Particle Steering In Magnetic Drug Targeting: A Simple Comsol Model

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Abstract

Magnetic nanoparticles offer numerous applications in medical diagnosis and therapy. One example of a possible application is the so-called Magnetic Drug Targeting (MDT), which is a therapeutic approach in cancer therapy. Thereby, the cancer drug is bounded to magnetic nanoparticles, which can be pulled into the tumorous tissue by an external magnetic field. This therapeutic approach enables a local chemotherapeutic treatment, which increases the dosage of the drug in the tumorous tissue, while side-effects for the patients get reduced.
In MDT, the magnetic nanoparticles are injected into the aorta in the vicinity of the tumor. The magnetic force due to the external magnetic field which distracts the particles is called magnetophoresis force. This force depends on several parameters, like the magnitude or susceptibility of the magnetic nanoparticles, the velocity or the density of the volume flow, or the gradient of the external applied magnetic flux density. To consider all the mentioned parameters, a simulation setup was implemented in COMSOL Multiphysics®.
Since the flow within an aorta can be assumed as laminar, the Laminar Flow (spf) interface from the Subsurface Flow Module with a stationary study was applied. Furthermore, to include the magnetic particles in the flow, the Particle Tracing for Fluid Flow (fpt) interface from the Particle Tracing Module with a time-dependent study was set up. To accomplish the movement of the particles, the velocity profile from the stationary study, had to be used as a hydrodynamic drag force. Therefore, the whole simulation consists of two studies. A 2D geometry was chosen, keeping the computational effort low.
To examine the laminar flow at a branch, a symmetrical Y-shaped geometry was accomplished in which the fluid moved from the left to the right side (Fig 1). As expected, the velocity in the split paths was nearly halved and no turbulence was observed. Moreover, the mesh size was optimized by reducing it, until the velocity profile got parabolic (Fig. 2). Subsequently, the particles were included and their density and magnitude were specified. As aforementioned, the movement of the particles was implemented by using a time-dependent study considering the parabolic velocity profile. At every time step, one particle was released and its trajectory was studied via an animation video.
Firstly, the particle movement without any external force was observed. As expected, the particles divided into the branches. Next, a gravitational force was applied. For the presented setup the gravitational force pulled the particles to the bottom branch. Additionally, a magnetophoresis force was considered short before the intersection. Since the magnetophoresis force depends on the gradient of the magnetic field, the external magnetic field H was chosen to Hy = H0*(y*c[1/m]). The constant c was observed in a parameter sweep. The magnetophoresis force was able to pull the particles in the upper branch (Fig. 3). With the observed simulation results, a magnet for steering magnetic particles through the cardiovascular system in the tumor, will be designed in future studies.

Figures used in the abstract

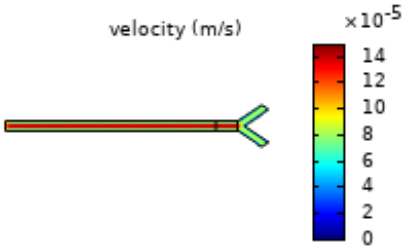

Figure 1 : Velocity profile for the observed geometry. The fluid streams from the left to the right side.

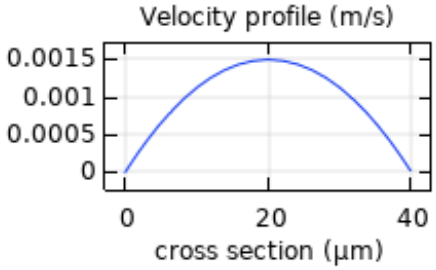

Figure 2 : Parabolic shape of the velocity profile in the cross-section before the intersection.

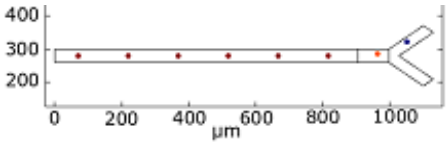

Figure 3 : Particle trajectory: The particles are pulled in the upper branch by the magnetophoresis force.