FM4L_12662

XXI International Congress of Theoretical and Applied Mechanics
Warsaw, Poland, August 15–21, 2004

Ferrohydrodynamic Hele-Shaw Cell Flows and Instabilities with Simultaneous DC Axial and In-Plane Rotating Magnetic Fields

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New flows and instabilities are presented for a ferrofluid drop contained in glass Hele-Shaw cells with simultaneously applied in-plane clockwise rotating and DC axial uniform magnetic fields. When a ferrofluid drop is stressed by a uniform DC axial magnetic field, up to $\sim$250 Gauss in 0.9–1.4 mm gap Hele-Shaw cells, the drop forms a labyrinth pattern. With subsequent application of an in-plane uniform rotating magnetic field, up to $\sim$100 Gauss rms at frequency 20–40 Hz, smooth spirals form from viscous shear due to ferrofluid flow. If the rotating magnetic field is applied first, the drop is held together without a labyrinth. Gradual increase of the DC axial magnetic field, to a critical magnetic field value, results in an abrupt phase transformation from a large drop to many small discrete droplets. A preliminary minimum magnetization and surface energy analysis is presented to model the phase transformation.

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