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New application for well test analysis: Locating closed perforation zones and damaged sections

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ABSTRACT

Closed perforations and damaged sections are two great challenges in the petroleum industry. Several reasons may cause these problems. Few of them depend on the type of formation and wellbore while others come from drilling, completion and stimulation activates before production process. Production rate and pressure drop may lead significantly to these two problems; therefore, production management sometimes plays a great role in controlling them. Millions of dollars are spent annually for the remedial process of these two problems. Therefore locating these closed or damaged sections is considered of great importance as an attempt to control them or reduce their negative impact on wellbore deliverability.

This paper introduces a technique to locate the closed perforations and damaged sections using pressure transient analysis. Pressure behaviors and flow regimes in the vicinity of horizontal wellbores are affected by the existence of the closed perforated zones and the formation sections where the resistance to reservoir fluid flow toward the wellbore is maximized. This resistance occurs because of the damaged permeability and high skin factor. Analytical models for locating these sections and determining how many zones of the horizontal well that are considerably closed have been introduced in this study. These models have been derived based on the assumption that wellbore can be divided into multi-subsequent segments of producing and non-producing intervals. Producing intervals represent free flowing zones where there is no problem and both formation and wellbore are assumed to be clean. Non-producing intervals represent zones where both formation and wellbore's perforations are closed or damaged.

The effective length of horizontal well where the perforated zones and the formation sections can not be considered problematic and the damaged length where both of them are significantly closed and damaged can be calculated. The numbers of the damaged zones can be calculated also. In addition, the locations of the damaged sections or closed perforated zones can be determined. Type-curve matching technique and the analytical models can be used for this purpose.

1. Introduction

Formation damage and perforation plugging are two common problems in petroleum industry. They happen in different times of reservoir development process starting from drilling to production. Many reasons have been noticed for the two problems in conventional reservoirs: solid particles invasion and migration of formation unconsolidated fine grains, chemical precipitations, bacterial growth and biofilms, scale deposit and hydrate formation in gas reservoirs. In unconventional reservoir, where the permeability of the matrices is significantly low (Nano-Darcies), capillary force is another reason for the formation damage. The gas in this case will be trapped and the flow toward the wellbore will be blocked by water (Bottero et al., 2010). Civan, 2000 described several kinds of formation damages and the way for the diagnosis, assessment of their potential.

Formation damage and closed perforated sections adversely affect the production rate of oil and gas and greatly reduce the productivity index. To remove the negative impact, several remedy and mitigation techniques can be used depending on the reasons that lead to the formation damage and closed perforated sections. However, both of them, the problem and the remedy, cause sharp increase in the operation cost. The following are some of the most frequently occurring problems that definitely lead to formation damages and closed perforated sections.

1.1. Asphaltic production problem

The asphaltic problem refers to the depositions of heavy materials (Asphaltene) in the near well formation, plugging the flow of reservoir fluids to the wellbore. Asphaltenes are arbitrarily

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Nomenclature

B	oil formation factor, RB/STB
c_t	compressibility, 1/psi
h	formation thickness, ft
k_x	formation permeability in the X direction, md
k_y	formation permeability in the Y direction, md
k_z	formation permeability in the Z direction, md
L_w	total length of horizontal well, ft
L_p	length of perforation section, ft
L_S	length of closed zone, ft
n	number of closed zones
P	pressure, psi
P'	pressure derivative
P'_D	dimensionless pressure derivative
P_D	dimensionless pressure
q_i	oil flow rate from perforation zone, B/D
q_t	total oil well flow rate, B/D
r_w	wellbore radius, ft
t	time, h
t_D	dimensionless time
t_p	producing time, h
x_w	the X coordinate of the production point
y_w	the Y coordinate of the production point
z_w	the Z coordinate of the production point

Greek Symbols

Δ	change, drop
ϕ	porosity
μ	viscosity, cp
ΔP	pressure difference, psi
$\Delta P'$	change of rate of pressure with time (pressure derivative), psi

Subscripts

ERF	early radial flow
IRF	intermediate radial flow
SERF	system early radial flow
PRF	pseudo radial flow
ELF	early linear flow
SLF	second linear flow
PSF	pseudo-spherical flow

defined as a solubility class of petroleum that is insoluble in light alkanes such as n-heptane or n-pentane but soluble in toluene or dichloromethane (Khanifar et al., 2011). This problem represents one of the major concerns in oil production process either in the formation and wellbore section or in the surface treatment facilities. Asphaltic materials are expected to be produced in all types of reservoirs, especially heavy oil reservoirs and in CO_2 injection projects. The asphaltic precipitation and deposition problem in the upstream petroleum industry is a considerable issue that requires attention.

The asphaltic material precipitation and deposition can negatively affect formation properties such as porosity and permeability. It can also change reservoir wettability and reservoir fluid viscosity. All these effects result on significant reduction in production rate and productivity index. Under normal formation condition, asphaltic material is held in the crude oil by resins. Changes in the crude oil composition and reservoir pressure and temperature may alter the bond between asphaltenes and resins. As a result, asphaltic material precipitation and deposition take place in the porous media primarily around the wellbore. The deposit of this material in the pore space means a reduction in the effective porosity and permeability of the formation. At the same time, asphaltic material around the wellbore can cause a great reduction in the cross-section area of the perforations or even close them completely.

1.2. Sand production problem

The sand production refers to the phenomenon of solid particles being produced together with the petroleum fluids. Sand production has simultaneous double effects for both conventional and heavy oil reservoirs. The first one is negative where additional operational difficulties happen in the production process of conventional reservoirs. The second one is positive where increasing productivity and inflow performance occur in heavy oil reservoirs. However, the benefits of the sand production phenomenon are less than the production problems caused by it. It is well known that this problem usually costs the petroleum industry billions of dollars every year. This cost comes from three different issues. The first one is the increasingly decreasing production rate. The second one is the damage that is created in the wellbore section and the surface equipment. The third one is the cost of frequent work-over to clean and remove sand deposit from the wellbore. Therefore, great attention has been focused first on the ability to predict the problem and second to use the right type of the remedy. Classically, gravel packing, slotted linear and pre-packed screen, resign injection, and frac-and-pack completions are several techniques to prevent sand from being produced with the oil and gas.

Taking into account that more than 70% of the world's oil and gas reserves are contained in sand formation where sand production is likely to become problem during the life of the wells (Osisanya, 2010). The sand production problem is caused by a variety of reasons. Many of them are related to the lithology of the formation, while others are connected to production conditions. Poorly consolidated sandstone formations and in-situ stress distribution around horizontal wellbore are two examples of the first group's reasons. The production rate and the pressure drawdown are two examples of the second group's reasons. At the same time, there are many factors affecting the sand production problem and determining how much sand is produced. Many of them are classified as driving factors such as stress magnitude and pressure gradient that acting to increase sand detachment potential from the formation layers. Others are classified as resisting factors such as material strength and inter-particle friction that are acting conversely.

Two types of sand are expected to be produced (Van Den Hoek and Geilikman, 2005). The first is the loose sand or formation fine particles that require a critical flow rate for mobilization and usually exist in the area behind the perforation holes. When the particles start mobilizing, the velocity of fluid provides sufficient drag force for these particles to keep moving with any flow rate. Loose sand can result in screen plugging and accumulate in the wellbore along fluid conduits (top of packers and nipples). The second is the failed sand which exists behind the loose sand area where it behaves like a rock mass that responds to fluid flow and stresses by deforming elasto-plastically. It relates directly to the change in the volumetric plastic strain. It consists of both loose sand and rock spalls and chips. Generally if the weight of