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# Study on Horizontal Well Layout Boundary Considering Wellbore Pressure Loss

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## Abstract

Based on the Dikken analytical calculation method of wellbore pressure loss under single-phase fluid and turbulent flow conditions, the correlation model between horizontal well output and horizontal section length and horizontal section distributed pressure difference is constructed. The influence degree of wellbore pressure loss on daily oil production of horizontal well, horizontal section pressure and production effect of horizontal well under different horizontal well lengths is analyzed, which provides certain reference for the design of horizontal well length and well layout.

## Keywords

Horizontal Well, Wellbore Pressure Loss, Length of Horizontal Section

## 1. Introduction

When studying and deducing the theories and calculation formulas of horizontal well production and pressure, the homogeneous and equal thickness, single-phase fluid reservoir model is mostly adopted, and the flow is stable flow or quasi-stable flow, without considering the pressure loss of horizontal well wellbore. Therefore, three-dimensional seepage in horizontal Wells can be simplified into elliptical 2D flows in the x-y plane and 2D flows in the z plane perpendicular to the horizontal section (see **Figure 1**). Domestic and foreign researchers derive a variety of theoretical calculation formulas for horizontal well output and pressure difference based on mathematical approximation, which is used in horizontal well output calculation and horizontal well length design [1]-[10].

With the expansion of the application range of horizontal well technology and the deepening of theoretical research, the problem of wellbore pressure loss has been gradually paid attention to. Foreign countries have carried out simulation

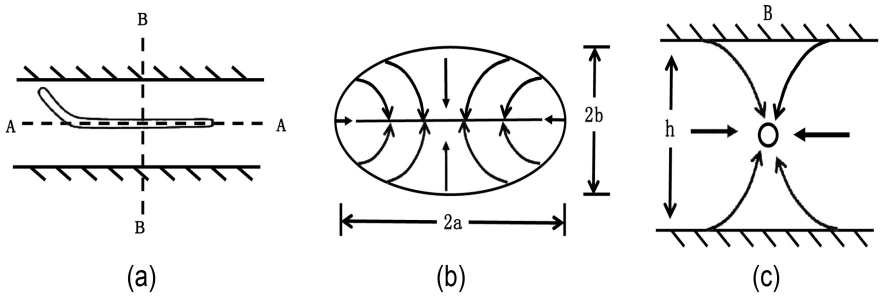


**Figure 1.** Flow line distribution of horizontal wells without considering wellbore pressure loss. (a) Horizontal well cross section. (b) X-Y plane streamline distribution. (c) Wellbore flow line.

experimental research and calculation research on wellbore pressure loss of surface horizontal well. The research results show that the wellbore pressure loss increases with the increase of horizontal section length and liquid production of horizontal well. Therefore, it has become a consistent view at home and abroad that the horizontal well pressure loss should be considered in the design of horizontal well length and well layout [9] [10] [11].

## 2. Wellbore Pressure Loss Theory

In 1990, Dikken proposed the analytical calculation method of wellbore pressure loss in horizontal Wells under single-phase fluid and turbulent flow conditions [11]. Dikken adopts infinite well bore to construct the fluid flow differential equation of horizontal well bore:

$$\frac{\mathrm{d}^2}{\mathrm{d}x^2} q_w(x) = J_s R_w q_w(x)^{2-\alpha} \tag{1}$$

Boundary conditions at point A ($x = 0$):

$$\lim_{x\to 0} p_w(x) = p_b \tag{2}$$

$$\lim_{x\to 0} \frac{\mathrm{d}}{\mathrm{d}x} q_w(x) = J_s \Delta p \tag{3}$$

Boundary conditions at point B ($x = 0$):

$$\lim_{x\to \infty} p_w(x) = p_i \tag{4}$$

$$\lim_{x\to \infty} \frac{\mathrm{d}}{\mathrm{d}x} q_w(x) = 0 \tag{5}$$

Wellbore fluid flow resistance under turbulent conditions:

$$R_w = 0.316 \left( \frac{\pi \mu_o d}{4\rho_0} \right)^{\alpha} \frac{8\rho_0}{\pi^2 d^5} \tag{6}$$

$x$ is distance between any point in the horizontal segment and point A, m; $J_s$ is oil recovery index, $m^3$/MPa; $q_w$ is horizontal wellbore flow, $m^3$/d; $\alpha$ is horizontal wellbore pressure loss index (Dikken coefficient), $\alpha = 0$ is rough surface, $\alpha = 0.25$ is a smooth surface (generally: 0, 0.15, 0.25); $R_w$ is wellbore flow re-

sistance, MPa; $d$ is horizontal wellbore diameter, cm; $\rho_0$ is oil density, kg/m$^3$; $\mu_0$ is oil viscosity, mPa·s; $p_x$ is horizontal pressure; MPa; $p_b$ is pressure at point A, MPa; $\Delta p$ is pressure difference at point A, MPa; $\Delta p = p_i - p_b$.

Introduce dimensionless variables, dimensionless horizontal segment distance $x_D$ (distance is 0 at point A at the heel end of horizontal segment):

$$x_D = \frac{1-\alpha}{2K}\sqrt{\frac{2J_{os}R_w}{3-\alpha}}x \tag{7}$$

$K$ is the coefficient, calculated according to the following formula:

$$K = \left[\Delta P\sqrt{\frac{(3-\alpha)J_{os}}{2R_w}}\right]^{\frac{\alpha-1}{3-\alpha}} \tag{8}$$

The dimensionless distribution of production in the horizontal section is:

$$q_{wD} = K^{\frac{2}{1-\alpha}}q_w(x) \tag{9}$$

The dimensionless production and dimensionless distance relationship of horizontal wells is:

$$q_{wD}(x_D) = (1-x_D)^{\frac{2}{\alpha-1}} \tag{10}$$

The dimensionally distributed differential pressure in the horizontal section is:

$$\Delta P_{wD} = \frac{P_w(x)-P_{wf}}{P_i-P_{wf}} = 1-(1+x_D)^{\frac{3-\alpha}{\alpha-1}} \tag{11}$$

## 3. Application

According to Dikken's calculation method of pressure loss in horizontal section, the horizontal section pressure distribution and the relationship between daily oil production and horizontal well length under different bottom-hole pressure were calculated for M oilfield (**Figure 2**).

The results show that the pressure at the end of the horizontal section (point B) and the beginning end (point A) is unbalanced. The flow pressure at point A is the lowest and the production pressure difference is the largest. When the length of the horizontal section is greater than 500 m, the wellbore pressure near point B is basically balanced with formation pressure, and the production pressure difference is smaller (**Figure 2(a)**). Accordingly, the production pressure difference at point A of horizontal well is the largest, and the flow rate of fluid from formation into point A is the largest. Point B has the smallest production pressure difference, the smallest flow rate of fluid from formation into point B, and the lowest production (**Figure 2(b)**).

It can also be seen from the relationship between horizontal well production and horizontal section length that, regardless of wellbore pressure loss, horizontal well production increases linearly with the increase of its length. Considering the wellbore pressure loss, the output of horizontal Wells increases nonlinearly

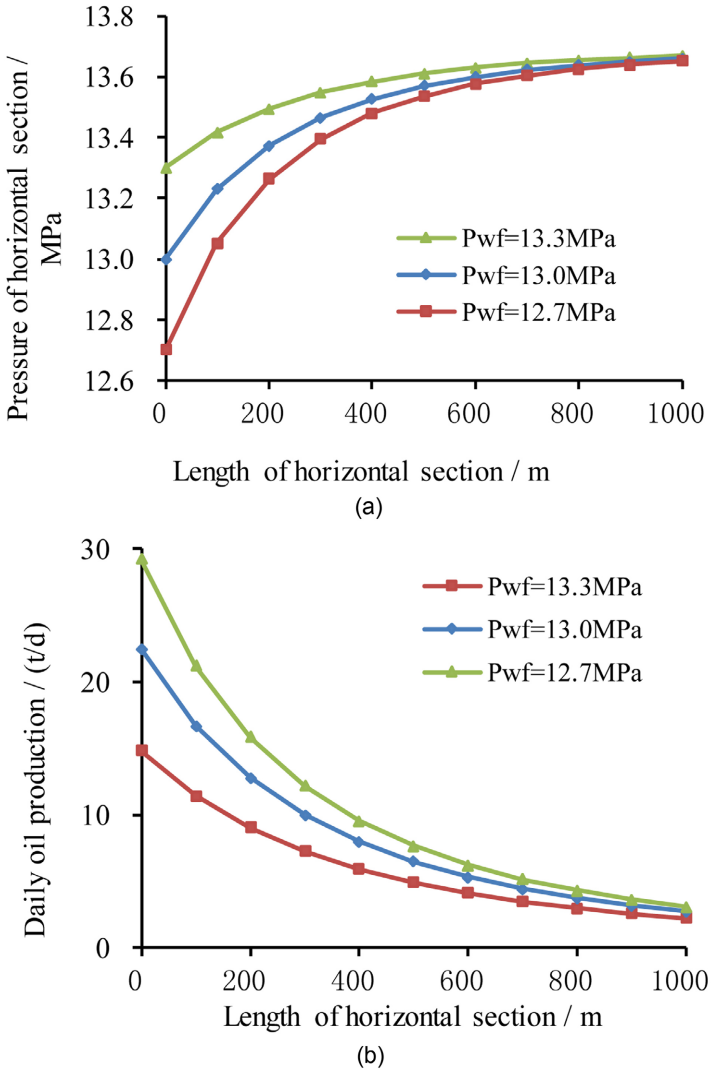


**Figure 2.** Relationship curves of horizontal pressure, daily oil production and horizontal well length under different bottom-hole pressure ($p_i$ = 13.7 MPa). (a) Horizontal pressure distribution. (b) Oil production distribution in horizontal section.

with the increase of their length (**Figure 3(a)**). When the length of horizontal Wells is greater than 300 m, the impact of the wellbore pressure loss is greater. With the further increase of the length of horizontal Wells, the increase of output decreases significantly, and the oil recovery index of horizontal Wells in meters also decreases significantly (**Figure 3(b)**).

According to the Dikken method calculation results, when the liquid production is low, the pressure loss is relatively small, and the horizontal section can be appropriately extended to 500 m. The length of the horizontal well was set as 300 m, and the wellbore pressure loss was considered as 0.1 MPa, 0.3 MPa and 0.5 MPa respectively, and the pressure loss sensitivity simulation research was carried out on the production of the horizontal section with constant flow pressure in sections. The simulation results show that when the water cut of horizontal

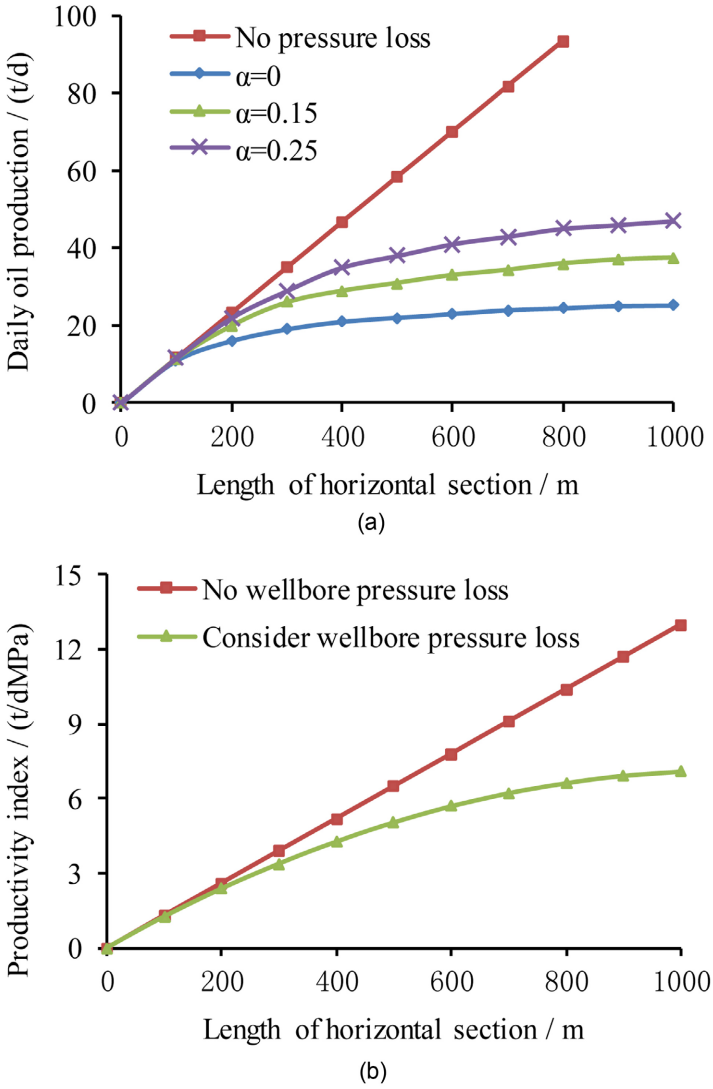


**Figure 3.** Horizontal well production and oil recovery index with horizontal well length. (a) Horizontal well production. (b) Horizontal well productivity index.

Wells reaches a certain level, there is little difference in the production effect of horizontal Wells within a small pressure loss range (**Figure 4**).

## 4. Conclusions

1) The longer the horizontal section, the greater the wellbore pressure loss, the lower the flow velocity of the horizontal section near the toe of horizontal well end from the formation into the wellbore, and the longer the horizontal section with low flow speed.

2) Due to the influence of wellbore pressure loss, horizontal well has a reasonable length, so it is not necessary to blindly pursue horizontal well length.

3) In the case of low fluid volume, the effect of wellbore pressure loss on the overall production of horizontal Wells is considered to be small.

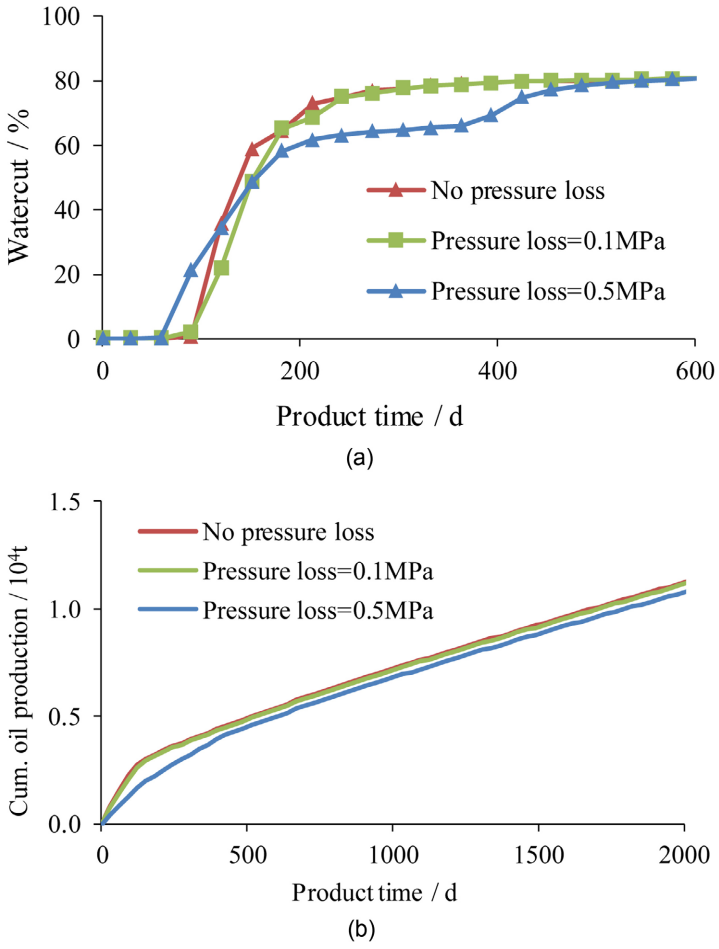


**Figure 4.** The relationship between water cut, cumulative oil production and production time with and without pressure loss. (a) Relationship between water content and time. (b) Relationship between Cum. oil production and time.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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