$$e = \alpha + \beta \frac{1}{d^2} + \gamma i + n,$$

where α, β and γ are constants that depend on the Hall effect sensor used as well as the geometry of the system and n is the noise process that corrupts the measurement [4]. It follows from Newton's second law that

$$m\ddot{d} = mg - k\frac{i}{d^4}.$$

Moreover, it follows from the Kirchhoff's voltage law that

$$v = Ri + L\dot{i}.$$

Conclusion.

According information marked above prototype of this system was made and tested. Now this system must be improved to achieve maximum precision.

The initial objective was completed successfully. The result of the conducted research is the ability to contemplate the effect of magnetism in reality. It can be said for certain that magnetism will find its place in many appliances and that there are many ways to develop and improve the levitation system.

REFERENCES

1. A. Smaili and F. Mrad, Applied Mechatronics. MA: Oxford, 2008.
2. Blink Tutorial, http://arduino.cc/en/Tutorial/Blink.
3. D. K. Cheng, Field and Wave Electromagnetics. MA: Addison-Wesley, 1983.

TWO-PHASE FLOW IN A POROUS MEDIUM MODELING

Рябикина А.С.
(Томск, Томский политехнический университет)

This research is devoted to the multiphase modeling in substances containing pores. The experimental setup is built in Comsol Multiphysics package and constitutes a soil column that deals with two substances when one of them goes from above of the column while the other one goes from below. Throughout the experiment air represents the 'upper' substance while the second one varies. The varying matter allows checking the model for its accuracy. After the check the transition to the air/oil system is done. The result of simulation is distribution of substance pressure in the laboratory column at the final time.

Multiphase Flows. In general, porous medium stands for a solid object that contains pores or voids. Studies of flows in porous media form the basis in soil mechanics, industrial filtration, groundwater hydrology, water treatment and others. In oil extraction, flow modeling is used to model processes when water or gases are entered to the oil-saturated medium in order to displace and collect oil [1].

Phase is one of the substance states which could be liquid, solid or gaseous. Multiphase flow is a simultaneous flow of a few liquid-and-gas mixture phases [2].

Experimental Setup. The whole experiment is divided into 2 parts: the first one employs water and air while the second one includes air and oil. As two substances take part in this experiment one of them is referred to as 'wetting fluid' (water or oil) while another one is referred to as ‘nonwetting fluid’ (air). To study processes that occur in multiphase flows peculiar experimental setups are constructed the way as it is shown in Fig.1.

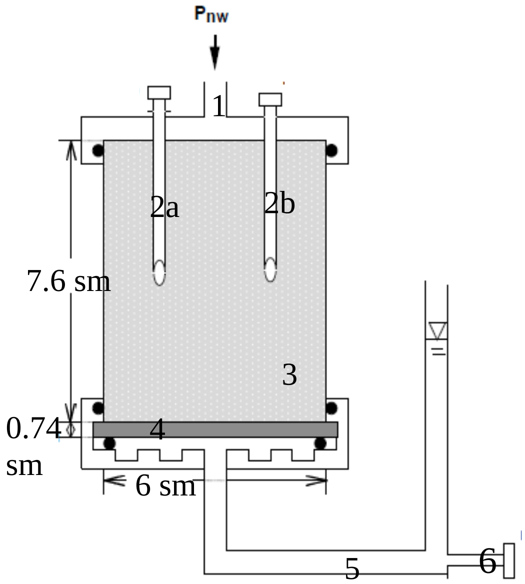

Fig.1. Experimental setup

The experimental setup consists of: 1 – inlet; 2a, 2b – pressure sensors; 3 – soil column; 4 – ceramic disk; 5 – buret; 6 – wetting phase pressure sensor.

Initial time, the soil column posed on a ceramic disk 4 is saturated with the wetting fluid located in the receiving buret 5. Then, air is injected over the surface of the laboratory column 3 through the inlet 1 from 0.2 meters height under pressure of $p_{\mathrm{nw}}(t)$. Air pressure is increased in time in order to observe the wetting fluid pressure behavior. The two-phase flow experiment covers 170 hours [3].

Governing Equations. The following equations describe two-phase flows in porous media for the wetting fluid and the nonwetting fluid respectively [3]:

$$\mathrm{C}_{p,\mathrm{w}}\frac{\partial}{\partial t}(p_{\mathrm{nw}}-p_{\mathrm{w}})+\nabla\cdot\left[-\frac{\kappa_{\mathrm{int}}k_{\mathrm{r,w}}}{\eta_{\mathrm{w}}}(\nabla p_{\mathrm{w}}+\rho_{\mathrm{w}}\mathrm{g}\nabla D)\right]=0,$$

$$-\mathrm{C}_{p,\mathrm{w}}\frac{}{\partial t}(p_{\mathrm{nw}}-p_{\mathrm{w}})+\nabla\cdot\left[-\frac{\kappa_{\mathrm{int}}k_{\mathrm{r,nw}}}{\eta_{\mathrm{nw}}}(\nabla p_{\mathrm{nw}}+\rho_{\mathrm{nw}}\mathrm{g}\nabla D)\right]=0,$$

where $\mathrm{C}_{p,\mathrm{w}}$ ($\mathrm{C}_{p,\mathrm{nw}}$) – wetting (nonwetting) fluid specific capacity (1/Pa); t – time (hrs); κ_{int} – intrinsic permeability of the porous medium (m^2); $k_{\mathrm{r,w}}$ ($k_{\mathrm{r,nw}}$) – relative permeability function for the wetting (nonwetting) fluid; η_w (η_{nw}) – dynamic viscosity for the wetting (nonwetting) fluid (kg/m*s); p_{w} (p_{nw}) – wetting (nonwetting) fluid pressure (Pa); ρ_{w} (ρ_{nw}) – wetting (nonwetting) fluid density (kg/m^3); g – acceleration of gravity (m/s^2); D – the coordinate (for example, x, y, or z) of vertical elevation (m).

Boundary and initial conditions for both systems are shown in Table 1.

Table 1.Boundary and Initial Conditions.

<table>
<tr><th colspan="2">Air/Water System</th><th colspan="2">Air/Oil System</th></tr>
<tr><th colspan="4">Wetting phase</th></tr>
<tr><th colspan="2"><i>Initial Conditions</i></th><th colspan="2"><i>Boundary Conditions</i></th></tr>
<tr><td colspan="2">$p_w^{init}=-\rho_{\mathrm{w}}\mathrm{g}D.$</td><td colspan="2">inlet and sides: n· $\left[-\frac{\kappa}{\eta}(\nabla p_{\mathrm{w}}+\rho_{\mathrm{w}}\mathrm{g}\nabla D)\right]=0,$
base: $p_{\mathrm{w}}=0.1*\rho_{\mathrm{w}}\mathrm{g},$ where n is the unit vector normal to the boundary.</td></tr>
<tr><th colspan="2">Nonwetting phase</th><th colspan="2">Nonwetting phase</th></tr>
<tr><th><i>Initial Conditions</i></th><th><i>Boundary Conditions</i></th><th><i>Initial Conditions</i></th><th><i>Boundary Conditions</i></th></tr>
<tr><td>$p_{nw}^{init}=0.2\rho_{\mathrm{w}}\mathrm{g}+(8.34-D)\rho_{\mathrm{nw}}\mathrm{g},$ where 0.2 – the first air pressure head (m water); 8.34 – soil column</td><td>inlet: $p_{\mathrm{nw}}=\rho_{\mathrm{nw}}\mathrm{g}h(t),$
base and sides: n· $\left[-\frac{\kappa}{\eta}(\nabla p_{\mathrm{nw}}+\rho_{\mathrm{nw}}\mathrm{g}\nabla D)\right]=0,$</td><td>$p_{nw}^{init}=\frac{\sigma_{ao}}{\sigma_{aw}}0.2\rho_{\mathrm{w}}\mathrm{g}+(8.34-D)\rho_{\mathrm{nw}}\mathrm{g}.$</td><td>$p_{\mathrm{nw}}=\frac{\sigma_{ao}}{\sigma_{aw}}\rho_{\mathrm{nw}}\mathrm{g}h(t),$
where σ_{ao} (σ_{aw}) – interfacial tension between air and oil (air and water); $p_{c,aw}$ ($p_{c,ao}$) – capillary pressure for</td></tr>
</table>

length (m).	where $h(t)$ - pressure head (m water).		air/water (air/oil) system.

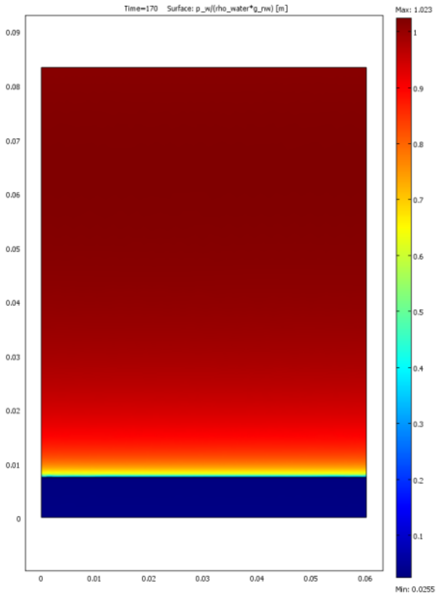

Fig.2. Oil pressure distribution ($t = 170$ hrs)

Modeling. Such equations are difficult to solve because of its nonlinearity, however computers allow to find a solution via approximate numerical methods. Finite element method (FEM) built-in Comsol Multiphysics is one of them.

To prove model robustness via comparison with other authors experimental observations were made for air/water system. The experiment showed that results corresponded to the outputs obtained by other researchers thus the created model can be used for further observations and substances may be varied.

After that the model was modified so that the wetting fluid would be represented with oil instead of water. The study output is oil pressure in the laboratory column at 170 hours (Fig.2). Conclusively, the experiment showed that despite air injection through the column’s inlet, oil concentration is higher on top of the column thus the model can be used to study problems which require oil or any other substance extraction.

REFERENCES

1. Scheidegger, A. (1960) *The physics of flow through porous media.* Moscow: State Scientific and Technical Publisher of Petroleum and Technical Bibliography.
2. Kluev, N. & Solovieva, E. (2009) *Mathematical models of two-phase flows.* Samara: Samara university.
3. Hopmans, J. et al. (1998) *Parameter estimation of two-fluid capillary pressure saturation and permeability functions.* Cincinnati: U.S. Environmental Protection Agency, National Risk Management Research Laboratory.

СПОСОБ ОЦЕНИВАНИЯ ВЗАИМНЫХ ФАЗОВЫХ СИГНАЛОВ ПО ФУНКЦИИ КАЧЕСТВА ПРИ ФАЗОЧАСТОТНОМ ПРОСЛЕЖИВАНИИ СЕЙСМИЧЕСКИХ ВОЛН

Сидоренко С.Н.
(г. Томск, Томский политехнический университет)

При анализе реальных материалов анализируемые сигналы часто интерферируют между собой, поэтому выделить их и проследить по исходным разрезам практически не удается. Фазочастотное прослеживание (ФЧП) позволяет значимо повысить возможность выделения интерферирующих сигналов и увеличить их разрешение.

Стандартный интервал дискретизации $\Delta t = 2 \cdot 10^{-3}$ с, используемый в цифровой обработке сейсмических данных, оказывается недостаточным при оценке взаимных спектров отраженных волн. Поэтому используется способ, позволяющий изменить интервал дискретизации при прослеживании сигналов.