Abstract

Magnetic drug targeting (MDT) offers a more targeted form of chemotherapy by binding drugs onto magnetic nanoparticles and steering them towards tumor regions with an external magnetic field. While initial clinical trials on humans and animals show reasonable efficacy for safely treating shallow and easily accessible targets, tumors that reside relatively deep in the body still pose a serious challenge. These challenges demand further investigation into how ferrofluid behaves in blood flow as well as in complicated magnetic control systems that can more aptly control ferrofluid from a wider range of distances.

In this thesis, a 3-dimensional direct numerical simulation of a magnetic fluid droplet suspended in water is developed. This simulation utilizes the Parallel Robust Interface Simulator (Paris), a parallel finite volume code that solves immiscible multi-phase flows with a Volume-of-Fluid (VOF) approach for interface advection and a height function method for interfacial curvature and normal vector computations. Mag-Paris, the modified version of Paris which includes the implementation of magnetic forces, is tested with two simple test cases: an applied uniform field and an applied linear magnetic field gradient. Through the test cases, the ability to move and deform a magnetic fluid droplet was validated based on both theory and qualitative criteria.

Additionally, a new experimental testbed for quantifying the volume loss of a magnetically trapped ferrofluid region under pulsatile flow in a model blood vessel is developed. A miscible ferrofluid region is held in place by a permanent magnet and subject to pulsatile flow at various Reynolds and Womersley numbers. A novel photographic method is used to quantify the instantaneous volume loss of the aggregate and Particle Image Velocimetry (PIV) is used to visualize the surrounding flow behavior that causes such loss.