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MECHANICAL ENGINEERING

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Dynamics of Magnetic Oblate Spheroids Suspended in Newtonian Fluids under Magnetic Field

Travis W. Walker, Ph.D.
Oregon State University

Abstract: Anisotropic structures are found in many natural materials, such as teeth, mollusk shells, and plants. Researchers are committed to developing new materials that contain aligned particles. These materials can exhibit enhanced magnetic, mechanical, optical, and diffusive properties. The anisotropic properties of spheroids allow them to be aligned by an external driving torque. In this study, a rotating magnetic field is used to align magnetic oblate spheroids, creating a planar anisotropy where all particles are aligned into the plane of the field. We developed an analytic solution describing the alignment dynamics that covers the entire possible frequency range of a rotating magnetic field. We also developed asymptotic solutions at both the high-frequency limit and the low-frequency limit of the rotating field, which can be applied in industrial implementations. The analytics are confirmed via finite difference numerics. Detailed single-particle experiments are shown to be in agreement with the model.

Our ongoing work investigates the dynamics of many-particle systems. If the magnetic field persists after the particles align, chaining of particles is observed. Since the induced magnetic particles can generate magnetic fields of their own, particles can either attract or repulse others, depending on their relative positions. The induced dipoles can be assumed to be identical, and the magnetic interacting force can be assumed to be pairwise. The lubrication force that prevents particles from colliding or overlapping can be included in the hydrodynamics for near-field interaction. With the knowledge of the dynamics, we strive to create novel metamaterial composites with anisotropic structures. Our current focus uses a three-axis electromagnetic coil system to align particles to the desired orientation, before the particles are frozen inside a solid matrix (e.g., using a UV-curable polymer solution).

Biography: Dr. Travis Walker is an Assistant Professor in the School of Chemical, Biological, and Environmental Engineering at Oregon State University. In 2008, he graduated from South Dakota School of Mines and Technology with a BS is Chemical Engineering and a BS in Applied and Computational Mathematics. He then completed his MS and PhD degrees in Chemical Engineering at Stanford University in 2010 and 2013 respectively. Travis is a transport phenomena engineer who works to develop both theoretical and experimental methods that can be applied to the study of complex fluids, soft solids, miscible fluid interactions, and biological systems. He is interested in multiphase systems and the mechanics of materials. His ultimate goal is to provide new detailed insights into the macroscopic characteristics of materials and processes through an in-depth understanding of the fundamental physics active at the molecular level. Currently, the Walker Group has projects in aligning magnetic particles with advanced magnetic fields for engineering nanocomposite metamaterials, advanced extensional rheological characterizing of weakly viscoelastic fluids, implementing highly elastic fluids in CMP processing for enhanced particle removal, and measuring transient rheology of biofilm formation grown in various media. They also have new work starting in measuring the rheological dynamics of blood coagulation and cervical mucus. Their past work includes modeling the interfacial stress rheometer (ISR), investigating the drop impact of miscible liquids, and experimentally tracking the two-fluid hydraulic jump.

For additional information, please contact Prof Ugur Pasaogullari or
Elizabeth Dracobly at (860) 486-4001