Resonance Behavior in Ferrofluid with Oscillatory Shear Flow

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磁性流体は、コバルトフェライト、マグネタイト、バリウムフェライトなどの磁性ナノ粒子の水性あるいは油性コロイド溶液である。我々は、磁性流体の振動場におけるレゾナンス的振る舞いについてコンピュータシミュレーションを行い、シェア率と周波数との関係性を調べた。

1 Introduction

Magnetic fluid is an oil or a water-based colloidal suspension of ferromagnetic nanoparticles such as Co-ferrite, magnetite and Ba-ferrite [1], [2]. Since the properties of these fluids can be easily influenced by an external field, they have recently attracted much scientific and technological interest [1], [2]. There are many applications such as magnetic fluid rotary seals, magnetic clutch, and turnable dampers.

We studied final states of microscopic structure of ferrofluid by changing shear rates and frequency and obtained three typical aggregational patterns of ferrofluid.

2 The Model

We assume spherical particles dispersed in a suspension in a thin plate. The coating layer of each particle causes a repulsive force between particles. On the other hand, the dipole-dipole interaction causes attractive force between particles.

We consider a magnetic field in the z-axis, shear flow in the direction of the x-axis. The direction of magnetic field is in the z-axis. When chain structure is made, we add an oscillatory shear along the x-axis without the external magnetic field,

Under these conditions, the equations of motion of $r_i = x_i\hat{\mathbf{x}} + y_i\hat{\mathbf{y}} + z_i\hat{\mathbf{z}}$ (translational motion) and n_i (rotational motion) for interacting particles:

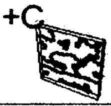
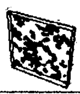
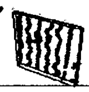
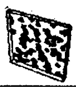
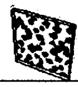
$$\frac{d\vec{r}_i}{dt} = \dot{\gamma} z_i \hat{\mathbf{x}} + \frac{1}{\xi_t}[\sum_{j(\neq i)}^{N}(\vec{F}_{ij}^1 + \vec{F}_{ij}^2) + \vec{R}_i(t)], \tag{1}$$

$$\frac{d\vec{n}_i}{dt} = [\frac{\dot{\gamma}}{2}\hat{\mathbf{y}} + \frac{1}{\xi_r}(\sum_{j(\neq i)}^{N}\vec{T}_{ij}^1 + \vec{T}_{ij}^2 + \vec{N}_i(t))] \times \vec{n}_i, \tag{2}$$

where, the $\vec{F}_{ij}^1$ is the force on the i-th particle due to the dipole-dipole interaction between particles i and j. $\vec{F}_{ij}^2$ is the short range repulsive force due to surfactant. $\vec{T}_{ij}^1$ is the dipole induced torque and T_{ij}^2 is the torque induced by the external magnetic field, with the translational drag force coefficient $\xi_t \equiv 6\pi a\eta$, and the rotational drag force coefficient $\xi_r \equiv 8\pi a^3\eta$. These forces are given by [1],[2]

3 Conclusions

We obtained three typical patterns of the fainal state. The transient process and the equation for the relationship between $\gamma_0(shearrate)and\omega(frequency)isundertheway.$

γ_0 / ω	0.01	0.05	0.1
0.01	I+C 	I 	I 
0.05	C 	I+C 	I 
0.1	C 	Resonance 	I 
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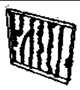
1.0	C 	C 	C 

図 1: Phase diagram of microstructures for various values of the frequency ω and shear magnitude γ_0 (C: Chained pattern; I: isotropic pattern)

参考文献

[1] Rosensweig R.E. *Ferrohydrodynamics* New York: Cambridge University Press, (1987).

[2] S. Odenbach, *Magnetoviscous Effects in Ferrofluids*, Springer, Berlin, 2002