Python-provided algorithm for calculating oil field operation parameters for expansion drive reservoirs

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Abstract. The paper provides a brief description of the Python programming language, as well as its advantages and disadvantages. It considers a practical task to be solved for the oil and gas industry and ways to solve it through the Python capabilities. It proposes calculations for expansion drive oil reservoirs. Recently, much attention has been paid to computer-assisted systems aimed at processing huge amounts of expert information in the field of technical and economic appraisal of oil and gas fields. From an applied point of view, economic efficiency of an oil and gas investment project is assessed through a certain mathematical model built for calculating and analyzing project criteria based on a variety of forecast technological indicators for reservoirs produced and the field as such. Mathematical modeling in projects is challenging and demanding due to constant updating, because each field is individual, being developed in its own specific geological and technological way, with multiple options and standards for capital and operating costs. In this regard, the paper aims to create and apply smart information technology for field development, which involves collecting information on gas production wells using the Python software. The calculated dependencies and the Python software product can determine critical and recommended flow rate (with a margin of 10-20%) for wells to operate smoothly as long as sand and fluid is accumulated at the bottomhole.

1. Introduction

Recently, much attention has been paid to computer-aided systems designed to process large amounts of expert information in the field of technical and economic appraisal of oil and gas fields [1-4]. Calculating physical and mathematical models requires a responsible approach to programming languages selected for data processing. In addition to convenience and clarity, a programming language must have a powerful functional base and extensive computation, construction, processing and output capabilities.

Under a dissolved gas regime, oil is displaced from the reservoir to the wells by the gas energy released from the oil when the pressure drops below saturation pressure. Since gas is dissolved throughout the entire oil-saturated region, it is obvious that producing this type of reservoirs requires wells to be placed so that the reservoir energy could be equally used. Provided that this condition is met, it is possible to arrange wells in such a way so that each of them (concurrently put into operation) exploit its specific reservoir volume or specific drainage area. Each such volume or specific drainage area is conventionally bounded by the so-called neutral lines, where the pressure gradient should be equal to zero [5-7].
The form of specific area depends on the accepted well spacing: triangular, rectangular (square), or non-uniform (in accordance with reservoir heterogeneity). Since the deposit that houses the wells is conventionally divided into elementary specific volumes (areas), it is obviously enough to study only one of them operating (standard well) that runs one (its own) specific volume. This makes hydrodynamic calculations much easier. However, this does not address the interference of wells. This assumption entails significant errors in estimating technological development factors, and especially when the wells are put into operation at different times. Unsteady radial movement of a carbonated fluid in a porous medium [8-10].

Due to being extremely complicated, actual filtration of reservoir fluids makes it impossible to build absolutely identical physical or geometric models. Hence, in most cases, approximate modelling of filtration flows is limited to provide an adequate mathematical description of oil and gas field development. This process can be explored based on simplified (idealized) model-schemes describing one-dimensional and non-one-dimensional steady-state or unsteady filtration flows. Studying filtration liquid and gas flows in natural reservoirs calls for a geometric form of motion to be schematized in such a way as to create design schemes tailored to the main impacts and allowing the flow parameters to be defined.

2. Materials and methods
For studying elementary filtration flows, the basic models built are steady and unsteady filtration of single-phase fluids (incompressible or compressible) in a homogeneous (isotropic) porous medium. These models are classical, based on mathematical physics to study filtration flows. However, the need to solve more sophisticated non-one-dimensional problems related to filtration of liquids, gases and their mixtures in natural formations required creating more advanced mathematical models based on better knowledge and understanding of hydrodynamic and physicochemical processes to occur in the reservoir until it is produced. The use of these models is usually associated with numerical methods and modern computer technology. The paper deals with the simplest one-dimensional steady-state flows of liquid and gas in a porous medium aligned with linear and nonlinear filtration laws. A one-dimensional filtration flow of liquid or gas is the one, in which the filtration rate, pressure and other characteristics are one-coordinate functions counted along the flow path. The most characteristic, as applied to oil, water and gas filtration processes, one-dimensional flows involve:

- flat radial filtration flow;
- radial spherical filtration flow.

Here is a brief description of these flows.

Flat radial filtration flow. Let us suppose that fluid filtration implies that all particles are moving in parallel paths, while filtration rates at all points of any transverse (perpendicular to flow paths) section are equal to each other. The laws of motion in all paths in such a filtration flow are the same, and therefore it is sufficient to study the motion in one of the paths that can be taken as an x-axis of coordinates. A flat radial flow can be modelled in laboratory settings given that a liquid or gas moves through a cylindrical core or through a straight uniform pipe filled with a porous medium; in some sections of productive formation when fluids move to the row of wells, provided that the formation of uniform thickness has a rectangular shape in a plan view. It is solely near the wells that flow paths will curve. Given that the wells are more compact in the row by replacing the row with a continuous straightway working battery, then the path to the battery will be strictly rectilinear-parallel. The flow can be considered flat radial in a certain section between the injection and production wells. As in gas field operations, bottomhole sand plugs and ball-ups result from too high speeds permitted near the well. If the speed is too high, the carbonated liquid entraps the smallest and finest fractions of sand and cementing grit, thereby resulting in bottomhole sand plugs clogging pore throats. To avoid these implications, oil wells under the above conditions should be operated in such a way that the rate of liquid and gas filtration in the bottomhole formation zone does not exceed a certain permissible maximum value, depending on the mechanical composition, degree of sand cementation and physical properties of liquids and gases. Maintaining this maximum permissible filtration rate at the bottom
during the operation of an oil well means that as much oil as possible is recovered and at the same
time eliminates the possibility of operational complications associated with permitted excessively high
fluid and gas speeds.

The initial (first months) unsteady radial filtration of carbonated liquid under dissolved gas
conditions is characterized by high liquid and gas flow rates. The fluid flow rate decreases rapidly
over time. The gas flow decline rate is less than the liquid flow decline rate.

Consequently, regardless of prior production conditions, during the remaining period for the oil
reservoir development, liquid and gas are withdrawn at a constant well pressure. Approximate
accounting procedure for interference and rates of wells being commissioned when heterogeneous
reservoirs are produced. A number of minor expansion drive reservoirs were developed in CIS
countries. Most of the US expansion drive reservoirs are operated in the early stage of oil
development, and only in the later pressure coherent stages of development.

One of the most urgent tasks in the design and development of oil fields is that of setting an
expedient time for the start of development using impact systems and, in particular, waterflooding.

To solve the above mentioned tasks, it is necessary to perform hydrodynamic calculations of
changes in depletion drive reservoir performance. Until now, these hydrodynamic calculations are
performed for idealized conditions of uniform well spacing and simultaneous commissioning. In this
case, the calculations are provided for one well alone, and the indicators of reservoir performance as
such are summed up proportionally to the number of wells ignoring the interference and the rate of
commissioning.

Multiple examples seem to indicate that in the first years of oil development, exploratory wells are
used, irregularly spaced and subsequently drilled out following one or another well spacing algorithm
as specified by an integrated development scheme for 3-5 years. Failure to respect the interference and
the rate of well commissioning significantly affects the design technical and economic indicators of
development. These factors have an especially pronounced effect on oil recovery in expansion drive
reservoirs. Indeed, during the period of putting wells into operation (depending on the rate of
commissioning), the properties of carbonated oil may vary significantly. These wells will be operated
under different physical and thermodynamic conditions (compared to those previously commissioned).
Usually, oil recovery $\eta$ in depletion gas reservoirs is determined only by the pressure-saturation
dependence.

In the above calculations, peripheral deposit areas were assumed to have sufficiently high filtration
properties. Nonetheless, even with this assumption, the circular contour pressure drops quite
dramatically.

Given that peripheral permeability is several times lower than that in the reservoir, or the reservoir
wedges out beyond the oil-bearing contour, as is often the case, water inflow into the oil-saturated
section becomes insignificant and the oil reservoir can be considered to be closed and the permeability
water to be inactive.

In the case under consideration, gas bubble release from the oil is thought to be difficult due to the
reservoir stratification. In this case, a pure dissolved gas drive will develop in the reservoir.

Python is a general-purpose scripting language. Scripting languages are routinely used to solve
small tasks, but Python is an exception. Unlike, for example, Java Script, the scope of Python is not
limited to mere web development. Python is a flexible language with a minimalist syntax. This
programming language is interpreted, which means that code in Python is not converted into machine
code, but executed by an interpreter program. Hence, we conclude that Python is a practical platform.
Any code in Python will run wherever there is an interpreter. Python can also be used as a regular
calculator. The Python programming language was found to have the following advantages, namely:
simple syntax as the code is easy to write, read and maintain; large standard library and a great number
of alternate libraries; support for object-oriented programming and other paradigms; cross-platform
and support for nearly all modern systems. A key factor in choosing Python as the underlying
programming language for solving practical problems is its integrative ability. The language is able to
interact with other languages. For example, Python can call a function from C/C ++. The software
interface is user-friendly, thus making it easily used for creating software products for the oil and gas
industry.
SymPy is an open source Python library for symbolic computation. It provides computer algebra
capabilities. Mathematical modeling of processes and objects should rely on algorithms in the Python
language using symbolic computation. Based on the SymPy library, Python successfully copes with
equations and systems, integrates and differentiates, calculates limits, expands and sums series,
simplifies expressions, searches for solutions to differential equations and systems.

3. Calculations

With Python, let us calculate a deposit in an enlarged well with radius $R_3$, operated in an aquifer
with a time-constant flow of water “$q_w$” flowing into the deposit.

According to the Van Everdingen and Hurst formula, contour pressure history in the enlarged well
$P(R_3)$ is defined by the following equation:

$$P(R_3, t) = P_H - \frac{q_w \mu_v}{2\pi h} \bar{P}(f_0)$$

where $f_0 = \frac{\lambda}{R_3^2}$ is the Fourier parameter; $h, \kappa, \chi$ are reservoir thickness, permeability and piezo
conductivity coefficients; $\mu_v$ is dynamic viscosity; $\bar{P}(f_0)$ is tabulated function.

Second option. Let the reservoir be an enlarged well, operated with a constant aquifer pressure drop:

$$\Delta P = P_H - P(R_3)$$

To calculate the total amount of water that will flow into the deposit by the time $t$, Van Everdingen
and Hirst derived the expression:

$$Q_w(t) = \frac{9\pi h R_3^2}{\mu_v \lambda} \Delta P \cdot Q(f_0)$$

where $Q(f_0)$ is a tabulated function.

In the first option, the dynamics of water inflow into the reservoir is known in the form of a time
dependence of the flow rate in the enlarged well, $q_w(t)$. It is necessary to find the contour pressure in
the enlarged well by the moment $t$, i.e. $P(R_3, t)$.

Let us write a program code that will facilitate the calculations to estimate the operation parameters
of expansion drive oil fields (Fig.1).
4. Conclusion

Thus, herewith the Python programming language supported calculations to solve a practical problem in the oil and gas industry. Based on the foregoing, the Python platform proves to be versatile and convenient for various physical and mathematical operations, construction of mathematical models, visualization, and data processing. Constructing algorithms supported by the program differs significantly from the others in a way it ensures simplicity and consistency, as well as great functionality. To simplify calculations of reservoir development touched upon in the paper, gas flow to each well, bounded by radius contour $r_c$, can be assumed as quasi-stationary – steady in each flow path, but time-varying.

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