A Microscopic Simulation for Structure Formation in Ferrofluid in a Magnetic Field with Oscillatory Shear Flow

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In this simulation, we consider a model of colloidal suspension of nano sized ferro particles dispersed in a thin plate. In this model, we take into account a dipole-dipole interaction between ferrofluid particles and a resistance by Stokes' law depending on the shape of ferrofluid particle. At each simulation step we calculate the position and the direction of dipole moment of each particle by using molecular dynamics simulation methods. This model also includes effects of an external magnetic field and a shear flow.

When an external magnetic field is applied along a thin plate (z-axis), ferrofluid particles form a chain structure along the external magnetic field (z-axis) as is shown in Fig 1. Afterwards we add an external oscillatory shear flow with an angular frequency ω to the chain structure perpendicularly (x-axis):

$$\gamma = \gamma_0 \sin(\omega t), \tag{1}$$

without the external magnetic field.

In the present simulation, we study an effects of γ_0 (shear strength) and ω (frequency) on cluster formation process.

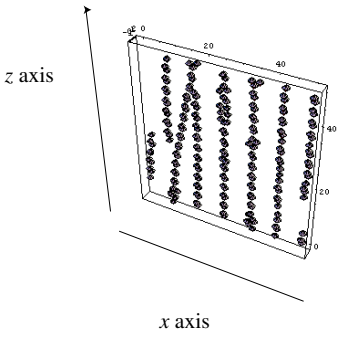

Figure 1: Ferrofluid nano particles forming chain structure in a magnetic field

We have found that there are three characteristic phases of the cluster formation dynamics. Typical relationships between the average moment of each particle (n_x(x-axis) and n_z(z-axis)) and ω (frequency) for some range of γ_0 (shear strength) are as follows:

1. For $\omega = 0$: the average of $n_x \to 0$ and $n_z \to 0$
2. For $\omega =$ moderate: the average of $n_x \to$ moderate and $n_z \to$ moderate
3. For $\omega =$ strong: the average of $n_x \to 0$ and $n_z \to 1$

In the case of phase 2, the chain structure remains even without an external magnetic field(Fig 2). This is due to the resonance between oscillatory shear flow and dipole-dipole interaction. Such resonance behavior between n_x, n_z and $\gamma_0 \sin(\omega t)$ is shown in Fig 3.

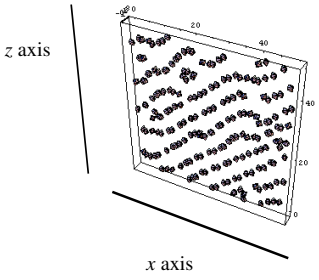

Figure 2: Ferrofluid nano particles forming chain structure without an external magnetic field

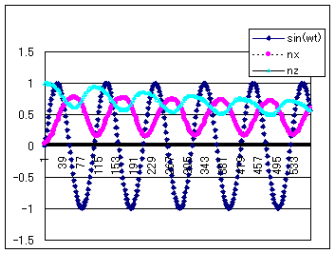

Figure 3: change of the average moments of ferrofluid particles with shear $\gamma = \gamma_0 \sin(\omega t)$

More details on these results will be discussed at the conference.