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SIMULATIONS OF BEHAVIOR OF MAGNETIC PARTICLES IN MAGNETIC FUNCTIONAL FLUIDS BY USING HYBRID DISCRETE PARTICLE METHOD

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In the presence of magnetic field, chain-like clusters of magnetic particles appear in magnetic functional fluids such as magnetic fluids and magnetorheological fluids. Microstructure formation of magnetic particles in the magnetic functional fluid has an important role on the macroscopic properties of the fluid such as apparent viscosity. Not only using viscosity of magnetic functional fluids but also behavior of micrometer-size magnetic particles in the fluid can be directly applied to micro devices in MEMS or biotechnical systems [1,2].

In this study, we perform the simulations of behavior of magnetic particles in the fluid in the presence of magnetic field by using a hybrid method of three simulation methods: discrete particle method based on the simplified Stokesian dynamics [3], immersed boundary method for describing the interactions between particles and fluid [4], and lattice Boltzmann method for simulating fluid flow [5]. One of our target phenomena is magnetic microchains or magnetic microswimmer [1,2]. Using our simulation method, behavior of magnetic microchains or magnetic microswimmers can be simulated with considering interaction between particles and fluid.

Figure 1 shows the analytical model for simulating magnetic microchain. In our simulations, 9 or 15 magnetic particles are initially arranged in line in the direction of static magnetic field. Both static directional magnetic field and oscillating magnetic field perpendicular to the static field are applied.

Figure 2 demonstrates the behavior of a magnetic microchain consisting of nine magnetic particles in the presence of magnetic field as an example of our simulation results. From Fig. 2, slightly bending motion is observed and basically the magnetic microchain vibrates rigidly with applied oscillating magnetic field. On the other hand, when the directional static magnetic field is rather weak, the magnetic microchain breaks into two parts as shown in Fig. 2(b). These phenomena are also observed in the previous experimental reports [2].

Basic mechanisms of magnetic microchains and magnetic microswimmers are investigated and typical behaviors such as oscillation, propulsion, split and reattachment are duplicated as their behaviors in experiments.

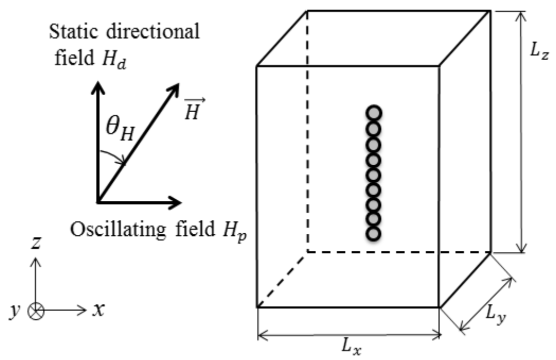

Fig. 1 Analytical model for simulating magnetic microchains in the presence of magnetic field.

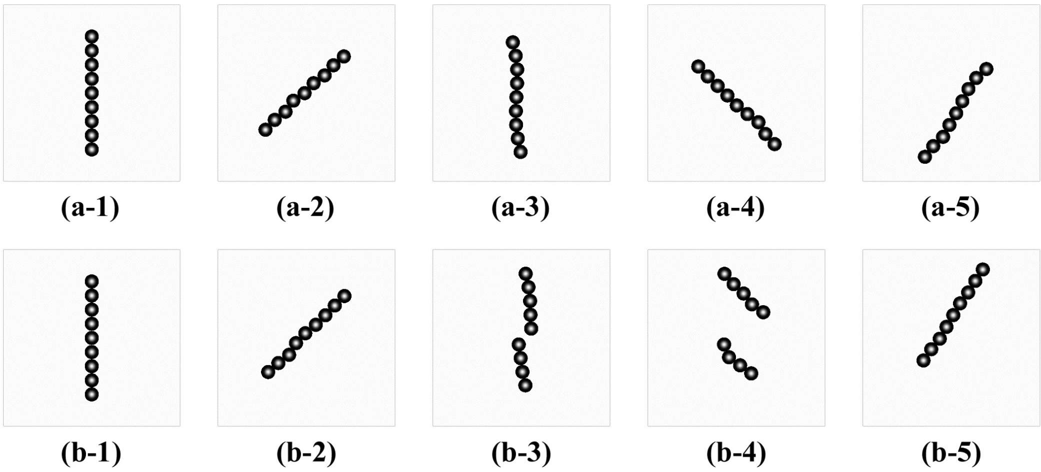

Fig. 2 Sample snapshots of magnetic microchains in the repsence of magnetic field. The strength of static dirctional field is 25.08 and that of oscillating field is (a) 22.21 and (b) 20.26. The time step is (1) initial, (2) 3×10^4, (3) 6×10^4, (4) 9×10^4, and (5) 1.2×10^5, respectively.

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