Magnetic Fields for Cell Cultures Suspended in a Perturbed Diamagnetic Medium

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Abstract

The effect of static magnetic fields (SMF) on living matter such cell cultures and living organisms has been a promising research field. Efforts have been given in the understanding of the underlying mechanisms and interaction between the field and the biological system with its biochemistry. In this work, we study cell cultures subjected to SMF, both experimentally by implementing different set ups in the laboratory as well as performing experimental measurements, and numerically by modeling with COMSOL Multiphysics®. We created a 3D geometry corresponding to the experiment in the lab, which consists of a ring of permanent magnets surrounding a glass flask filled with a medium for the cell culture. A thin pipe enters the top of the flask to inject bubbles in the liquid, which due to buoyancy results in circulation of the fluid inside the flask. We used geometrical parameters of the real flask and the actual material properties. To specify magnetization vector for each magnet, we performed experimental measurements of the field by using a Hall sensor. Based on the exact-analytical solution of the field for a single magnet, we determined the remnant flux density to be specified for an individual-specific magnet belonging to a ring of each experimental replicate. The measurements of the field allowed for comparing the first computations of the magnetic field for the geometry and material properties with the measurements of the field near the surface of the magnets. It was found that the relative error for the magnetic flux density norm was below 3%. The next step after geometry and material definition, parameters determination and error estimation was to perform different computations with the following goals. (1) Solving Maxwell equations of magnetostatics with the Magnetic Fields No Currents interface to determine the magnetic flux density and the force per unit volume due to the field gradient for the geometry and material properties. (2) Solving Navier-Stokes equations with the Bubbly Flow interface. (3) Recalculating the velocity field with progressive increased complexity approaching the real geometry as much as possible. At this stage, we completed the experimental measurements of the field as well as the computation and analysis of steps 1 in 3D and 2 for laminar und turbulent flow in 2D. The geometry of the inflow of air was modified to allow for numerical convergence. Using the Particle Tracing Interface, movement of cells was visualized. Solutions of the magnetic field allow for calculating the pressure on a generic cell membrane due to the magnetic field gradient. Step 3 and the relationship with the measurements of cell response are in progress. Future work based on the modeling results can focus on the influence of magnetic field on

ion transport in biological cells.

Figures used in the abstract

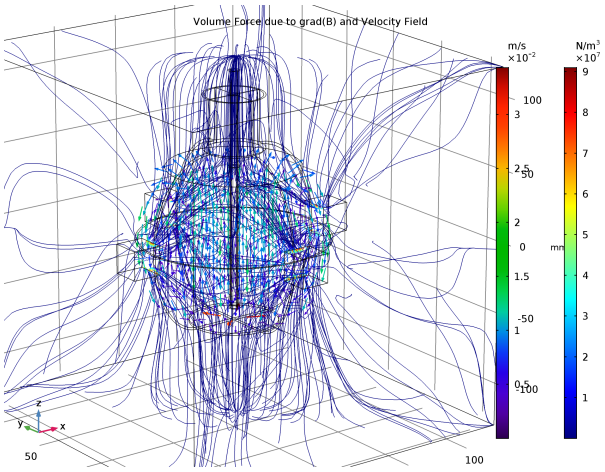

Figure 1: Model of a glass flask surrounded by an array of neodymium permanent magnets. The flask is filled with a fluid or medium for a cell culture. A thin pipe enters the top through which there is an inflow of air to inject bubbles, which due to buoyancy there is circulation of the fluid inside the flask. The plot shows the volumetric force due to the gradient of the magnetic flux density (streamlines) as a solution of Maxwell equations for magnetostatics. In addition, the plot depicts the velocity field (arrows) coming from the solution of a simplified version of Navier-Stokes equations (creeping flow). Next step in the modeling and simulation is to solve for the velocity field for the realistic case. The goal of this investigation is to determine and visualize the conditions which will affect cell cultures in terms of growing and biochemical response.