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Verification of interfacial phenomena of the numerical method for multi-component fluid system

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[Introduction] Various texture and internal structure are observed in igneous rocks, however, the flow dynamics related with the pattern formation is relatively not understood systematically than the thermodynamics. As a matter of fact, the thermodynamic factor is affected by the flow. Therefore it is important problem to understand the flow dynamics of the pattern formation of the rock.

For the difficulties of this problem, there is a cause in the structural characteristics that rock is generally heterogeneous and the gethering body of the small materials. Especially in the partially molten rock, the crystals and the melt between them define the flow dynamics of the system.

These systems consisting of many different materials are called multi-phase system. The dynamics is one of the most difficult problems because multi-scale in the whole system must be considered from microscopic process to macroscopic phenomena. For the multi-phase system that the small materials with deformation gathered densely, such as magma or partially molten state, it must be taken into account that the deformation of the small materials, the interaction between them, and the fluidity of the whole system. Besides, wetting property that originates in interfacial tension between materials is also important in the partially molten rock. There are only a few study about the dynamics (e.g. Niimura,2000).

We are planning a numerical experiment to obtain the relations between the dynamics of the multi-phase system under shear stress and some physical parameters such as wetness, viscosities, and volume fractions of the small materials. The system consists of viscous fluids with different components. We developed the numerical method for 3D system based on multi-phase model of Lattice-Boltzmann method (Shan&Chen,1993). According to the model, the interfacial tension is reproduced as a result of the interaction between distribution functions of fluid components s0 and s1. Two-phase systems like gas-fluid mixtures have been investigated with the model so far. However the validity of the model for the multi-component system has never been investigated, and there is no quantitative study about the interfacial tension. Therefore, we verified that the model satisfies the interface physics, and we calibrated the interfacial tension, contact angle between different fluids of the multi-component system.

[Method] As the initial condition, two or three fluids are set on static field. At the equilibrium state, the shape of the interface and the pressure are measured. For two-fluid system, the calculation size of 60x60x1 and the size of 60x60x60 are used, and a fluid circle (sphere) is put on the center. For three fluids the size of 140x70x1 is used and a fluid circle is put on the interface of two fluids which are arranged to the layer-shaped.

[Results] From two-fluid system, the following things are verified: Laplace's law (dp=g01*n, dp: pressure difference, g01: interfacial tension between fluid 0 and 1, n:curvature, n=1/R (2D), n=2/R (3D), R:radius) is satisfied in 2D and 3D system, and the interfacial tension depends also on the third component diffused in the back ground. The ratio of the two interfacial tension, g12/g01, are obtained in the range of 1.0 - 2.0. This corresponds with the contact angle of 120 - 0 degree. It means that various wetness are able to be calculated by the model. From three-fluid system, it is verified that the contact angle (F) satisfies the physics of the balance of the three interfacial tensions, g12=2*g01*cos(F/2).

[References]

H.Niimura, 2nd Japanese-European Two-Phase Flow Group Meeting, 2000.

X.Shan and H.Chen, Phys.Rev.E, 47, 1993.