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Phasing Skin Factor Analysis for Oil Wells Completions

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Abstract

This paper presents a comparative analysis of the effect induced by perforation skin in case of vertical production oil wells. The Karakas and Tariq method has been used, by applying it both to the classic perforation system and to the one developed by Penetrator Canada Inc.

Key words: *skin, phasing skin, producing well system, MaxPerf*

Calculation of the Skin Effect

For calculation of perforation skin, according to perforations type, we used a simple and accurate semi-analytical method introduced and developed by Karakas and Tariq (1988, 1991) for perforated systems.

In this method it is assumed that perforation skin is the summation of horizontal, vertical, wellbore and perforation crush skin:

$$S_{perf} = S_H + S_V + S_{Wb} + S_C \tag{1}$$

Figure 1 gives all the relevant variables to calculate the perforation skin. These include the well radius (r_w), the perforation radius (r_{perf}), the perforation length (l_{perf}), the angle of perforation phasing (α) and the vertical distance between two successive perforations (h_{perf}).

Horizontal Skin, S_H

The horizontal skin is:

$$s_H = ln \frac{r_w}{r_w(\alpha)} \tag{2}$$

where $r_w(\alpha)$ is the effective wellbore radius and it is a function of phase angle, α.

$$r_w(\alpha) = a_\alpha \cdot l_{perf}, \alpha = 0(360°) \tag{3}$$

$$r_w(\alpha) = a_\alpha (r_w + l_{perf}), \alpha \neq 0(360°) \tag{4}$$

The constant a_α depends on the perforation phasing (Table 1). The total contribution of the horizontal skin is usually small.

Table 1. Constant for perforation skin effect [3]

α	a_α	a_1	a_2	b_1	b_2	c_1	c_2
0	0.25	-2.091	0.0453	5.1313	1.8672	0.16000	2.675
180	0.5	-2.025	0.0943	3.0373	1.8115	0.02600	4.532
120	0.648	-2.018	0.0634	1.6136	1.777	0.00660	5.32
90	0.726	-1.905	0.1038	1.5674	1.6935	0.00190	6.155
60	0.813	-1.898	0.1023	1.3654	1.649	0.00030	7.509
45	0.86	-1.788	0.2398	1.1915	1.6392	0.00005	8.791

Vertical Skin, S_V

The vertical skin effect is:

$$s_V = 10^a h_D^{b-1} r_D^b \tag{5}$$

where:

$$h_D = \frac{r_{perf}}{l_{perf}} \sqrt{\frac{k_H}{k_V}} \tag{6}$$

$$r_D = \frac{r_{perf}}{2h_{perf}} \left(1 + \sqrt{\frac{k_H}{k_V}} \right) \tag{7}$$

$$a = a_1 \log r_D + a_2 \,;\; b = b_1 \log r_D + b_2 \tag{8}$$

and k_H, k_V are the horizontal and vertical permeabilities.

The vertical skin effect has the largest contribution for total perforation skin and takes important values according to perforation densities and radius.

Wellbore Skin, S_{Wb}

For wellbore skin effect, the calculation formula is:

$$s_{wb} = c_1 e^{c_2 r_{wb}} \tag{9}$$

where

$$r_{wb} = \frac{r_w}{l_{perf} + r_w} \tag{10}$$

is an dimensionless factor; the constants c_1 and c_2 can also be taken from Table 1.

Perforation Crush Skin, S_C

This skin effect has an important contribution to total perforating skin effect; it is well highlighted in Figure 2 and it can be calculated with the following equation:

$$s_C = \frac{h_{perf}}{l_{perf}}\left(\frac{k_H}{k_C} - 1\right)\ln\frac{r_c}{r_{perf}} \tag{11}$$

where k_C is crushed zone permeability and r_C is the distance from the center of perforation to the edge of crushed zone.

MaxPERF Penetration System

Penetrators Canada Inc. has developed completion and stimulation systems that provide a more efficient method to establish the communication between the wellbore and the target zone. **MaxPERF** tool system (fig. 3) can be run in new or existing well to drill multiple radial tunnels in the formation, up to 1.8 m laterally from the wellbore and 25.4 mm diameter.

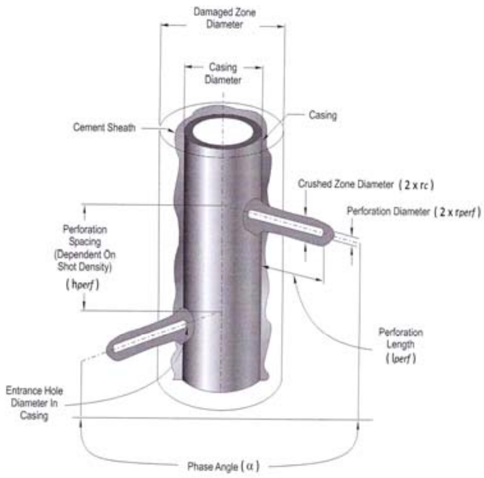

Fig. 1. Well variables for perforation skin [3]

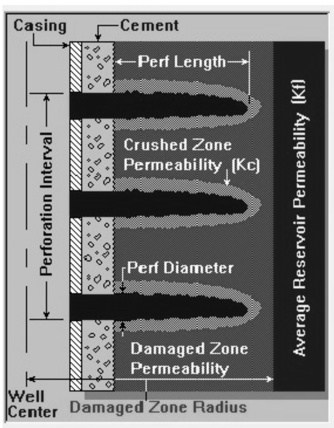

Fig. 2. Crushed and damaged zone

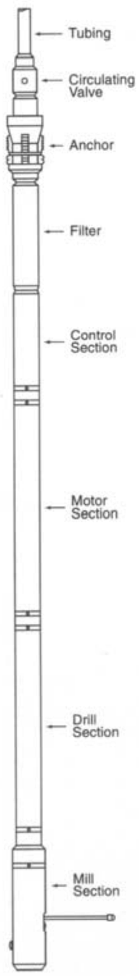

Fig. 3. MaxPERF Tool [7]

Application

Well "A" Data
(Standard penetration)

- Well Radius, r_w = 0.07 m
- Perf Length, l_{perf} = 0.152 m
- Perforation Spacing, h_{perf} = 0.166 m
- Perforation Radius, r_{perf} = 6.35 mm
- Shot Density = 6 SPM
- Crushed Zone Radius, r_c=12.7 mm

Well "B" Data
(MaxPERF penetration)

- Well Radius, r_w = 0.07 m
- Perf Length, l_{perf} = 1 m
- Perforation Spacing, h_{perf} = 0.166 m
- Perforation Radius, r_{perf} = 12,7 mm
- Shot Density = 6 SPM
- Crushed Zone Radius, r_c = 0 mm

Table 2. Perforation skin effect vs. permeability anisotropy (k_V/k_H) and phase angle

k_V/k_H	α = 360°	α = 180°	α = 120°	α = 90°	α = 60°	α = 45°
	S_{perf}					
1	2.35	1.51	1.56	1.41	1.63	1.59
0.8	2.54	1.76	1.83	1.65	1.88	1.83
0.6	2.87	2.13	2.22	1.99	2.26	2.17
0.4	3.42	2.74	2.85	2.54	2.84	2.71
0.2	4.66	4.06	4.21	3.68	4.06	3.81

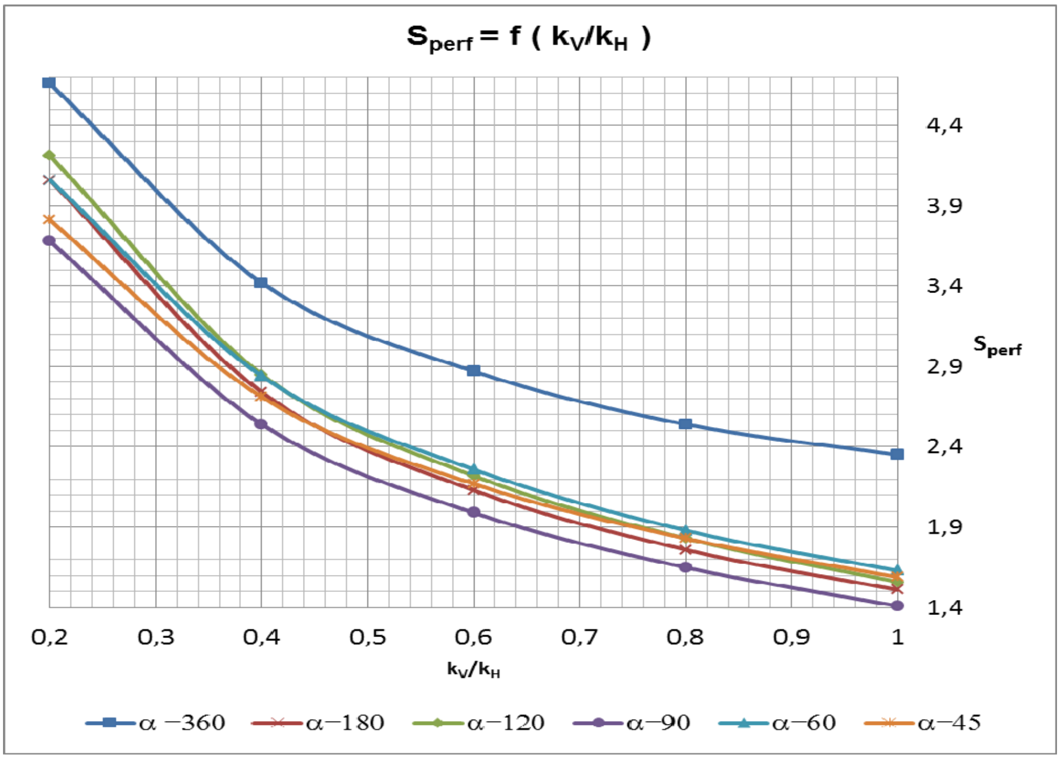

Fig. 4. Perforation skin effect vs. k_V/k_H and phase angle

Table 3. Perforation skin effect vs. k_H/k_V, phase angle and crushed zone for Standard and MaxPerf perforations

α	Standard perforations						MaxPerf	
	$k_c = k_H$		k_c = 0.1 k_H		k_c = 0.01 k_H		L_{perf} = 1m r_{perf} = 12.7mm	
	k_H/k_V =10	k_H/k_V =1	k_H/k_V =10	k_H/k_V =1	k_H/k_V =10	k_H/k_V =1	k_H/k_V =10	k_H/k_V =1
	S_{perf}	S_{perf}	S_{perf}	S_{perf}	S_{perf}	S_{perf}	S_{perf}	S_{perf}
360°	6.42	2.32	13.26	9.16	81.6	77.5	-0.6	-1
180°	5.87	1.51	12.7	8.35	81.1	76.7	-1.19	-1.8
120°	6.02	1.56	12.85	8.4	81.2	76.8	-1.2	-1.97
90°	5.15	1.41	11.97	8.25	80.3	76.6	-1.25	-2.02
60°	5.6	1.63	12.42	8.46	80.8	76.8	-1.14	-2.04
45°	5.19	1.59	12	8.43	80.4	76.8	-1.12	-2.03

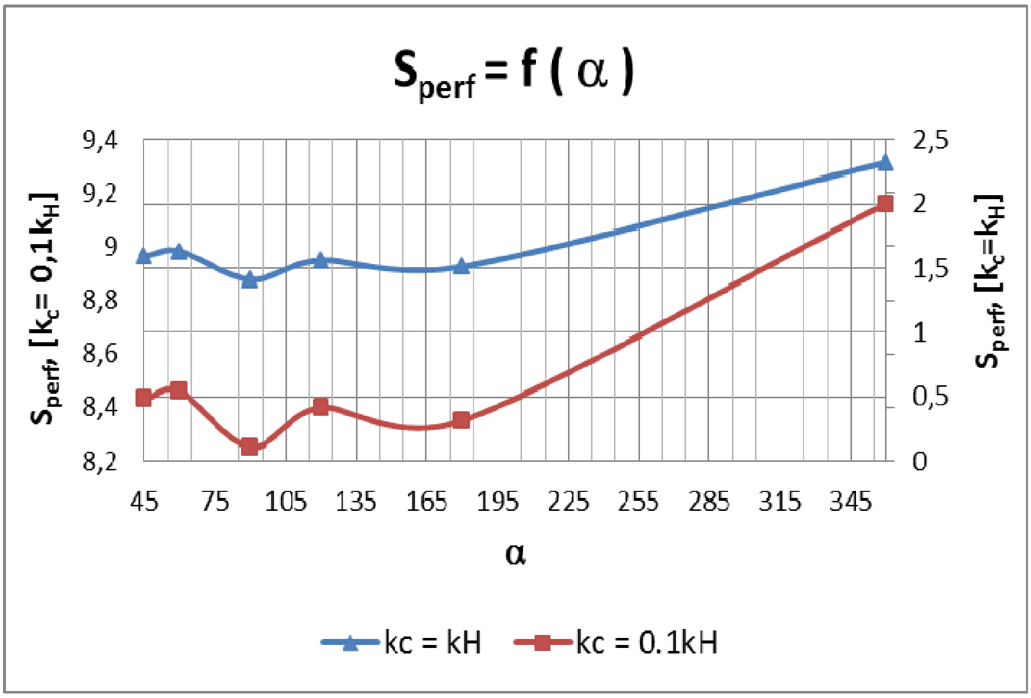

Fig. 5. Perforation skin effect vs. phase angle for different crush zone permeabilities

Conclusions

Both phasing skin and permeability anisotropy have a major influence to Total well Skin Factor. The crush zone made by perforated system also increases the skin factor four times (see fig. 5).

By using MaxPerf Penetrating System, the crush zone will be eliminated, the perforated length will be 1m instead of 0.152 – 0.203 m and also the total well skin factor will reach negative values (see fig. 6).

This analysis indicates that the smallest phasing skin was recorded for phase angle = 90° (see figs. 6 and 7) regardless of the perforated system used.

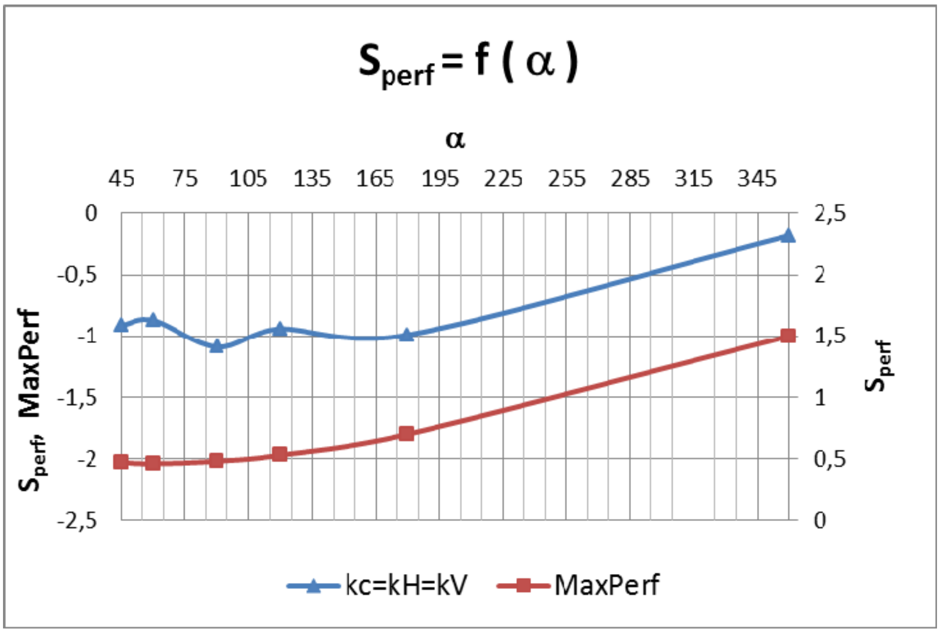

Fig. 6. Perforation skin effect for Standard and MaxPerf perforations

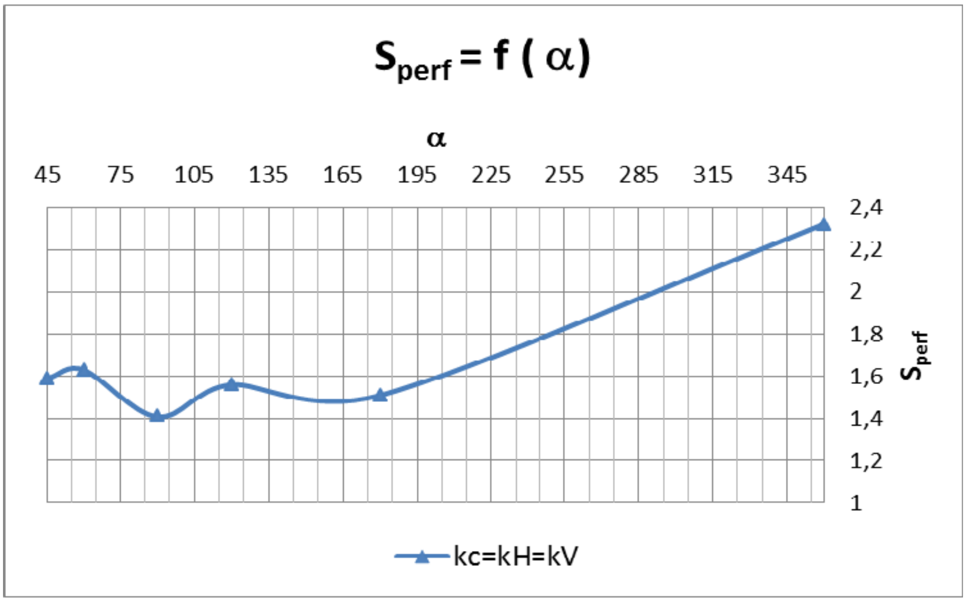

Fig. 7. Perforation skin effect vs. phase angle

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Analiză asupra factorului de skin datorat diferitelor moduri de perforare

Rezumat

În această lucrare este prezentată o analiză detaliată, în cazul a două sonde de țiței, a influenței modului de perforare asupra factorului skin. S-a utilizat metoda semi-analitică Karakas şi Tariq, aplicată atât sistemului de perforare clasic, cât şi modului de deschidere a stratelor productive dezvoltat de Penetrator Canada Inc.