ASPECTS OF SKIN FACTOR CALCULUS IN AN ACID-STIMULATED WELL

*Iuliana Veronica GHEŢIU**

Abstract: *Acidification operations lead to increased probe productivity. By determining the Skin Factor following the analysis of the well parameters, the efficiency of this operation is monitored. This paper follows the results obtained after the acidification of an oil well located on Muntenia Structure for which the productive layer has 65% dolomite.*
Keywords: acidification, Skin Factor, treatment solution, injection rate

1. Introduction

In order to improve the fluid flow conditions in the area around the probe well, various stimulation operations are applied, which have the effect of increasing the productivity of the wells.

The detailed knowledge of the causes that determine the blockage of fluid flows into the well and their effects as well as the reactions and phenomena occurring in the productive formations subjected to acid treatments proved the necessity of the permanent improvement of the treatment technologies.

Among the problems that arise from acidification stimulation treatments, one is the physic-chemical incomplete knowledge of the reactants and the products resulting from the complex reactions occurring in the area adjacent to the probe well between the rock, the fluids circulated in the probe or injected into the layer and the fluids present in the pores of the productive formation.

2. Theoretical and experimental data

This paper investigates the skin factor following an acidification stimulation operation with a 15% HCl solution of a productive formation on Muntenia Structure, which is made up of 65% of dolomite, as well as the effect of the injection rate in the range between 0.5-1.6m^3/s and the volume of acidic solution to the skin factor for three injection rate values.

Laboratory research and site experiments have shown that the use of high-concentration HCl solutions increases the efficiency of well-stimulating operations that open productive layers with a carbonate content of over 30-40%, because it has a longer consumption and attacks the rock on a larger area around the probe.

Based on this research, it has been shown that 15% HCl solutions achieve a more efficient network of flow channels in soft limestone rocks, while for the treatment of harder and dense limestone rocks with low initial permeability, it is more efficient to use hydrochloric acid solutions with high concentration (28% HCl).

A complex phenomenon from a technical point of view in the treatment of productive strata is the interaction of acids with carbonate rocks. In carbonate rocks, acid (15% or 28% HCl) can react with contaminated substances, but also with rocks from the field, creating large, conductive channels that cross the contaminated area. These channels are referred to in literature as worm diggers because of their shape.

When considering the hydraulic properties of this set of "worm channels", it is possible to define the equivalent radius of the r_s hole. This ray behaves so that, by injecting into a r_s radius probe, in the presence of the created channels, similar injectivity conditions are obtained when the probe has the radius r_s. This effect is similar to the skin effect.

Table 1. *Data on the analyzed structure*

1	Radius of the probe, r_s [m]	0,1
2	The thickness of the treated production layer, h [m]	26
3	The porosity coefficient of the rock, m	0,16
4	Density of dolomite, ρ_r [kg/m^3]	2700
5	Rock diffusivity coefficient, D [m^2/s]	10^{-9}
6	Specific volume of treatment solution, V_{sp} [m^3sol 15%HCl/m perforat]	1,2
7	Injection flow, q_i [m^3/min]	0,6

* *Asist.Ph.D.eng. Universitatea of Oil and Gas, Ploiești*

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The results of the experimental research show that the skin factor decreases more rapidly to the kinetics of mass transfer than to the surface reaction kinetics.

$$\Delta s = -\frac{1}{d}\ln\left(1 + A_c \mathrm{N}_{Pe}^{-\frac{1}{3}} \frac{bV}{\pi hmr_s{}^d}\right)$$

$$A_c = \frac{mC}{\nu C}$$

$$\mathrm{N}_{Pe} = \frac{q}{Dh}$$

where: A_c is the number of acid capacity

m - the porosity coefficient of the rock;

C - acid concentration (mol / l)

v - stoechiometric constant;

C_i - the concentration of the dissolved mineral (mol/l)

N_{pe}- Peplet number for radial flow;

q- injection rate;

D - diffusion constant

d - coefficient expressing the type of reaction kinetics (for dolomite d = 2)

h - the thickness of the productive layer

The reaction between dolomite and hydrochloric acid results in the stoichiometric constant of hydrochloric acid being equal to v = 4.

Table 2. *Methodology of calculation*

Concentration of HCl in one liter of solution	$C_S = \frac{G_{HCl} / M_{HCl}}{1}$	4,41 mol/l
The weight of a dm^3 of dolomite	$G_{CaMg(CO_3)_2} = V_r \cdot \rho_r \cdot C_r$	1755 g
Molecular weight of dolomite	$M_{CaMg(CO_3)_2}$	184 g
Dolomite concentration in a dm^3 of rock	$C_i = \frac{G_{CaMg(CO_3)_2} / M_{CaMg(CO_3)_2}}{1}$	9.53 mol/l.
Number of acid capacity	$A_c = \frac{mC_S}{\nu C_i}$	0.01853
Peclet Number	$\mathrm{N}_{Pe} = \frac{q_i}{Dh}$	$3.846 \cdot 10^{5}$
The skin factor	$\Delta s = -\frac{1}{d}\ln\left[1 + A_c \mathrm{N}_{Pe}^{-1/3} \frac{bV}{\pi hmr_s{}^d}\right]$	-6.09

The skin factor obtained by acidification has a negative value and indicates the success obtained after acidification of the productive layer.

By replacing the Peclet number from the above equation and with the injection rate values in the 0.5-1.6 m^3/s range, the skin factor values are obtained. The values thus obtained were tabulated and it was possible to achieve the skin factor variation plot depending on the injection rate.

$$\Delta s = -\frac{1}{d}\ln\left[1 + A_c \left(\frac{q_i}{Dh}\right)^{-1/3} \frac{bV}{\pi hmr_s{}^d}\right]$$

If we consider that the specific volume of the treatment solution is 1.2 m^3 of permeated 15% HCl /m soil, then we will obtain the total volume of the hydrochloric acid solution as follows:

$V=V_{sp}*h=31{,}2\ m^3$- the hydrochloric acid solution

In order to draw conclusions on the influence of the volume of injection on the skin factor were calculated for values of the specific volume of hydrochloric acid between 0.6 m^3 -1.6 m^3 and the injection rate between the values 0,01 m^3/s-0,03m^3/s, the volume of the hydrochloric acid solution and the skin factor.

The results obtained from the calculations for determining the volume of acid solution ($V_{st} = a*h$) and the skin factor for different values of the injection rate were centralized in the form of a table.

Table 3. *Skin factor values based on injection rate*

q^i (m^3/s)	0,5	0,8	1	1,6
s	-3,705	-3,627	-3,589	-3,511

Table 4. *Skin factor values at injection rate of 0.01m³/s*

$q_{1\ inj}$ = 0,01 m³/s		
Nr.crt	**Δs**	**V**
1	-4,028	17,4
2	-4,172	23,2
3	-4,284	29
4	-4,375	34,8
5	-4,452	40,6
6	-4,519	46,4

Table 5. *Skin factor values at injection rate of 0.02m³/s*

$q_{2\ inj}$ = 0,02 m³/s		
Nr.crt	**Δs**	**V**
1	-3,913	17,4
2	-4,057	23,2
3	-4,168	29
4	-4,259	34,8
5	-4,336	40,6
6	-4,43	46,4

Table 6. *Skin factor values at injection rate of 0.03m³/s*

$q_{1\ inj}$ = 0,03 m³/s		
Nr.crt	**Δs**	**V**
1	-3,845	17,4
2	-3,989	23,2
3	-4,101	29
4	-4,192	34,8
5	-4,269	40,6
6	-4,336	46,4

3. Conclusions

The skin factor records lower values as the injection rate increases (Figure 1), which confirms that the increase of the injection flow has positive effects.

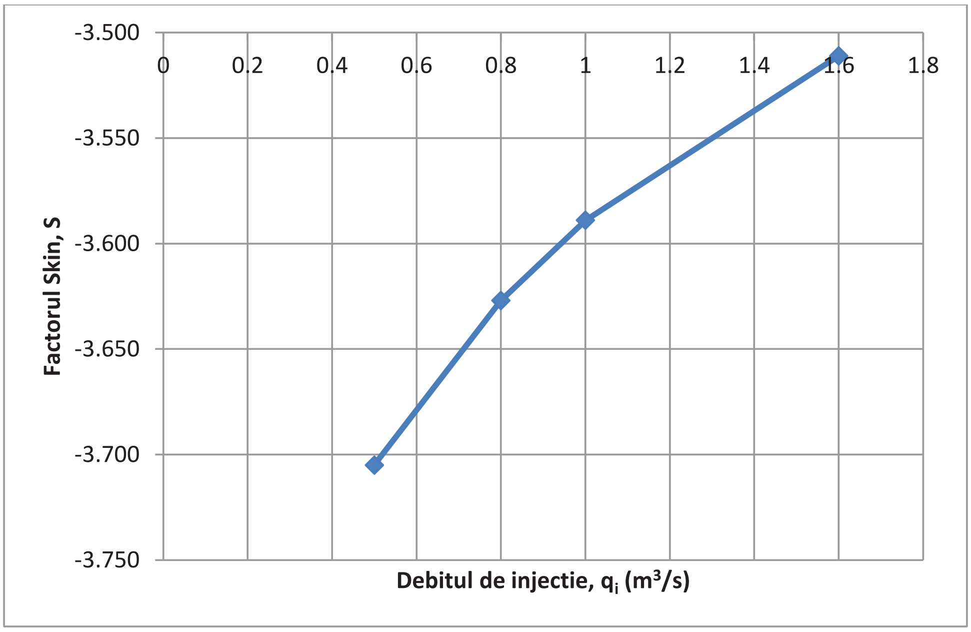

Fig. 1 *Skin factor variation with injection rate*

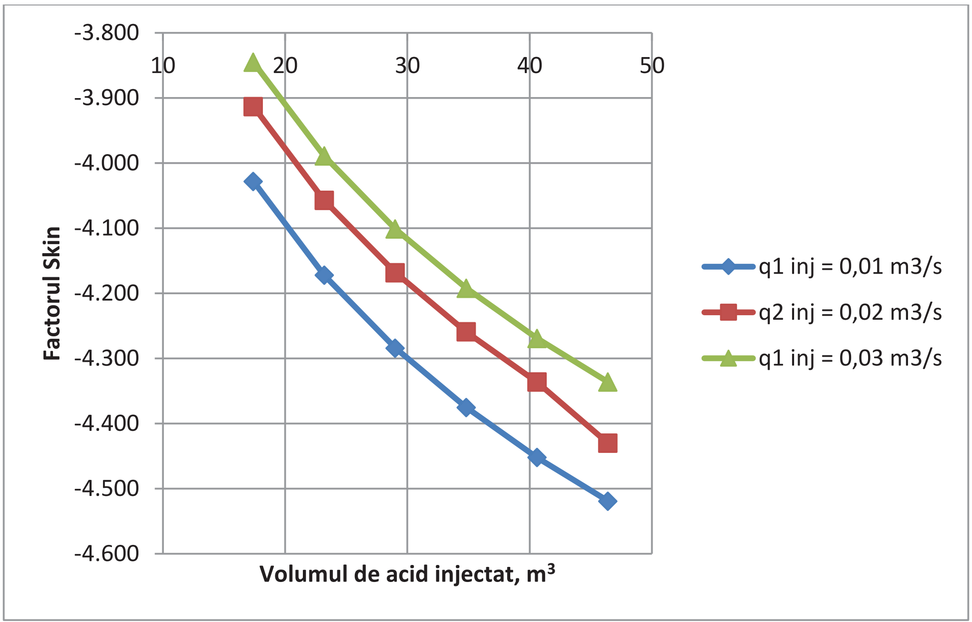

Fig. 2 *Skin factor variation with the volume of injected acid*

By varying the injection rate, the skin factor (Figure 2) was calculated, and for lower flow rates, a lower skin factor was obtained regardless of the injected volume.

In fact, for a volume of $0.01m^3/s$, with the same volume injected, a skin factor of -4,519 will be obtained, and for a higher injection rate, $0.03m^3/s$, with the same volume injected, a skin factor of -4,336 is obtained.

By increasing the volume of the injected acidic solution, the skin factor grows and with the same volume of the treatment solution by increasing the injection rate, the skin factor decreases. To reduce the skin factor value, the injection rate should increase.

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Prof.Ph.D.eng. Lazăr AVRAM
UPG Ploiești