The flow test and the skin-effect determination for oil wells according to pressure build up

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Abstract. Such parameters as the flow test and the skin-effect determination with the application of data of the pressure build up when carrying out hydrodynamic research are considered in the paper. The necessity to increase the determination accuracy of layer parameters according to well flow test is a highly topical issue for many oil companies. Therefore ranges of values of calculated parameters and the state of a bottom hole part of the layer corresponding to them are presented in the paper.

1. Introduction

Hydrodynamic methods of research of oil and gas wells are carried out for the purpose of determination of physical properties of layers: piezoconductivity, permeability, the degree of layer contamination, etc. It is absolutely impossible to receive the real hydrodynamic models of layer reflecting natural conditions of development of fields without careful comprehensive hydrodynamic researches of layers. One of types of the conducted research is a record of the curve of pressure build up (PBU curve), it makes possible to determine the flow test and to estimate the behavior of a bottomhole zone of the layer. [1, 2].

2. Results and Discussion

Well productivity $kh$ is determined by a formula:

$$kh = 0.183 \frac{q \mu B}{i},$$

where $k$– effective permeability, $m^2$; $h$– formation thickness, $m$; $q$– the established output before the completion of a well, $m^3/s$; $\mu$ – viscosity of oil; $B$ – volume coefficient of oil; $i$– a slope ratio of a straight section of a curve of pressure build up depending on $\lg \frac{t_p + \Delta t}{\Delta t}$ (for an infinite system) or $\lg \frac{\Delta t}{\Delta t}$ (for a limited system), here $\Delta t$ – the duration of a stop of the production well, $s$; $t_p = \frac{N}{q}$ – operating time of the well on the constant mode, $s$; $N$– the volume of the extracted oil from the last pressure measurement, $m^3$.

The pressure fluctuation in the well which is in a limited system (the exploitation well is surrounded with other exploitation wells) will be the same, as in an infinite system until the depression wave in the
layer reaches the external boundary or border of the interference connected with the interaction with nearby wells.

Time $t_k$ demanded in order that the depression wave in layer reached an external boundary can be calculated on the equation:

$$ t_k = \frac{m \mu \beta r_k^2 T_k}{k} \quad (2) $$

where $m$– porosity; $\beta$– oil compressibility, $Pa^{-1}$; $r_k$– radius of an external boundary, $m$; $T_k$– dimensionless time for which the depression wave will reach an external boundary.

For the determination $T_k$ it is possible to use a curve of pressure build up in coordinates $P_\theta$ (dimensionless pressure) – $T_\theta$ (dimensionless time) (figure 1).

![Figure 1. Dependence $P_\theta$ from $T_\theta$](image)

Extrapolation of a straight section of this curve on the abscissa axis presents that the complete pressure build up will happen at $T_k=0.445$, therefore the equation (2) can be written down as follows:

$$ t_k = \frac{0.445 \cdot m \mu \beta r_k^2}{k} \quad (3) $$

If $t_k$ is less than $t_p$, then the value of a tangent of the deviation angle of a straight section of the PBU curve should be determined by the pressure-time diagram in the well from $\lg \Delta t$. If $t_k$ is higher than $t_p$ (the depression wave in layer did not reach an external boundary), then the pressure-time diagram in the well from $\lg \frac{t_p + \Delta t}{\Delta t}$ is applied.

The relation of productivity $(kh)_\eta$ determined by the efficiency coefficient (without a skin-effect), to the actual productivity determined $(kh)_{KBU}$ by a curve of pressure build up (taking into account a skin-effect):
where \( r_c \) – the radius of the well, \( m \); \( P_{n}\) – reservoir pressure, Pa; \( P_c(0) \) – pressure in the well before completion, \( P_a \).

The productivity rate is calculated at the known radius of drainage and rather long-term operation of the well with a constant output.

The pressure difference causes the inflow of liquid to the well with the output depending on properties of layer, viscosity of liquid, resistance (damage or a skin-effect) created near the well as a result of drilling, completion and operation of the well.

The solution to equation of diffusion for the distribution of pressure in an infinite layer was offered taking into account the layer damage [1]:

\[
P_c(0) = P_{pr}(0) - \frac{q \mu B}{4 \pi kh} \ln \left( \frac{kt}{m \mu B r_c^2} + 0.809 + 2s \right),
\]

where \( P_{pr}(0) \) – pressure in layer before the completion, \( P_a \); \( S \) – skin-effect.

If the operation time of the well on the constant mode \( t_p \) is much more than the time of pressure build up \( \Delta t \), the formula is applied:

\[
P_{c,\Delta t} = P_{pr}(0) - \frac{q \mu B}{4 \pi kh} \ln \left( \frac{t_p}{\Delta t} \right),
\]

where \( P_{c,\Delta t} \) – pressure in the well received by results of a hydrodynamic research. Subtracting the equation (6) from (5):

\[
P_{c,\Delta t} - P_c(0) = \frac{q \mu B}{4 \pi kh} \left( - \ln \left( \frac{t_p}{\Delta t} \right) + \ln \frac{kt_p}{m \mu B r_c^2} + 0.809 + 2s \right) =
\]

\[
= \frac{q \mu B}{4 \pi kh} \left( \ln \Delta t + \ln \frac{k}{m \mu B r_c^2} + 0.809 + 2s \right) .
\]

As \( 0.183 \cdot \frac{q \mu B}{kh} = i \) and \( k = 0.183 \frac{q \mu B}{ih} \), the equation (7) will take a form:

\[
P_{c,\Delta t} - P_c(0) = \frac{i}{4 \pi \cdot 0.183} \left( \ln \Delta t + \ln \frac{0.183 qB}{ihm \beta r_c^2} + 0.809 + 2s \right) .
\]

If to pass to the expression (8) from a natural logarithm to a decimal logarithm, having substituted the value \( \Delta t = 1 \) hour = 3600 c and the corresponding value of borehole pressure \( P_{c,1\text{h}} \) (pressure in the well in an hour after the completion):

\[
P_{c,1\text{h}} - P_c(0) = \frac{i}{2.3} \left( \ln 3600 + \ln \frac{0.183 qB}{ihm \beta r_c^2} + 0.809 + 2s \right) =
\]
From the received expression the following formula for a skin-effect test is received:

\[
s = 1.151 \frac{(P_c(1) - P_c(0))}{i} - 1.151 \frac{1479.442 QB}{i h m \beta r_c^2} .
\]  

3. Conclusion

The capacity rate is also determined as a damage rate of the layer or a factor of damage. The values \((kh)_{30}\), which are not exceeding 0.8 indicate the existence of damages or that the permeability in a nearfield zone is less than in the field of drainage. Values in the range from 0.8 to 1.2 specify that damages are absent or are insignificant. Values more than 1.2 indicate that the permeability in a nearfield zone is higher than in the field of drainage.

The skin-effect determination is another way of resistance estimate in a nearfield zone. Positive values \(S\) indicate the existence of pollution while the negative skin-effect indicates the resistance elimination (geological and technical actions for inflow intensification are held). The values close to zero (from 0.5 to 0.5) indicate small or insignificant resistance (the permeability of a nearfield zone is approximately equal to permeability in the field of drainage).

The advantage of a method of resistance estimate by a skin-effect is that the complete pressure build up is not required and the radius of field of drainage can be not known.

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