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A SENSITIVITY ANALYSIS FOR THE EFFECTIVE PARAMETERS DISPARITY ON PRESSURE AND PRESSURE DERIVATIVE OF WELL-TESTING IN A HORIZONTAL WELL

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Abstract

In this study, the pressure and pressure derivative of a drawdown test for a horizontal well was investigated. The examined well, it is located in the middle of a homogeneous oil reservoir and the calculation has been obtained using an industry standard PTA software known as Saphir software. Afterward, from the pressure derivative curve, initial radial, linear and final radial flow periods were observed, respectively. Then, the variation of the effective three parameters was inspected using the sensitivity analysis tool provided in Saphir software. The considered parameters are the ratio of the vertical to horizontal permeability (K_z/K_r), skin factor (S) and the horizontal length of the well (L_w). that the results reveals that by increasing the ratio of K_z/K_r and L_w the pressure curve is lowered, and it shifts upward with growing the S parameter. Meanwhile, by increasing the value of parameter K_z/K_r ratio, the initial radial flow becomes shorter in the pressure derivative curve and the linear flow starts earlier. In the other hand, within a pressure derivative diagram, as the value of S parameter rises, the hump becomes larger resulting a delay in the start of the first radial flow. Besides, the other consequences will be shifting downward the curves of the first radial flow and linear flow periods, increasing the duration of the linear flow, and also the final radial flow starts later. The analysis outcomes of this study were in conjunction of what it will be expected in well-testing procedure.

***Keywords**: Horizontal Well; Skin Factor; Permeability; Well-Testing; Saphir well-testing Software; Sensitivity Analysis.*

1. Introduction

Horizontal drilling is one of the most advanced technologies which has been used in the last thirty years in oil and gas industry. In fact, the horizontal wells are type of directional wells and they have many different practical applications. Those can be categorized in different aspects. The horizontal wells are being employed to reach the reservoirs located below the sea, lake, river, residential areas and mountainous terrain, where vertical access to these reservoirs is not possible [1]. In oil reservoirs with a high ratio of vertical to horizontal permeability, oil has a much tendency to move in a vertical direction. Therefore, horizontal wells cause an increase in oil production from this type of reservoirs [2]. These kinds of wells reduces the pressure drop due to production in the area around the well, slows down and delays water and gas coning phenomena, which is the main application of horizontal wells [1]. In reservoirs with thin pay zone, horizontal wells cause a greater degree of the well to reservoir contact, thus the production from this type of reservoirs increases, significantly [2]. Moreover, in the naturally fractured oil reservoirs, drilling horizontal wells leads to the division of existing vertical fractures, resulting in a considerable improvement in oil production [2]. Figure 1 shows a schematic representation of a horizontal production well.

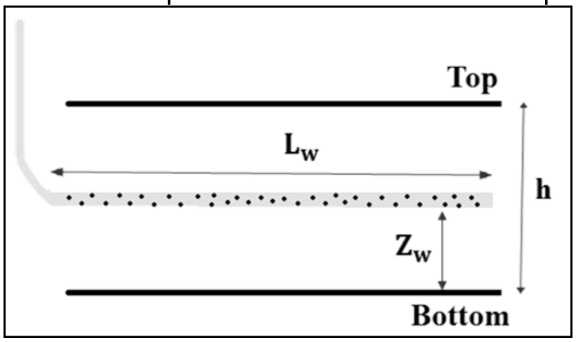


Figure 1.Schematic representation of a horizontal production well [3]

As shown in Figure 1, a well with the horizontal length of L_w is drilled in a reservoir with thickness h in a way that the distance from the lower horizontal line of the reservoir is Z_w.

Above the benefits of using horizontal wells, there are several applications of such a wells which they cause the interpretation of their pressure and the pressure derivative curves. Accordingly, there are some important and effective parameters [3]. In this study, we did a sensitivity analysis on the effect of changes in three different parameters of K_z/K_r ratio, Skin factor (S), and the horizontal length of the well (L_w) on the pressure and its derivative of a horizontal well. Since inside the horizontal wells, the motion of oil or gas is exist it is important to introduce briefly different type of fluids.

2. Different types of flow around a horizontal production well

It is assumed that the storage effect has not affected any flow period near the horizontal well. Therefore, during the analysis of pressure behavior of a horizontal production well which is drilled close to one of the upper or lower reservoir boundaries (Top or bottom), four unsteady state flow regimes can be observed in the middle time region [5]. The mentioned flow regimes are characteristics of the reservoir that are listed as follows:

2.1. Initial radial flow

As the oil production starts from the reservoir, a radial flow in the vertical direction is formed around the horizontal production well (Fig. 2). This regime is indicated with the existence of a straight line with zero slopes in the pressure derivative diagram (Fig. 6).

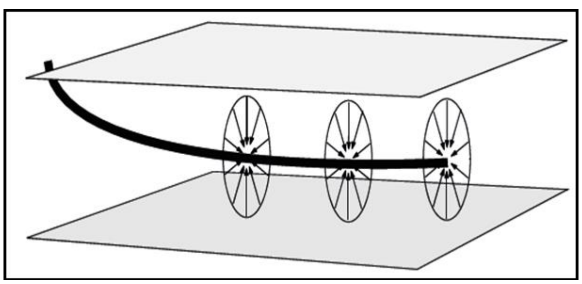


Figure 2. Initial radial flow (normal radial flow) [4]

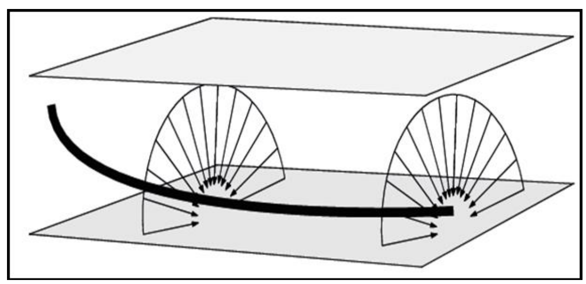


Figure 3. Semi-radial flow [4]

2.2. Semi-radial flow

In the case that the horizontal production well is drilled near one of the upper or lower reservoir boundaries (Top or bottom), the radial flow is terminated when the pressure pulse reaches the nearest boundary and the semi-radial flow starts (Fig. 3). Observing a horizontal straight line on the pressure derivative with more value than the radial flow indicates the semi-radial flow period (Fig. 6).

2.3. Linear flow

After the semi-radial flow reaches to the farthest vertical boundary of the reservoir, the linear flow is formed (Fig. 4). In this state, the behavior of the horizontal well is similar to the behavior of a vertical well with infinite conductivity fractures. The existence of the straight line with slope + 0.5 in the pressure derivative curve is the sign of this flow regime (Fig. 6).

2.4. Final radial flow

Since a radial flow in the horizontal direction causes the conduction of oil towards the production well, the final radial flow is called the horizontal radial flow (Fig. 5). The existence of the straight line with zero slopes in the pressure derivative diagram indicates this flow regime (Fig. 6).

It should be mentioned that all four regimes cannot be observed in real well- testing because the wellbore storage effects cover the first radial and semi-radial flow regimes [4]. More details of using the flow regimes resulted in this study will provide in following sections.

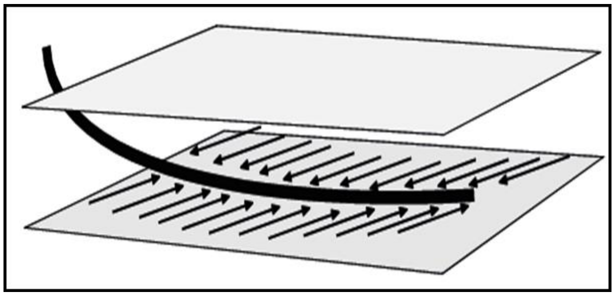


Figure 4. Linear flow [4]

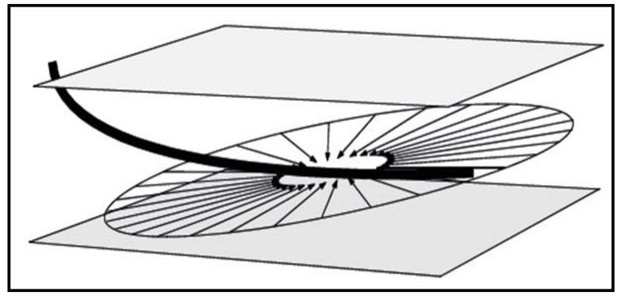


Figure 5. Final radial flow (horizontal radial flow) [4]

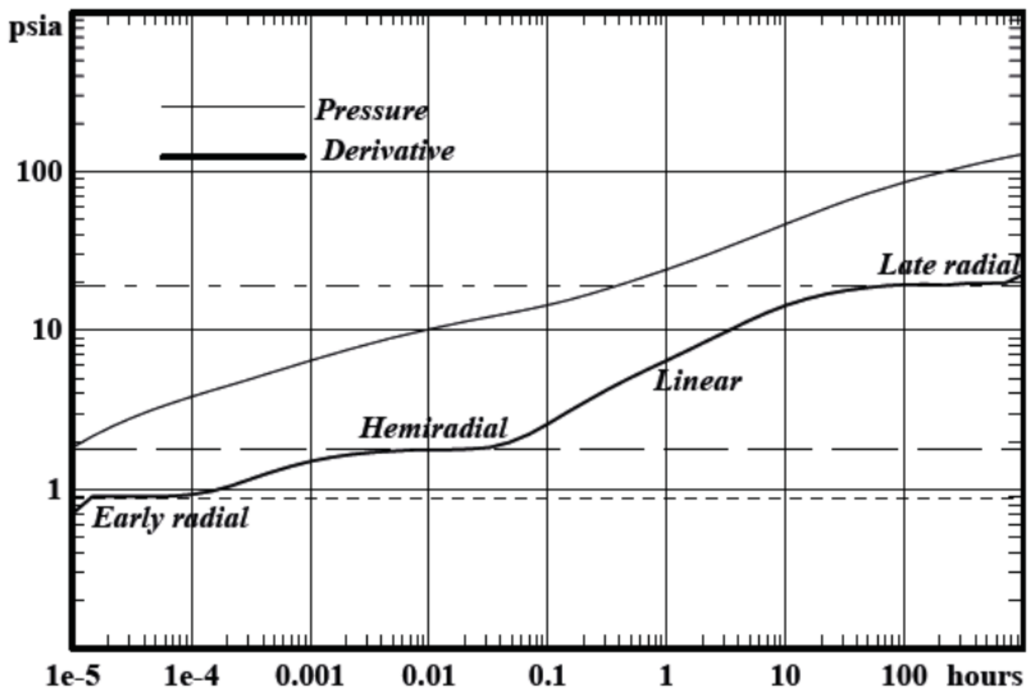


Figure 6. Pressure and pressure derivative curves in a horizontal well [4]

3. Research method

A drawdown test was performed on a horizontal production well which is located in the middle of a homogeneous oil reservoir. In this test, a horizontal well produced with a constant rate of 500 STB/day during a flow period of 78498.3 hours. The data of flowing pressure change (P_{wf}) is obtained with time (t) shown in Table 1, as presented in previous literature [3]. The other primary properties of the horizontal well as well as the indicated reservoir are listed in Table 2.

Table 1. Data of flowing pressure change (P_{wf}) is obtained with time (t) in a drawdown test

t (hr)	P_{wf} (psia)	t (hr)	P_{wf} (psia)	t (hr)	P_{wf} (psia)
0.00078	4985.61	0.63672	4849.689	516.4664	4509.059
0.00095	4983.088	0.76694	4846.231	622.0856	4483.915
0.00114	4980.402	0.92378	4842.784	749.3043	4457.79
0.00137	4977.49	1.11269	4839.348	902.5397	4430.767
0.00165	4974.351	1.34024	4835.921	1087.112	4402.932
0.00199	4970.968	1.61433	4832.503	1309.431	4374.371
0.0024	4967.354	1.94446	4829.091	1577.214	4345.168
0.00289	4963.524	2.34211	4825.676	1899.76	4315.403
0.00348	4959.497	2.82108	4822.24	2288.267	4285.151
0.00419	4955.311	3.398	4818.75	2756.226	4254.478
0.00505	4950.996	4.09291	4815.157	3319.884	4223.443
0.00608	4946.595	4.92992	4811.401	3998.812	4192.102
0.00732	4942.146	5.93811	4807.415	4816.583	4160.499
0.00882	4937.684	7.15247	4803.129	5801.591	4128.675
0.01062	4933.242	8.61518	4798.484	6988.037	4096.665
0.01279	4928.844	10.37701	4793.428	8417.115	4064.498
0.01541	4924.508	12.49915	4787.914	10138.45	4032.199
0.01856	4920.249	15.05527	4781.899	12211.79	3999.79
0.02236	4916.07	18.13412	4775.341	14709.15	3967.289
0.02693	4911.973	21.84262	4768.196	17717.22	3934.711
0.03244	4907.953	26.30951	4760.416	21340.46	3902.068
0.03907	4904.006	31.6899	4751.952	25704.65	3869.373
0.04706	4900.126	38.1706	4742.751	30961.35	3836.632
0.05668	4896.305	45.97662	4732.763	37293.05	3803.854
0.06827	4892.537	55.379	4721.93	44919.61	3771.045
0.08224	4888.814	66.7042	4710.197	54105.83	3738.211
0.09905	4885.132	80.34544	4697.509	65170.67	3705.354
0.11931	4881.486	96.77637	4683.812	78498.3	3672.48
0.14371	4877.87	116.5675	4669.051		
0.1731	4874.281	140.4059	4653.18		
0.2085	4870.716	169.1195	4636.158		
0.25114	4867.171	203.705	4617.953		
0.3025	4863.645	245.3634	4598.545		
0.36436	4860.135	295.541	4577.931		
0.43887	4856.64	355.9803	4556.122		
0.52862	4853.159	428.7795	4533.148		

Table 2. Primary Properties of the horizontal well and reservoir

Parameters	Unit	Value
h	ft	100
r_w	ft	0.3
B_o	rbbl/STB	1.53951
μ_o	cP	0.342268
ϕ	----	0.23
C_t	$Psia^{-1}$	$1.06044*10^{-5}$
P_i	psia	5 000

Considering the provided data, pressure and flow rate diagrams were plotted with time by entering data from Tables 1 and 2 as well as production flow rate of well into Saphir software. The results are shown in Figure 7. Later, by using the icons for separating the pressure and pressure derivative (i.e. dp and dp$'$ respectively), the pressure and pressure derivative of the horizontal well were plotted and matching procedure was implemented in Figure 8. Consequently, the final properties of the horizontal well and reservoir were determined and the results are shown in Table 3. Other results would achieved and three types of flow were observed around the horizontal well and shown in the pressure derivative diagram of Fig. 8. Those flow types were initial radial flow, linear flow, and final radial flow, respectively.

Table 3. The final properties of the horizontal well and reservoir

Parameters	Unit	Value
S	-	0.00756612
C	rbbl/psi	0.00114098
Z_w	ft	50.4052
L_w	ft	1097.39
K_h	md.ft	104.282
K	md	1.04282
K_z/K_r	-	0.886349

In the final stage of this study, the effect of variation of different parameters on pressure and the pressure derivative of the horizontal well was investigated using the sensitivity analysis icon in Saphir software. In this study, sensitivity analysis is performed on three different parameters as the ratio of the vertical to horizontal permeability (K_z/K_r), the skin factor (S) and the horizontal length of the well (L_w). The results of such study are described in following sections.

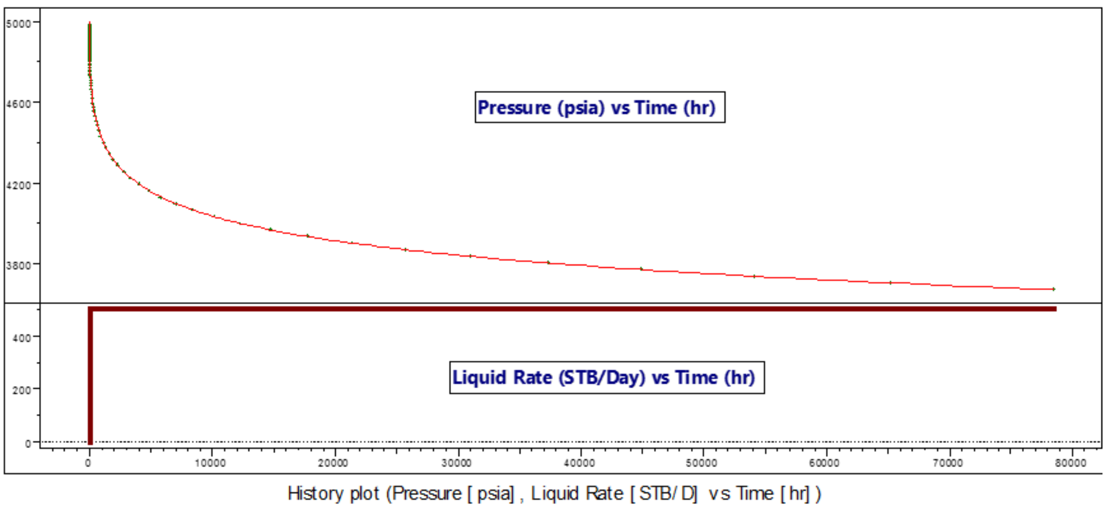


Figure 7. Pressure change and flow rate diagram

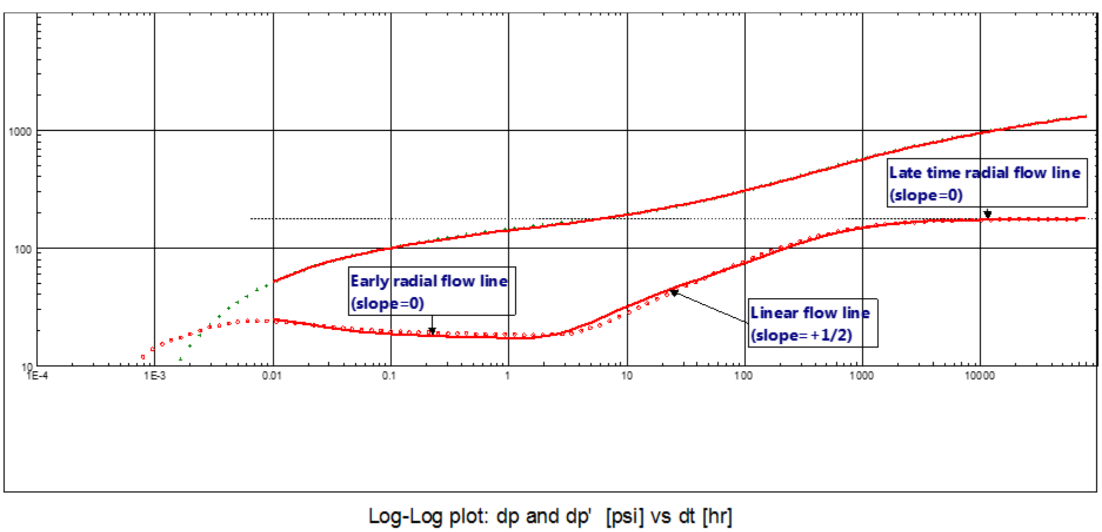


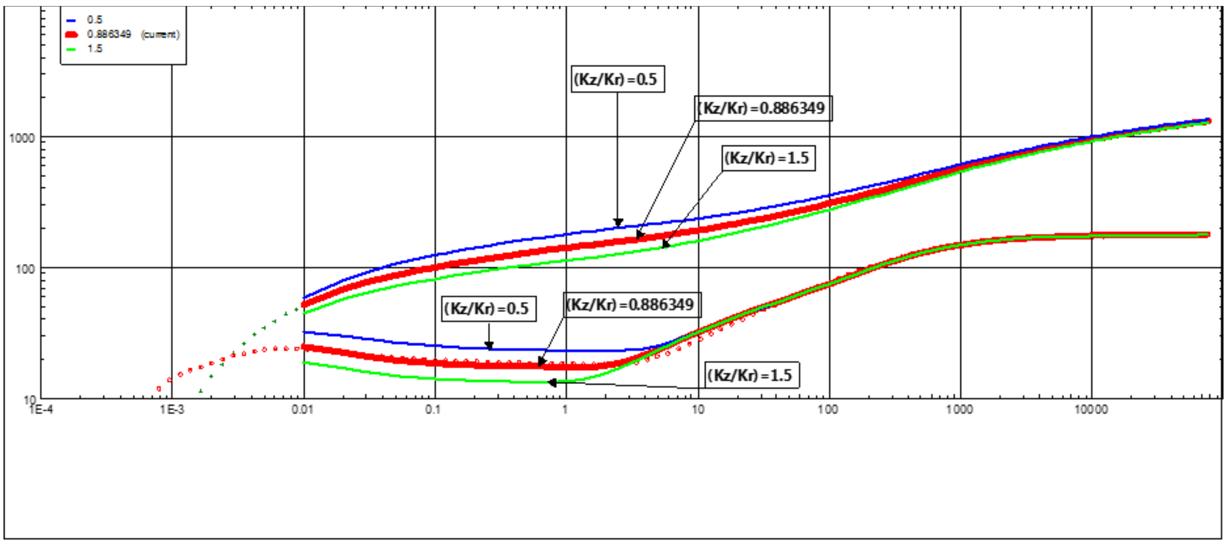
Figure 8. Pressure and pressure derivative diagram of the horizontal well after performing matching procedure

4. Results and discussions

In this section the effect of three critical parameters on pressure and pressure derivative diagrams in a nominated horizontal well are being discussed respectively as follow:

4.1. Effect of variation of vertical to horizontal permeability (K_z/K_r)

Counting on pressure curves in Figure 9, it reveals that the more the value of parameter K_z/K_r, the pressure diagram will be lower. Besides, as shown in the pressure derivative in Fig. 9, as the value of parameter K_z/K_r goes higher, the propagation speed of initial radial flow in the vertical direction will be more. Consequently, the initial radial flow reaches the upper and lower boundaries, sooner. This causes the initial radial flow to be shorter leading to the earlier start of a linear flow and its shorter duration.



Sensitivity to kz/kr: dp and dp' [psi] vs dt [hr]

Figure 9. The effect of variation of the vertical to horizontal reservoir permeability (K_z/K_r) on the pressure and pressure derivative diagrams in a horizontal well

4.2. Effect of skin factor (S) variations

As shown in pressure diagrams in Fig. 10, the more the *S* parameter, the pressure diagram will be higher. Moreover, as observed in the pressure derivative diagrams in Figure 10, the higher the *S* parameter value, the height of hump will be larger. Following the mentioned trend, initial radial flow delays and its duration decreases, too. Additionally, as shown in Figure 10, when the *S* parameter goes to higher values, the distance between the two pressure and the pressure derivative graphs will be also higher.

4.3. Effect of variation of the horizontal length of the well (L_w)

In Figure 11 the pressure graphs is plotted for the sensitivity analysis on L_w parameter. From this figure, it can be seen that as the L_w parameter goes higher, the pressure diagram will be lower the pressure diagram.

Meanwhile, as in the pressure derivative diagrams in Figure 11, it is indicated that as long as the value of L_w parameter reach higher, the level of initial radial and linear flow periods will be lower, and the period of linear flow will be longer. Those illustrations can be a reason that the final radial flow begins later in compare to other flow regimes.

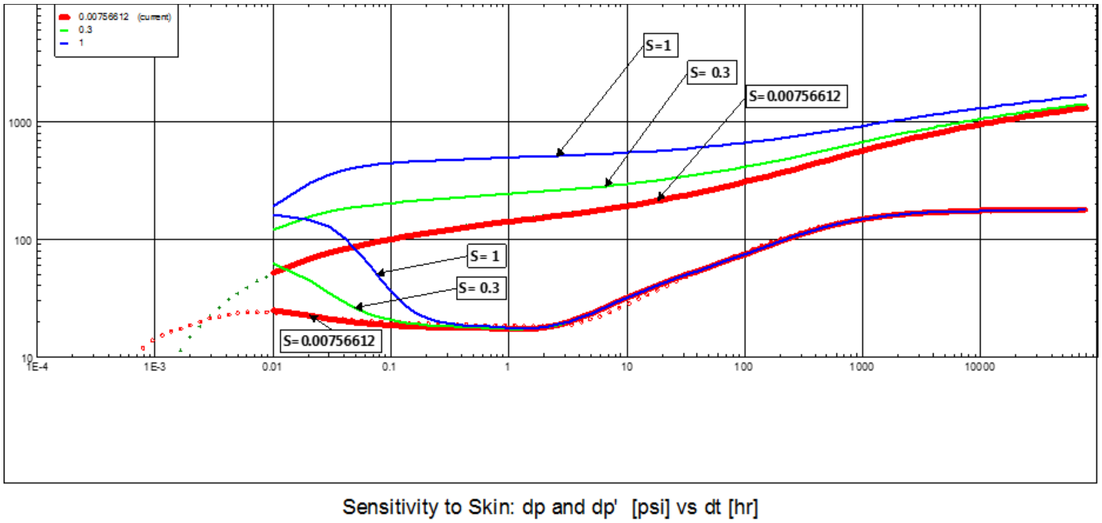


Figure 10. Effect of the skin factor parameters (S) on the pressure and the pressure derivative diagrams of a horizontal well

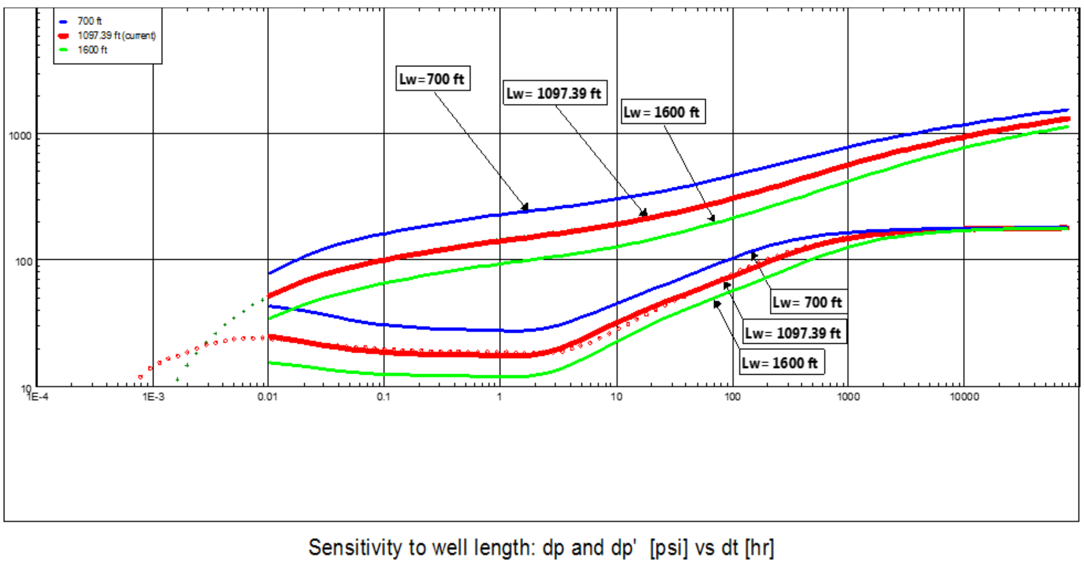


Figure 11. Effect of variation of the horizontal length of the well (L_w) on pressure and the pressure derivative diagrams of a horizontal well

5. Conclusions

Three parameters which affecting the pressure and pressure derivative diagrams (known as (K_z/K_r), (S) and the L_w), were subjected for sensitivity analysis in this study and some results were achieved. The results indicated that by increasing the parameter K_z/K_r increases, the pressure diagram is lowered. Also, considering the pressure derivative diagram, the higher the parameter K_z/K_r, the sooner the initial radial flow is over so that the linear flow starts earlier and its duration is longer. In contrast, as the value of the parameter S increases, the pressure graph shifts upward. In the pressure derivative diagram it indicated that, the larger S parameter values, the higher the hump height. Additionally, the initial radial flow begins later, and its time period is shorter. The higher values of S parameter it is shows the same trend for the distance between the two pressure and the pressure derivative graphs which will be higher too. In contrast, the pressure diagram shifts downward with an increase in parameter L_w. Furthermore, the higher the parameter L_w, the lines of the pressure derivatives of the initial radial and linear flow periods will be lower. Besides, the duration of the linear flow becomes longer, resulting in the later start of the final radial flow.

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