Formation of Particle Clusters From Rotating Particle Chains

D. Kappe[1], A. Hütten[1]

[1]Universität Bielefeld, Bielefeld, Germany

Abstract

Wittbracht et al. [1] proposed a technique to assemble highly ordered monolayers of magnetic beads utilizing rotating magnetic fields. The magnetic beads align their magnetization with any applied magnetic field. As long as this field is homogeneous, the particles will only interact with each other. As their magnetic moments are all facing the same direction, they will attract each other if they come close. This leads to the formation of 1D particle chains observed by Promislow et al. [2]. These chains will follow the rotation of the applied magnetic field for low frequencies. The particle chains deform into an s-shape as soon as the drag of the fluid gets stronger. Increasing the rotation frequency further leads to the fragmentation of the chains into smaller and more stable chain fragments. The highly ordered monolayers form at even higher frequencies.

There are some publications on the simulation of rotating particle chains [3]. A similar model is used here to study the transition from rotating chains, fragmented chains to highly ordered particle layers. Therefore, the Particle Tracing for Fluid Flow interface in the COMSOL Multiphysics® software is used. There are three forces acting on the particles. First of all a magnetic force which lets the particles interact with each other by means of their magnetic stray fields. A repulsive force to prevent the particles from overlapping and the drag of the viscous fluid. The particles start aligned in a chain (see Figure 1) along the direction of the applied magnetic field. The rotation frequency is then linearly increased until the chain breaks apart and forms a cluster.

First results show, that the behavior previously seen in experiments [1,3] may be retrieved numerically. The rotation of the particle chain closely resembles the rotation of the magnetic field for slow rotation frequencies (see Figure 1), deforms into a s-shape for higher frequencies (see Figure 2) and then breaks apart into smaller fragments (see Figure 3) and finally merge into a highly order layer (see Figure 4).

The results so far look promising and will be compared to experimental data. This will enable to study of the stability of the assembled clusters, which thereafter may be used to assess their utility as valves for example.

Reference

[1] Wittbracht, F., Eickenberg, B., Weddemann, A., & Hütten, A. (2011, August). Rotating magnetic field assisted formation of highly ordered two-dimensional magnetic bead arrays. In ICQNM 2011, The Fifth International Conference on Quantum, Nano and Micro Technologies (pp. 99-102).

[2] Promislow, J. H., Gast, A. P., & Fermigier, M. (1995). Aggregation kinetics of paramagnetic colloidal particles. The Journal of chemical physics, 102(13), 5492-5498.

[3] Gao, Y., Hulsen, M. A., Kang, T. G., & den Toonder, J. M. J. (2012). Numerical and experimental study of a rotating magnetic particle chain in a viscous fluid. Physical Review E, 86(4), 041503.

Figures used in the abstract

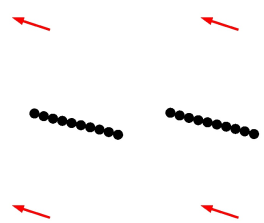

Figure 1: Two particle chains (10 particles) rotating at a frequency of 4Hz

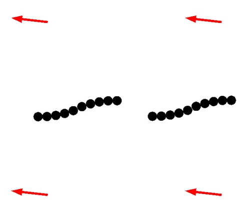

Figure 2: The same configuration at a rotation frequency of 16Hz

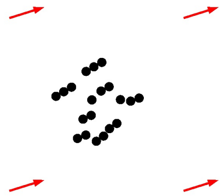

Figure 3: Strong fregmentation is visible at 100Hz

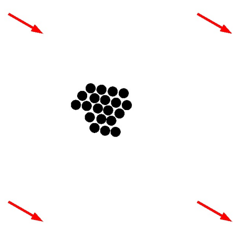

Figure 4: Formation of clusters at frequencies above 1kHz