Direct simulation of proppant transport in hydraulic fractures based on the immersed boundary method

Kuranakov D.S., Esipov D.V., Lapin V.N., Chirkov D.V.

Institute of Computational Technologies SB RAS, Novosibirsk, Russia

The problem of the proppant transport in the hydraulic fracture has great importance in science and technology. Nowadays direct simulation of this process has become possible. A new model of incompressible viscous fluid flow with the immersed solid particles is developed. The model is based on the Immersed Boundary Method (IBM) [1] that uses the uniform staggered Eulerian grid for the fluid flow and moving Lagrangian grid for the particles. This approach allows to consider particle movement without remeshing the domain for fluid flow. To interpolate variables between one mesh to another a regularized delta function is used. To solve Navier-Stokes equations Crank-Nicolson approximation scheme is used for all terms including convective and pressure ones. SIMPLE-like method uses internal iterations for correction of pressure and velocity until the needed accuracy is reached. In the fluid-particle interface special force is applied to correct the velocity in such a way to fulfill the no-slip boundary condition. Particle transfer and rotation are simulated using the Newton-Euler equations that are solved explicitly.

The proposed model was verified using the following benchmark problems: cavity flow problem, flow around the cylinder, the transfer and rotation of a single particle in Poisseuille flow (Segre-Silberberg effect [4]). It was shown that the particles tend to move to their equilibrium position between the walls and the center of channel independently on the starting position. The influence of particle size and Reynolds number on equilibrium position was investigated.

After verification the model is used for modeling of proppant transport in the channel. The ruling parameters of this process are particle concentration, size, buoyancy and Reynolds number. Particle The profiles of the fluid, particle and mixture velocities were averaged over fixed time interval. The analysis of influence of the parameters on velocity profiles is made. Averaged particle velocity is always a little bit more than the averaged fluid velocity, and the difference decreases with concentration growth. Increasing Reynolds number influences the particle mixing.

The work was supported by the Russian Science Foundation (grant No. 17-71-20139)

References

[1] M. Uhlmann, *An immersed boundary method with direct forcing for the simulation of particulate flows.* J. Comput. Phys., Vol. **209**(2), pp. 448–476, 2005.