 5 m, 25 m and 50 m

The productivity ratio, i.e. the ratio between the productivity index of a horizontal probe and that of a vertical probe is given by the formula (6) and the large ellipse semi-axis is calculated with formula (2). The results obtained are shown in Table 2.

$$\frac{IP_h}{IP_v} = \frac{\ln\left(r_{ch} / r_s\right)}{\left[\ln \frac{a + \sqrt{a^2 - \left(\frac{L}{2}\right)^2}}{\frac{L}{2}} + \frac{\beta h}{L} \ln \frac{\beta h}{2 r_s}\right]} \quad (6)$$

Table 2. *Results obtained for different anisotropy values*

Nr. Crt.	L	a	Productivity ratio $(IP)_h/(IP)_v$								
			h = 5 m			h = 25 m			h = 50 m		
-	m	-	β=2.5	β=1	β=0,25	β=2.5	β=1	β=0,25	β=2.5	β=1	β=0,25
1	60	250.9	2.129	2.539	2.744	0.889	1.621	2.467	0.482	1.055	2.129
2	100	252.5	2.775	3.176	3.364	1.328	2.229	3.108	0.756	1.545	2.775
3	150	255.6	3.490	3.903	4.091	1.823	2.896	3.834	1.077	2.093	3.490
4	200	260.1	4.187	4.628	4.825	2.298	3.534	4.551	1.389	2.616	4.187
5	250	266.08	4.905	5.386	5.599	2.770	4.182	5.307	1.698	3.139	4.905
6	300	273.4	5.668	6.202	6.436	3.254	4.859	6.114	2.011	3.676	5.668
7	350	282.2	6.494	7.092	7.355	3.756	5.580	6.994	2.331	4.239	6.494
8	400	292.6	7.396	8.076	8.374	4.284	6.359	7.964	2.661	4.883	7.396
9	450	304.5	8.388	9.166	9.507	4.842	7.204	9.038	3.002	5.466	8.388
10	500	318.0	9.481	10.380	10.770	5.434	8.123	10.230	3.356	6.141	9.481
11	550	332.9	10.684	11.720	12.180	6.060	9.121	11.549	3.723	6.861	10.684
12	600	349.3	12.002	13.200	13.740	6.721	10.20	13.005	4.103	7.627	12.002

On the basis of the relations (6) and (2) whose results are presented in Table 2, we have drawn the variation curves (figure 2), the productivity ratio *$(IP)_h/(IP)_v$*, depending on the length of the horizontal trace of the probe *L* for the three values of the anisotropy factor β and the three values of the net layer thickness h. The ratio of the productivity index of the horizontal probes and that of the vertical wells for different layer thicknesses and anisotropies has been calculated.

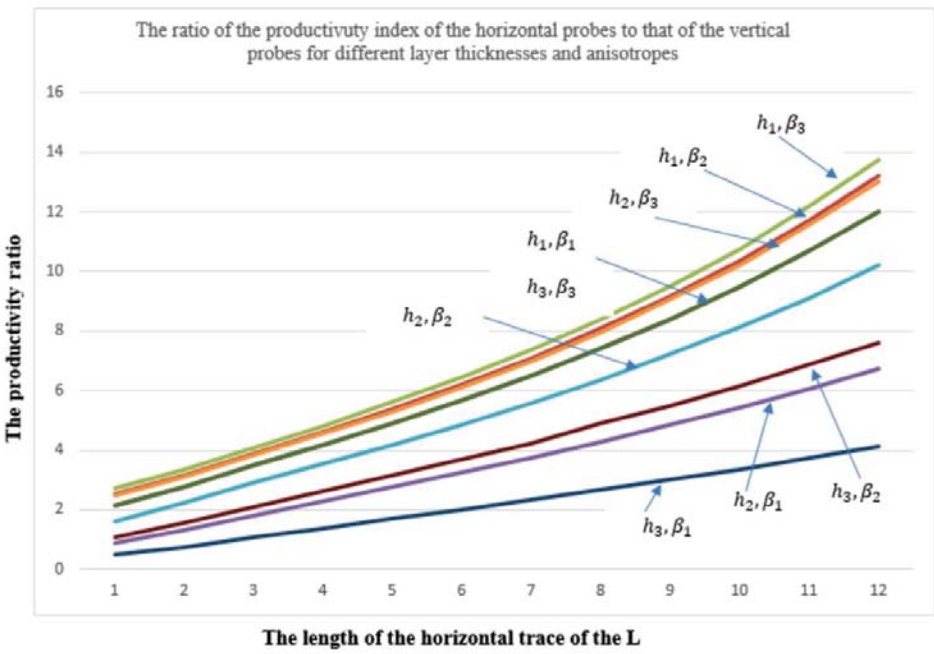

Fig. 2. *Variation curves of productivity ratio*

3. Conclusions

The graph drawn from the necessary calculations shows the importance of the anisotropy index and the thickness of the productive formation. Following the tracing of the curves, it is observed that the productivity ratio for anisotropy index value of 2.5 is less than 1, for anisotropy index value less than or equal to 1, the productivity ratio reaches up to 13, indicating that we have productive formations with many vertical natural cracks. The ratio of productivity indices drops evenly from 5 m thinner formations to 50 m thicker formations, which leads to the conclusion that horizontal probes represent a good option for use especially in thin layers.

If the productivity ratio is low, a horizontal probe drilled into an anisotropic pond does not maintain its profitability in front of a vertical probe. On the other hand, any horizontal probe drilled into a natural fissure field ($\beta = 0.25$) is much more efficient than a vertical probe. Thus, a large length probe (600m) shows a spectacular increase in the ratio of productivity indices to $\beta \leq 1$.

Analyzing the productivity of the horizontal probes, the following assessments can be made:

- ✓ For anisotropic layers ($\beta \leq 1$) with small and medium thicknesses, the horizontal probes have the highest yield;
- ✓ For layers with small or large thicknesses, but with ($\beta > 1$), the length of the horizontal path is an important factor that directly influences the increase of the probe productivity;
- ✓ Horizontal probes digested in low permeability layers, but with vertical cracks and micro-cracks, have higher productivity than vertical probes.

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