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Computer simulation of material transport with an SPH (Smoothed Particle Hydrodynamics) method

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For computer simulation of material transports, partial differential equations are usually solved to determine flow and deformation of continuum with a finite-difference or finite-element method in a spatially fixed coordinate. Particle dynamics is another method in which deformation and flow are analyzed based on the motions of particles that are controlled by a certain equation of motion with particle interactions. The particle dynamics gives change of the state of each material point more directly and deals with localized deformation and flow more flexibly without laborious arrangements of mesh points. A major disadvantage of particle dynamics is lack of clear correspondence to the conventional continuum dynamics but an SPH (Smoothed Particle Hydrodynamics) method, in which particles are subjected to the same equation of motion with the same concepts of density and stress as continuum, seems to be free from this difficulty. In the present paper consistency of the SPH method with continuum dynamics is examined with its applicability to problems of earth sciences.

Some numerical experiments made in the present study have revealed that the SPH method is able to represent behaviors of solid, fluid and their mixture reasonably well and that the effects of buoyancy force, locally applied pressure, elastic-wave transmission and fracture can be treated consistently with continuum dynamics. These experiments further suggest that various properties of materials, including thermal and chemical properties, can be taken into account easily in the analysis of the SPH method. For this purpose an arbitrary quantity defined in continuum dynamics, such as temperature and mixing ratio, is allocated to particles as their own variable and the particle interaction that determines change of the variable is formulated by conversion of the corresponding continuum relation. In this conversion a space derivative in continuum is replaced by a suitable average over particles using a kernel function of the SPH method. To include thermal effects in an SPH system, for instance, temperature is regarded as an additional variable of particles and its change is calculated by a converted thermal-conduction equation.

Due to such good correspondence with continuum dynamics the SPH method has a great applicability to various fields of earth sciences. For instance, magma ascent processes can be analyzed more easily from not only mechanical but also thermal and chemical viewpoints in the SPH method. Some other problems like mantle dynamics and earthquake occurrence also can be simulated in a flexible way.