DEVELOPMENT OF ALGORITHM AND PROGRAMS FOR TWO-DIMENSIONAL FILTERING PROBLEMS OF INCOMPRESSIBLE LIQUIDS

Dilmurod Tuhtanazarov*

*Senior Teacher,
Department of Modern ICT, International Islamic Academy of Uzbekistan,
Tashkent, UZBEKISTAN.
Email id: dtuxtanazarov@gmail.com

DOI: 10.5958/2249-7137.2021.02621.5

ABSTRACT

The paper presents the task of controlling the filtration process of oil and gas fields. A computer model has been created for controlling filtration processes using mathematical models of the oil and gas field development process. With the help of the created model, the permeability, viscosity, porosity and production were selected to a minimum of the differences between the computational and actual pressures. Certain optimal parameters are used for control and forecasting in the development of oil and gas fields.

KEYWORDS: *Field, Control, Control Task, Oil, Gas, Model, Mathematical Model, Wells, Permeability, Filtration, Equations, Viscosity, Porosity, Reservoir.*

1. INTRODUCTION

Trends in the development of the oil and gas industry imply the introduction of modern innovative ways of development that ensure economic efficiency at every stage from hydrocarbon exploration to their final implementation. The transition to an innovative way of development in the geological and oil and gas industries involves the technical re-equipment of the means of obtaining geological information, its processing, interpretation and provision for use at all stages from prospecting to the final development of deposits. One of the main stages of increasing innovative ways of developing geological exploration and development of oil and gas condensate fields is the introduction of full-scale innovative technologies for the study of the subsoil of oil and gas fields and their development. One of the main elements of this is three-dimensional geological and geophysical modeling at all stages from prospecting to field development and complex processing of GIS materials based on the latest programs. A three-dimensional geological and geophysical model allows a more reliable representation of the geological structure of the field, the production and refinement of hydrocarbon reserves and the preparation of the basis for hydrodynamic modeling of the field. In hydrodynamic calculations associated with the development of oil and gas fields, which are arbitrarily located in the earth's crust, one-dimensional approximations are insufficient. This largely depends on taking into account the non-uniform nature of the flow in the system of many wells. **[1-10]**

2. STATEMENT OF THE PROBLEM.

The mathematical formulation of a two-dimensional problem is reduced to the following. Let there be a reservoir with an area D. It is used to improve the dynamic viscosity μ. It is sealed using randomly applied wells with coordinates x and y in the mode of specified volumetric flow rates $Q_i(t)$.

Using Darcy's law, the equation of continuity and state, we obtain the power-averaged two-dimensional equation of fluid filtration, taking into account internal effluents:

$$\begin{cases} \frac{\partial}{\partial x}\left(K(x,y)\frac{\partial P(x,y,t)}{\partial x}\right)+\frac{\partial}{\partial y}\left(K(x,y)\frac{\partial P(x,y,t)}{\partial y}\right)=M(x,y)\frac{\partial P}{\partial t}+F(x,y,t) \\ \{(x,y)\in D, t>0\} \end{cases} \quad (1)$$

at the initial

$$P(x,y,t)\big|_{t=0}=P^0(x,y) \quad (2)$$

and the boundary condition along the contour:

$$\left.\frac{\partial P(x,y,t)}{\partial n}\right|_{(x,y)\in \Gamma}=0 \quad (3)$$

$$P(x,y,t)\big|_{(x,y)\in\Gamma}=P_R(t),$$

where, P - is the pressure, $K=h\frac{k}{\mu}$, k - is the permeability of the formation, μ - is the viscosity of the fluid, $M=mh\beta^*_н$, h - reservoir thickness, m - porosity, $\beta^*_н$ - reservoir fluid elasticity, $F=Q_i(t)\cdot\delta(x-x_i)(y-y_i)$, δ - is the Dirac delta function.

To calculate problem (1) - (3), we pass to the dimensionless variables:

$$\overline{K}=\frac{K}{K_x},\ \ \overline{x}=\frac{x}{L_x},\ \ \overline{y}=\frac{y}{L_y},\ \overline{H}=\frac{H}{H_x},\ \ Q=A\sum_{i=1}^{N}\delta(x-x_i,y-y_i)q_i,\ \ t=\tau\frac{K_x}{\beta^*\cdot L_x^{\ 2}}. \quad (4)$$

3. SOLUTION METHOD.

To solve the dimensionless problem, we use one of the following schemes of the finite-difference method:

1. Longitudinal-transverse scheme **[1].**
2. Locally one-dimensional scheme **[2].**
3. Splitting **[3].**

To do this, cover the given area with a uniform mesh:

$$\omega_{x,y}=\{(x_i=i\cdot h_x,\ \ h_x=\frac{1}{N_x}\ \ y_j=j\cdot h_y,\ \ h_y=\frac{1}{N_y}\ ),\ \ i=\overline{1,N_x},\ \ j=\overline{1,N_y},\ \}.$$

Then the finite-difference form of the given problem will take the form

$$m_{i,j}\frac{H_{i,j}^{k+1}-H_{i,j}^{k}}{\tau}=\left(K_{i+1/2,j}\frac{H_{i+1,j}^{k}-2H_{i,j}^{k}+H_{i-1,j}^{k}}{h_x^{\ 2}}\right)+\left(K_{i,j+1/2}\frac{H_{i,j+1}^{k}-2H_{i,j}^{k}+H_{i,j-1}^{k}}{h_y^{\ 2}}\right)-Q_{i,j}. \qquad (5)$$

For convenience, we will write it like this:

$$A_iH_{i-1}-C_iH_i+B_iH_{i+1}=-F_i\,. \qquad (6)$$

To solve equation (5), we use a longitudinal-transverse scheme using the method in the version of a conventional sweep in a chain of one-dimensional equations. A_i, B_i, C_i, F_i take the following form:

$$A_i=B_i=\frac{K_{i+1/2,j}}{h_x^{\ 2}};\ \ C_i=A_i+B_i+m_{i,j}\frac{2}{\tau};\ \ F_i=m_{i,j}\frac{2}{\tau}H_{i,j}^{k}+\left(K_{i+1/2,j}\frac{H_{i,j+1}^{k}-2H_{i,j}^{k}+H_{i,j-1}^{k}}{h_y^{\ 2}}\right)-Q_{i,j},$$

$$A_j=B_j=\frac{K_{i,j+1/2}}{h_y^{\ 2}};\ \ C_j=A_j+B_j+m_{i,j}\frac{2}{\tau};\ \ F_j=m_{i,j}\frac{2}{\tau}H_{i,j}^{k+\frac{1}{2}}+\left(K_{i,j+1/2}\frac{H_{i+1,j}^{k+\frac{1}{2}}-2H_{i,j}^{k+\frac{1}{2}}+H_{i-1,j}^{k+\frac{1}{2}}}{h_x^{\ 2}}\right)-Q_{i,j}. \qquad (7)$$

When applying the locally one-dimensional scheme, Ai, Bi, Ci, Fi take the form:

$$A_i=B_i=\frac{K_{i+1/2,j}}{h_x^{\ 2}};\ \ C_i=A_i+B_i+m_{i,j}\frac{2}{\tau};\ \ F_i=m_{i,j}\frac{2}{\tau}H_{i,j}^{k}-Q_{i,j},$$

$$A_j=B_j=\frac{K_{i,j+1/2}}{h_y^{\ 2}};\ \ C_j=A_j+B_j+m_{i,j}\frac{2}{\tau};\ \ F_j=m_{i,j}\frac{2}{\tau}H_{i,j}^{k+\frac{1}{2}}-Q_{i,j}. \qquad (8)$$

Calculating the equations using the splitting method, we get the following sequences:

$$K_{i+1/2,j}\frac{H_{i+1,j}^{k-\frac{2}{3}}-2H_{i,j}^{k-\frac{2}{3}}+H_{i-1,j}^{k-\frac{2}{3}}}{h_x^2}=m_{i,j}\left(\frac{H_{i,j}^{k-\frac{2}{3}}-H_{i,j}^{k-1}}{0.5\tau}\right),\quad 1)\ A_i=B_i=\frac{K_{i+1/2,j}}{h_x^{\ 2}};\ \ C_i=A_i+B_i+m_{i,j}\frac{2}{\tau};\ \ F_i=m_{i,j}\frac{2}{\tau}H_{i,j}^{k-1},$$

$$K_{i,j+1/2}\frac{H_{i,j+1}^{k-\frac{1}{3}}-2H_{i,j}^{k-\frac{1}{3}}+H_{i,j-1}^{k-\frac{1}{3}}}{h_y^2}=m_{i,j}\left(\frac{H_{i,j}^{k-\frac{1}{3}}-H_{i,j}^{k-\frac{2}{3}}}{0.5\tau}\right),\quad 2)\ A_j=B_j=\frac{K_{i,j+1/2}}{h_y^{\ 2}};\ \ C_j=A_j+B_j+m_{i,j}\frac{2}{\tau};\ \ F_j=m_{i,j}\frac{2}{\tau}H_{i,j}^{k-\frac{2}{3}},$$

$$3)\ H_{i,j}^{k+\frac{1}{3}}=H_{i,j}^{k-\frac{1}{3}}+2\cdot\tau\cdot Q_{i,j},$$

$$K_{i,j+1/2}\frac{H_{i,j+1}^{k+\frac{2}{3}}-2H_{i,j}^{k+\frac{2}{3}}+H_{i,j-1}^{k+\frac{2}{3}}}{h_2^2}=m_{i,j}\left(\frac{H_{i,j}^{k+\frac{2}{3}}-H_{i,j}^{k+\frac{1}{3}}}{0.5\tau}\right),\quad 4)\ A_j=B_j=\frac{K_{i,j+1/2}}{h_y^{\ 2}};\ \ C_j=A_j+B_j+m_{i,j}\frac{2}{\tau};\ \ F_j=m_{i,j}\frac{2}{\tau}H_{i,j}^{k+\frac{1}{3}}. \qquad (9)$$

$$K_{i+1/2,j}\frac{H_{i+1,j}^{k+1}-2H_{i,j}^{k+1}+H_{i-1,j}^{k+1}}{h_1^2}=m_{i,j}\left(\frac{H_{i,j}^{k+1}-H_{i,j}^{k+\frac{2}{3}}}{0.5\tau}\right),\quad 5)\ A_i=B_i=\frac{K_{i+1/2,j}}{h_x^{\ 2}};\ \ C_i=A_i+B_i+m_{i,j}\frac{2}{\tau};\ \ F_i=m_{i,j}\frac{2}{\tau}H_{i,j}^{k+\frac{2}{3}}.$$

Algorithm for computing one-dimensional problems with a conventional sweep [4]

$$\left.\begin{array}{l} \alpha_0 = \lambda_1; \quad \beta_0 = (1-\lambda_1), \\ i = 0 \ldots (N_x - 1), \quad i = 0 \ldots (N_y - 1), \\ \alpha_{i+1} = \dfrac{B_i}{C_i - \alpha_i \cdot A_i}, \quad \beta_{i+1} = \dfrac{A_i \cdot \beta_i + F_i}{C_i - \alpha_i \cdot A_i}, \\ i = (N_x - 1) \ldots 0, \quad i = (N_y - 1) \ldots 0, \\ H_N = \dfrac{(1-\lambda_2) + \lambda_2 \beta_N}{1 - \lambda_2 \alpha_N}, \quad H_i = \alpha_{i+1} H_{i+1} + \beta_{i+1}. \end{array}\right\} \tag{10}$$

Now let us consider the algorithm for solving the problem by the stream sweep method in variants of schemes I-III.

To apply streaming run, we introduce the variable $w_x = K\dfrac{\partial H}{\partial x}$ $w_y = K\dfrac{\partial H}{\partial y}$.

Then (1) takes the following form:

$$\frac{\partial w_x}{\partial x} + \frac{\partial w_y}{\partial y} = m\frac{\partial H}{\partial t} + Q. \tag{11}$$

The finite-difference form of equation (11) when calculated using the longitudinal-transverse scheme is as follows:

$$\begin{array}{l} \left(w_{x\,i+\frac{1}{2},j}^{\;k+\frac{1}{2}} - w_{x\,i-\frac{1}{2},j}^{\;k+\frac{1}{2}} \right) = m_{i,j}\dfrac{h}{\tau}H_{i,j}^{k+\frac{1}{2}} + \dfrac{h}{\tau}F_i; \;\; F_i = \tau \cdot \left(Q_{i,j} - \dfrac{w_{y\,i,j+\frac{1}{2}}^{\;k} - w_{y\,i,j-\frac{1}{2}}^{\;k}}{h} \right) - m_{i,j}H_{i,j}^{k}, \\ \left(w_{y\,i,j+\frac{1}{2}}^{\;k+1} - w_{y\,i,j-\frac{1}{2}}^{\;k+1} \right) = m_{i,j}\dfrac{h}{\tau}H_{i,j}^{k+1} + \dfrac{h}{\tau}F_j; \;\; F_j = \tau \cdot \left(Q_{i,j} - \dfrac{w_{x\,i+\frac{1}{2},j}^{\;k+\frac{1}{2}} - w_{x\,i-\frac{1}{2},j}^{\;k+\frac{1}{2}}}{h} \right) - m_{i,j}H_{i,j}^{k+\frac{1}{2}}. \end{array} \tag{12}$$

The use of calculations of the locally one-dimensional scheme leads to the following form:

$$\begin{array}{l} \left(w_{x\,i+\frac{1}{2},j}^{\;k+\frac{1}{2}} - w_{x\,i-\frac{1}{2},j}^{\;k+\frac{1}{2}} \right) = m_{i,j}\dfrac{h}{\tau}H_{i,j}^{k+\frac{1}{2}} + \dfrac{h}{\tau}F_i; \;\; F_i = \tau \cdot Q_{i,j} - m_{i,j}H_{i,j}^{k}, \\ \left(w_{y\,i,j+\frac{1}{2}}^{\;k+1} - w_{y\,i,j-\frac{1}{2}}^{\;k+1} \right) = m_{i,j}\dfrac{h}{\tau}H_{i,j}^{k+1} + \dfrac{h}{\tau}F_j; \;\; F_j = \tau \cdot Q_{i,j} - m_{i,j}H_{i,j}^{k+\frac{1}{2}}. \end{array} \tag{13}$$

Now we give the sequences by the splitting method:

$$\left(w_{i+\frac{1}{2},j}^{k-\frac{2}{3}} - w_{i-\frac{1}{2},j}^{k-\frac{2}{3}} \right) = m_{i,j}\frac{h}{\tau}H_{i,j}^{k-\frac{2}{3}} + \frac{h}{\tau}\left(F_i\right) \quad F_i = m_{i,j}H_{i,j}^{k-1},$$
$$\left(w_{i,j+\frac{1}{2}}^{k-\frac{1}{3}} - w_{i,j-\frac{1}{2}}^{k-\frac{1}{3}} \right) = m_{i,j}\frac{h}{\tau}H_{i,j}^{k-\frac{1}{3}} + \frac{h}{\tau}\left(F_j\right) \quad F_j = m_{i,j}H_{i,j}^{k-\frac{2}{.3}},$$
$$H_{i,j}^{k+\frac{1}{3}} = H_{i,j}^{k-\frac{1}{3}} + 2\cdot\tau\cdot Q_{i,j}, \tag{14}$$
$$\left(w_{i,j+\frac{1}{2}}^{k+\frac{2}{3}} - w_{i,j-\frac{1}{2}}^{k+\frac{2}{3}} \right) = m_{i,j}\frac{h}{\tau}H_{i,j}^{k+\frac{2}{3}} + \frac{h}{\tau}\left(F_j\right) \quad F_j = m_{i,j}H_{i,j}^{k+\frac{1}{.3}},$$
$$\left(w_{i+\frac{1}{2},j}^{k+1} - w_{i-\frac{1}{2},j}^{k+1} \right) = m_{i,j}\frac{h}{\tau}H_{i,j}^{k+1} + \frac{h}{\tau}\left(F_i\right) \quad F_i = m_{i,j}H_{i,j}^{k+\frac{2}{.3}}.$$

To calculate (12) - (14) by the stream sweep method [4], we use an algorithm of the following form:

$$\left.\begin{aligned}
&\alpha_N = \frac{-\lambda_2}{0.5\cdot\lambda_2 + (1-\lambda_2)}, \qquad \beta_N = \frac{\lambda_2 - 0.5\cdot\lambda_2 * F_N}{0.5\cdot\lambda_2 + (1-\lambda_2)},\\
&i = (N_x - 1)...0, \quad i = (N_y - 1)...0,\\
&\alpha_i = \frac{\frac{h^2}{\tau} - \alpha_{i+1}}{1 + \frac{h^2}{\tau} - \alpha_{i+1}}, \qquad \beta_i = \frac{\beta_{i+1} - F_i\left(\frac{h^2}{\tau} - \alpha_{i+1}\right)}{1 + \frac{h^2}{\tau} - \alpha_{i+1}},\\
&H_0 = \frac{\frac{h}{\tau}\cdot\lambda_1\cdot\beta_0 - \gamma_1\cdot\left(\alpha_0 - \frac{h^2}{\tau}\right) - 0.5\frac{h}{\tau}\lambda_1\cdot F_0\cdot\left(\alpha_0 - \frac{h^2}{\tau}\right)}{\left((1-\lambda_1) - 0.5\cdot\frac{h}{\tau}\lambda_1\right)\cdot\left(\alpha_0 - \frac{h^2}{\tau}\right) + \frac{h}{\tau}\lambda_1},\\
&i = 0...(N_x - 1), \quad i = 0...(N_y - 1),\\
&H_{i+1} = \left(\frac{\alpha_{i+1}}{\frac{h^2}{\tau} - \alpha_{i+1}}\right)\cdot\left(\beta_{i+1} - H_i\right) + \beta_{i+1}.
\end{aligned}\right\} \tag{15}$$

4. COMPUTATIONAL EXPERIMENT.

Let's check the accuracy of the algorithms created using the data given below. Let's create results for each method using programs using the Delphi programming language. An oil reservoir has a length and width $0 \le x, y \le 1000 \quad м$, constant thickness $h = 50 \quad м$, viscosity $\mu = 2$ and initial reservoir pressure $P_0 = 25 \quad Atm$.

The reservoir is being developed by 5 wells. Table 1 shows the pressure field at $t = 1800$ days.

TABLE 1

25.00	25.00	24.99	24.96	24.97	25.00	25.00	25.00
25.00	24.98	24.83	24.81	24.83	25.00	25.00	25.00
24.99	24.84	23.77	24.49	**23.77**	24.83	24.97	25.00
24.99	24.82	24.49	**22.96**	24.49	24.82	24.96	25.00
25.00	24.84	23.77	24.49	23.78	24.86	24.99	25.00
25.00	24.95	24.82	24.81	24.84	25.00	25.00	25.00
25.00	25.00	24.97	24.96	24.97	25.00	25.00	25.00

Figure 1 shows the view of the considered region D, and Fig. 2 shows the isoline of the pressure field at $t = 1800$ days.

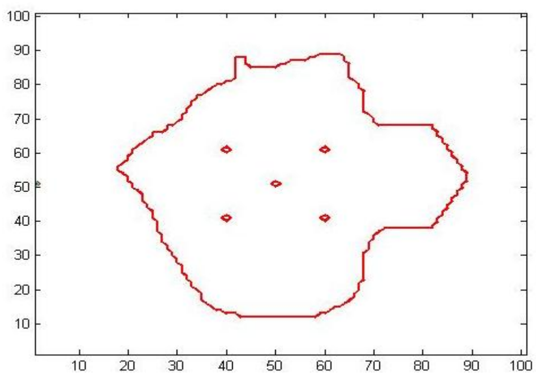

Figure 1. area D.

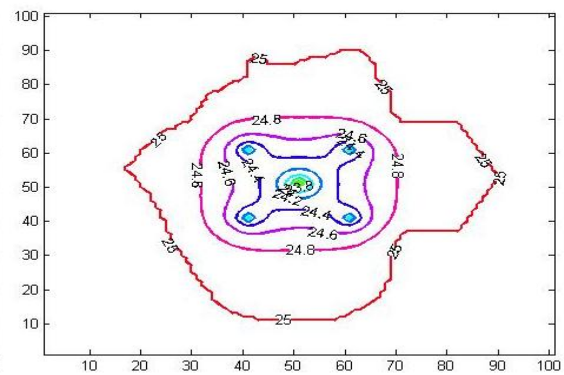

Figure 2. Isoline of the pressure field at $t = 1800$ days.

5. CONCLUSION

In conclusion, the most effective way to calculate the problem of two-dimensional liquid filtration is to apply the flow drive to the locally one-dimensional scheme. Because by applying this combination it is possible to reduce the calculation time by reducing the calculations and results close to other methods are achieved.

REFERENCES

1. Konovalov AN. Filtration problems for multiphase incompressible fluid. - Novosibirsk: Nauka, 1988. 165 p.

2. Samarskiy AA. Introduction to the theory of difference schemes. Moscow: Nauka, 1971. 550 p.

3. Tuhtanazarov D, Xolmatova I, Abdulbosit K. Model And Algorithm For Solving One-Dimensional Two-Phase Of Filtration Task. In 2019 International Conference on Information Science and Communications Technologies (ICISCT) 2019. pp.1-5.

4. Mirzaev S, Tukhtanazarov D, Karimova K, & Samadov N. Software for Determining Residual Oil Reserves in Oil Deposit Development. In IOP Conference Series: Materials Science and Engineering. 2020;883(1):012119.

5. Tukhtanazarov DS. Models for process management of developing oil and gas fields. Problems of Computational and Applied Mathematics, 2017;(2):41-46.
6. Tukhtanazarov DS, Sunnatov MS. Computational algorithm and program for determining well performance based on processing information from oil fields. In Modern technologies in oil and gas business. 2018. pp. 315-318.
7. Alimov I, Pirnazarova TE, Tukhtanazarov DS. Computational algorithm and software for determining residual oil reserves in the development of oil fields. Problems of Computational and Applied Mathematics, 2016;(4):95-99.
8. Pirnazarova TE, Tukhtanazarov DS. Mathematical modeling of two-dimensional problems of filtration of incompressible fluids. In Informatics: Problems, Methodology, Technology. 2015. pp. 374-376.
9. Dadamukhamedov AI. Virtual Youth Game "Blue Whale" Risk Elimination. Actual scientific research in the modern world, 2017;(3-2):138-142.
10. Dadamuxamedov A, Mavlyuda X, Turdali J. Cloud technologies in islamic education institutions. ACADEMICIA: An International Multidisciplinary Research Journal, 2020;10(8):542-557.