A simulation of suspension flow in an artificial porous medium.

Dariusz Knez[1]

Simulácia toku suspenzie v umelom poróznom médiu

The paper presents research results of a computer simulation of the suspension flow. One of the most difficult problems in petroleum industry is to optimally use different drilling fluids. It is usually a suspension interacting with a porous medium. The presented research is one of steps in our understanding the solid particles flow in the porous medium. An ideal porous medium consisting of regular balls is used to avoid additional effects caused by the grain shape. A computer simulation gives us a view on the flow in the porous medium. This paper shows some example results such as: velocity, pressure and the particle path lines contours.

Key words*: Computer simulation, suspension flow, drilling fluids*

Introduction

The drilling process uses fluids containing solid particles. It is one of cases when we need some idea about the interaction between the suspension and a porous medium. A laboratory and theoretical research shows it to be avery complicated problem [2] and still we do not have clear answers on many questions. One of the best empirical models was developed by A. Trzaska [4] and another one by A. Wojtanowicz [5 ,6, 7].

A computer simulation gives us more cheaper and faster solutions than the laboratory research. For this reason a research is carried out worldwide on numerical models of suspension flow in porous media [1]. Because of the computer power, such a model has to be simplified. One of the best numerical models was developed by A. G. Siqueira et. al [3] This model simplifies the porous space as a combination of cubes and cubicoides accordingly to the statistical description of porous volumes. A newly presented model describes the porous space as a free space between grains. In the first step, grains are simplified as balls. A next research will be carried out to achieve a more sophisticated model accordingly to the real grain size, shape and distribution. Using such a simplified geometry, a numerical model is build to find how the suspension behaves in the porous medium.

Numerical simulation

To simulate the suspension flow in the porous medium the numerical model is build. To verify the model laboratory, the measurement has to be done in the same conditions. So an artificial of bed 3 mm diameter glass balls is used to compare the laboratory to the numerical results (Fig. 1). To run the simulation, a sophisticated software is used from Cyfronet AGH Krakow. Using the preprocessor Gambit a geometrical model was created and than meshed (Fig. 2). Because of a natural packing of glass balls the rhomboedron geometry was chosen for the porous medium modeling.

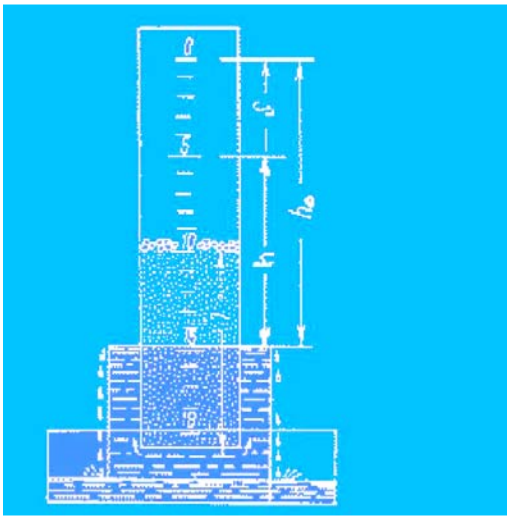

Fig. 1. Laboratory experiment to get permeability of 3 mm diameter glass balls artificial bed.

[1] *Dariusz Knez,* Faculty of Drilling, Oil and Gas, AGH University of Science and Technology, Cracow, Poland
(Recenzovaná a revidovaná verzia dodaná 5. 10. 2006)

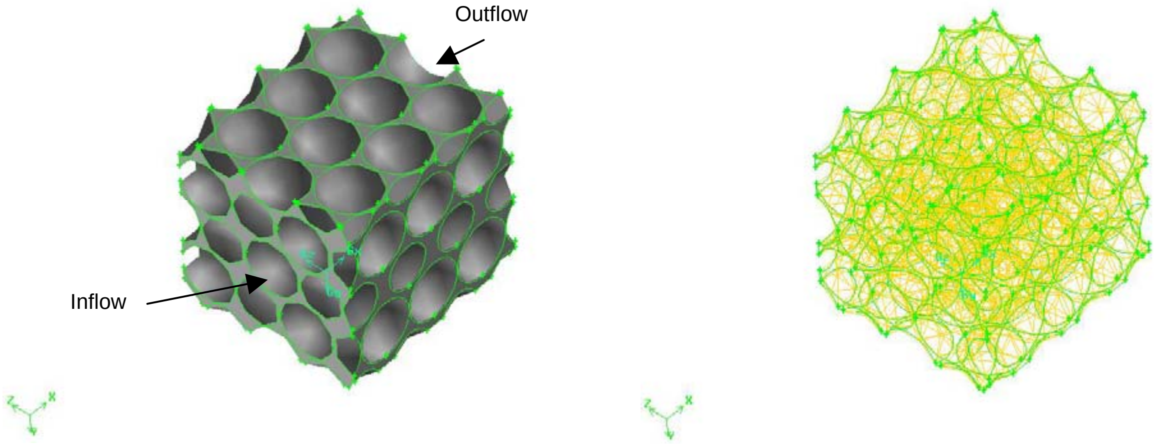

Fig. 2. Geometry and mesh of investigated porous medium artificial model.

The method of finite elements is the best solution method for such a complicated geometry. To run calculations, the Fluent simulator was used. To check the model reality, the results are compared to the laboratory outcome, and it agrees in the confidence interval. In the inflow face, as shown at the Fig. 2, the mass flow inlet was set at the flow rate Q = 0.004536 kg s^{-1}. At the same face, 10 % of suspension was injected. At the Fig. 3 some results are presented. We can observe a quite regular distribution of pressure, decreasing in the flow direction in accordance with the Darcy law. A next picture at the same figure shows the velocity vectors inside the porous space. It is difficult to draw some conclusions from it because of high density of vectors. For this reason, the porous space is sliced virtually and the results are shown in Fig. 4.

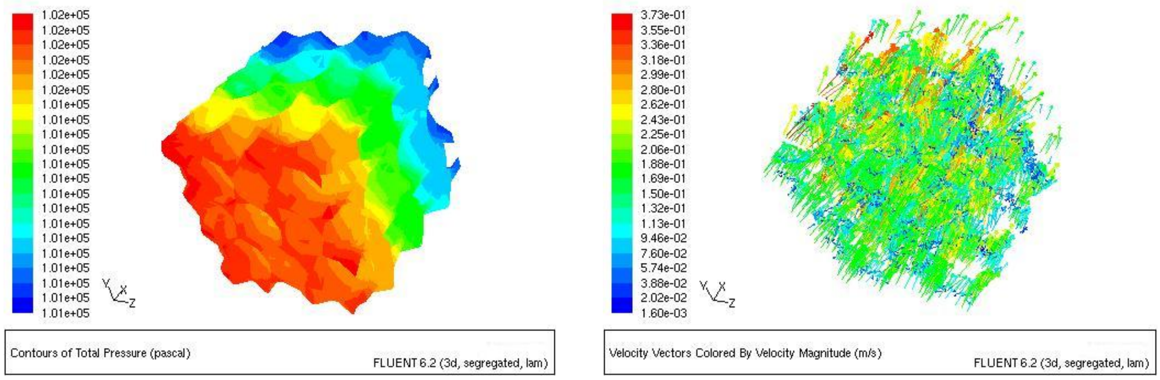

Fig. 3. Pressure and velocity contours.

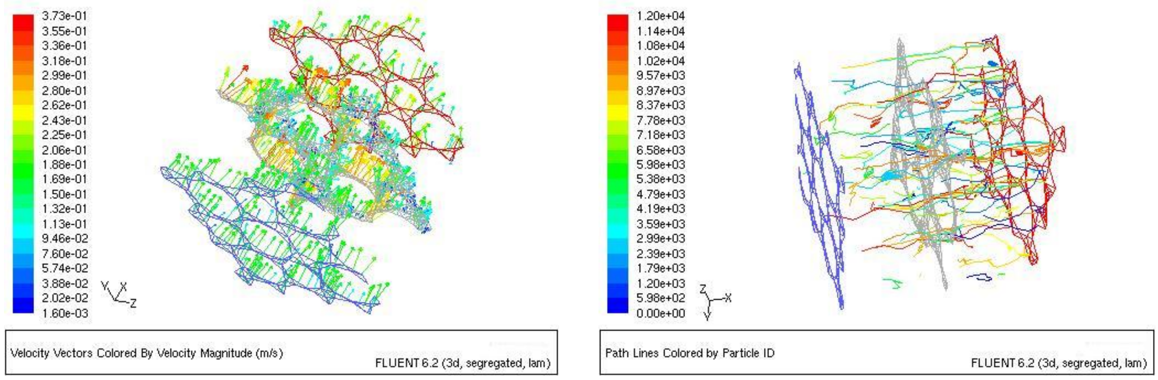

Fig. 4. Velocity vectors and path lines in virtual faces.

Now, we can see more precisely how the flow looks inside the artificial porous space. As we expected at the inflow, the face velocity distribution is homogenous. The middle slice has a heterogeneous velocity distribution. In narrow throats, the velocity vectors have higher values. The next picture at the same figure presents the path lines of the chosen suspension particles. It is not possible to show every path line at one picture because of its number. We can find some interesting conclusions. Principally, solid particles move in the main flow direction (X direction), but some of them go even in the opposite direction. We can observe where particles are trapped and, what is very interesting, some are released from the cake on the porous medium wall. Because of dimensions of the model it is difficult to look more precisely inside and it takes a long time to make any changes due to the computer calculation time. For this reason, a representative element was selected (Fig. 5). To get proper flow evolution, it has to have a longer length in the flow direction.

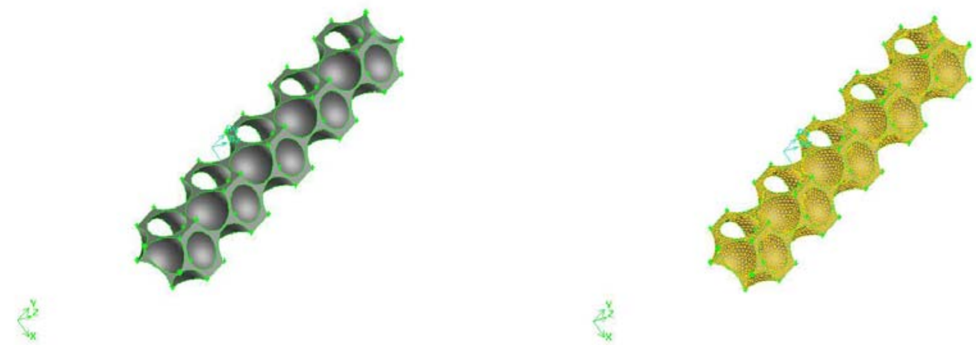

Fig. 5. Geometry and mesh of investigated porous medium representative element..

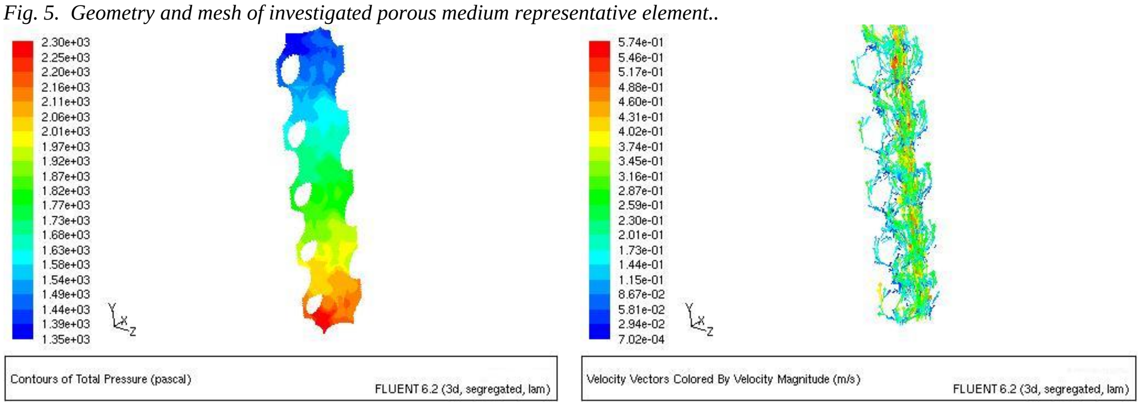

Fig. 6. Pressure contours and velocity vectors in representative element.

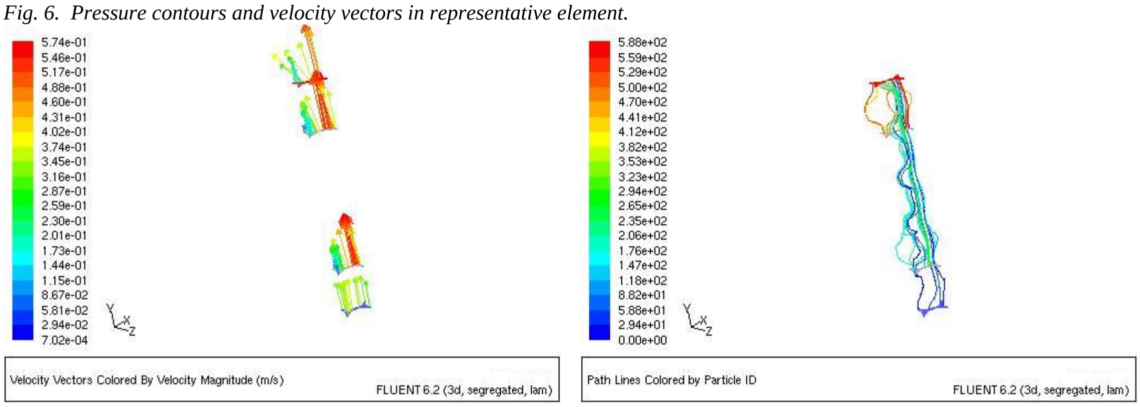

Fig. 7. Velocity vectors and path lines in virtual faces of representative element.

Fig. 6 shows some results of the simulation. The pressure distribution is still quite regular, but now we can see more clearly breakthrough areas. These are places where the pressure does not change with the flow direction so rapidly as in the surrounding area. The results are shown in the next picture at Fig. 6, where the flow velocity vectors can be observed. To see a more detailed picture, four faces are virtually chosen (Fig. 7). As we expected the inflow area has a homogeneous velocity distribution, but the next faces have a heterogeneous velocity distribution. A most interesting is the last picture, where the path lines of chosen solid particles are drawn. We observe a flow of particles through first few millimeters and some of them are trapped by the porous wall. It is interesting that after some distance a more rapid release from the cake on the porous medium wall can be found.

Conclusions

1. Computer simulation can be an useful tool to get an inside view in the suspension flow in porous media.
2. Near the wellbore wall, particles are trapped more often then inside this formation.
3. For the given flow conditions and the porous medium geometry a specific boundary of the intensive particle release area can be obtained.
4. It is necessary to continue our research to get a more precise suspension flow description in more realistic porous media.

Financed from research program
2006 WWNiG no 10.10.190.317

References

[1] Bedrikovetsky, P., G., Potsch, K., T., Polyanin, A., D., Zhurov Al.: Upscaling of the Waterflood Reservoir Propetiies on the Core Level: Laboratory Study, Macro and Micro Modelling, *SPE Middle East Oil Show, Bahrain, March 1995*.

[2] Perrit, C., L., Sorbie, K., S., Tardy, P., M., J., Crawshaw, J.,P.: Micro-PV: A New Technology for Pore Scale Flow Characterization in Micromodels, *SPE Europec/EAGE Madrid, Spain, June 2006*.

[3] Siqueira, A., G.: A 3D Network Model of Rock Permeability Impairment Due to Suspended Particles in Injection Water., *SPE European Formation Damage Conference, Hague, Netherlands 2003*.

[4] Trzaska, A.: On Researches of The Colmatage, *Archives of Mining Sciences, Volume 34, Issue 3, Warszawa-Kraków 1989*.

[5] Wojtanowicz, A., K., Krilov, Z., Langlinais, J., P.: Experimental Determination of Formation Damage Pore Blocking Mechanisms, *Journal of Energy Resources Technology, March 1988*.

[6] Wojtanowicz, A., K., Krilov, Z., Langlinais, J., P.: Oilwell Completion Fluid Solids Interaction With an Unconsolidated Oil Reservoir, *Particulate Science and Technology, 1987*.

[7] Wojtanowicz, A., K., Krilov, Z., Langlinais, J., P.: Study on the Effect of Pore Blocking Mechanisms on Formation Damage, *paper SPE 16233, Production Operations Symposium, Oklahoma City, Oklahoma, March 8-10, 1987*.