Numerical investigation of permeability anisotropy in porous media using a particle method

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It is important to analyze fluid flow in reservoir rocks in the production of oil, gas, and any other fluidal unconventional resources. For reservoir analyses, we require information on hydraulic conductivity of reservoir rocks, which could theoretically be estimated using the Kozeny-Carman equation under the assumption of laminar flow in isotropic media. However, some numerical and laboratory experiments indicated that the subsurface materials show anisotropic feature in permeability. This indicates that it is important to consider anisotropy in reservoir analyses for accurate simulations. In the present study, we simulate fluid flow in three-dimensional models which imitate reservoir rocks by using a smoothed particle hydrodynamics (SPH) method and investigate the effect of porosity, viscosity on anisotropy of permeability.

We assumed four digital specimens which imitate porous media, through which fluid flows depending on pressure gradient in different directions. We measure average fluid velocity component in the direction parallel to the pressure gradient for calculating permeability. The results indicate that our digital specimens show permeability anisotropy in various degrees although the porosity of the specimen is kept constant.

Next, we compare our numerical results with theoretical formulas. Our calculated permeability has good agreement with those derived from theoretical equations when the porosity is high. On the other hand, in the case of low porosity, our results show large difference with the theoretical ones. Since dominant flow path is limited in low porosity specimen, the bulk permeability is directly affected by the anisotropic feature of the dominant flow path. Therefore, permeability of low porosity specimen is sensitive to the direction of fluid flow. Our results indicate that it is important to consider permeability anisotropy in reservoir analyses in view of the porosity of reservoir rocks.

Keywords: permeability, anisotropy, numerical simulation, particle method

