

144h Velocity and Torque Measurements of Ferrofluid in Spin-up Flow

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The rotational flow induced in a ferrofluid by a uniform rotating magnetic field (commonly referred to as spin-up flow) was first described by Moskowitz and Rosensweig in 1967. Several approximations to the solution for the velocity profile and flow direction have been proposed and compared to the limited experimental data. Rosensweig showed that the surface flow is counterclockwise to the applied field rotation direction, in disagreement with the situation predicted from considering the ferrohydrodynamic equations. Rosensweig's measurements were made at the ferrofluid interface, as measurements of the bulk velocity profile have been lacking because the opaque nature of the ferrofluid precludes usage of standard flow visualization methods. The principal objective of our project is the characterization of the magnetomechanical coupling occurring in ferrofluids in rotating magnetic fields. Using ultrasonic Doppler velocimetry, we have obtained the first direct measurements of the azimuthal and axial velocity components during spin-up flow of a water based ferrofluid for magnetic field rotation frequencies of 50 to 100 Hz and amplitudes up to 144 Gauss rms. These experiments show that the direction of flow in the bulk of the fluid is the same as the direction of magnetic field rotation, whereas the surface flow is opposite. A rotational viscometer was also used to measure the torque required to restrain the cylindrical container with the ferrofluid, as a function of magnetic field amplitude and frequency, as well as ferrofluid physical properties and geometric aspect ratios. The velocity and torque measurements will be compared to the predictions of an asymptotic solution of the coupled ferrohydrodynamic problem and to a numerical solution applicable beyond the range of the asymptotic analysis.