3D-Modelling of Magnetophoretic Separation of Superparamagnetic Dispersions Using COMSOL Multiphysics® Particle Tracing Module

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Introduction: Magnetophoresis is a process of great interest for novel applications based on magnetic nanoparticles and colloids. Environmental applications and biomedical applications are just a few of the numerous technological areas which exploit the effect of magnetophoresis. In general, there are two main different types of magnetophoresis processes: cooperative magnetophoresis, a fast process enhanced by particle-particle interactions and noncooperative magnetophoresis which is driven by the motion of independent particles in magnetic gradient fields [1]. Using COMSOL Multiphysics we have created a 3D model which enables us to analyze noncooperative magnetophoretic separation of superparamagnetic dispersions.

Computational Methods: For our magnetophoretic separation simulations we have modeled a precision magnetophoresis system from SEPMAG [2], specifically the SEPMAG LAB 1 x 25 ml 2042 (Figure 1). Furthermore, we have used the „Particle Tracing“ physics interface of COMSOL Multiphysics. The magnetic force exerted by the external magnetic field *H* on a particle is given by

$$F = 2\pi {r_p}^3 \mu_o \mu_{r,f} \frac{\mu_{r,p}-\mu_{r,f}}{\mu_{r,p}+2\mu_{r,p}} \nabla H^2 \qquad (1)$$

where r_p is the particle radius, μ_0 is the permeability of the free space, H is the applied magnetic field at the location of the particle, $\mu_{r,f}$ is the relative permeability of the fluid and $\mu_{r,p}$ is the relative permeability of the particle. For the nanomagnetic particles we have assumed a particle radius of 6 nm and a relative permeability of 4. The liquid in which the nanoparticles are immersed is characterized by a relative permeability of 1.

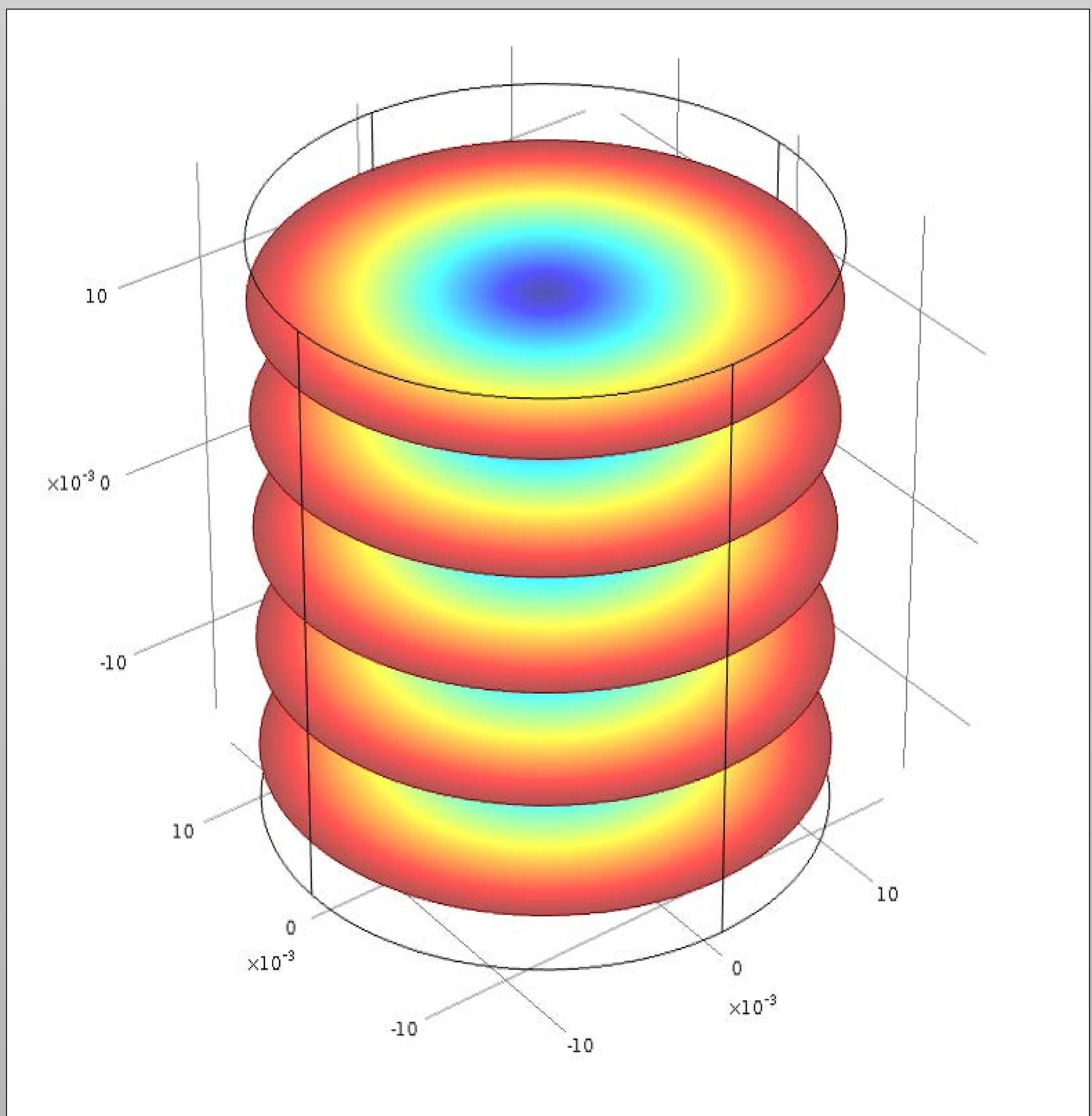

Figure 1. Simulation model of a SEPMAG LAB 1x25 ml 2042 experimental set-up. The geometry of the separator is a cylinder (radius L = 1.5 cm). As shown in color coding a static magnetic field is applied which increases linearly from zero in the center to a maximum value at the walls.

Results: We have performed transient simulations over a time interval of 2·10^6 seconds. As one can see in figure 2 initially 10000 nanomagnetic particles are evenly distributed in the liquid. As soon as a magnetic field gradient of 60 T/m is applied the particles start moving towards the walls of the cavity and eventually vanish from the cavity as set by the boundary condition to “disappear”. For a quantitative analysis of the kinetics we have monitored the fraction of particles that remain in the liquid after a certain time. Figure 3 shows the results. The calculations required only 127 seconds on a quad-core Intel Core i7-2670QM processor.

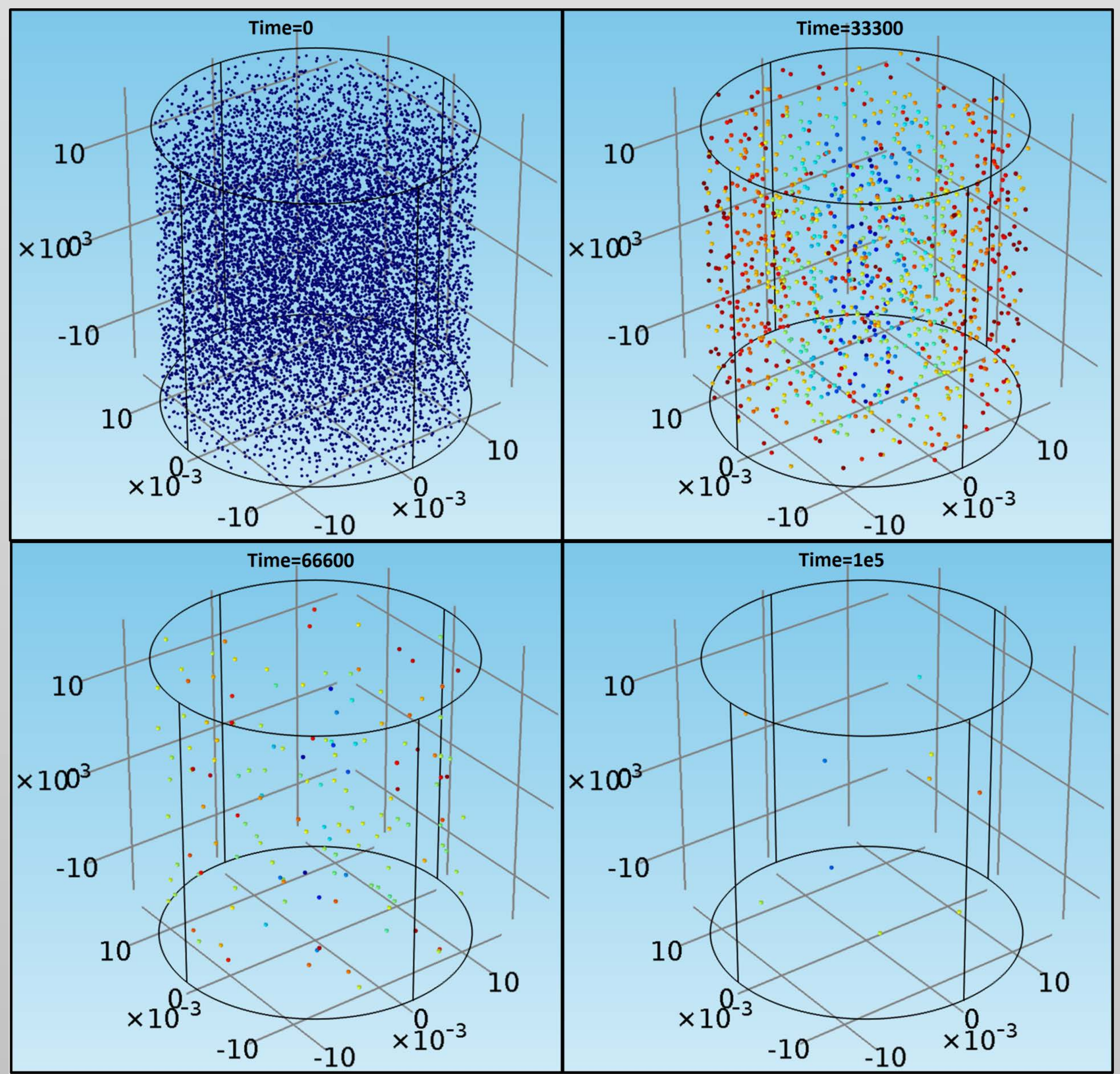

Figure 2. Snapshots of our simulations of the magnetophoretic separation process at different times.

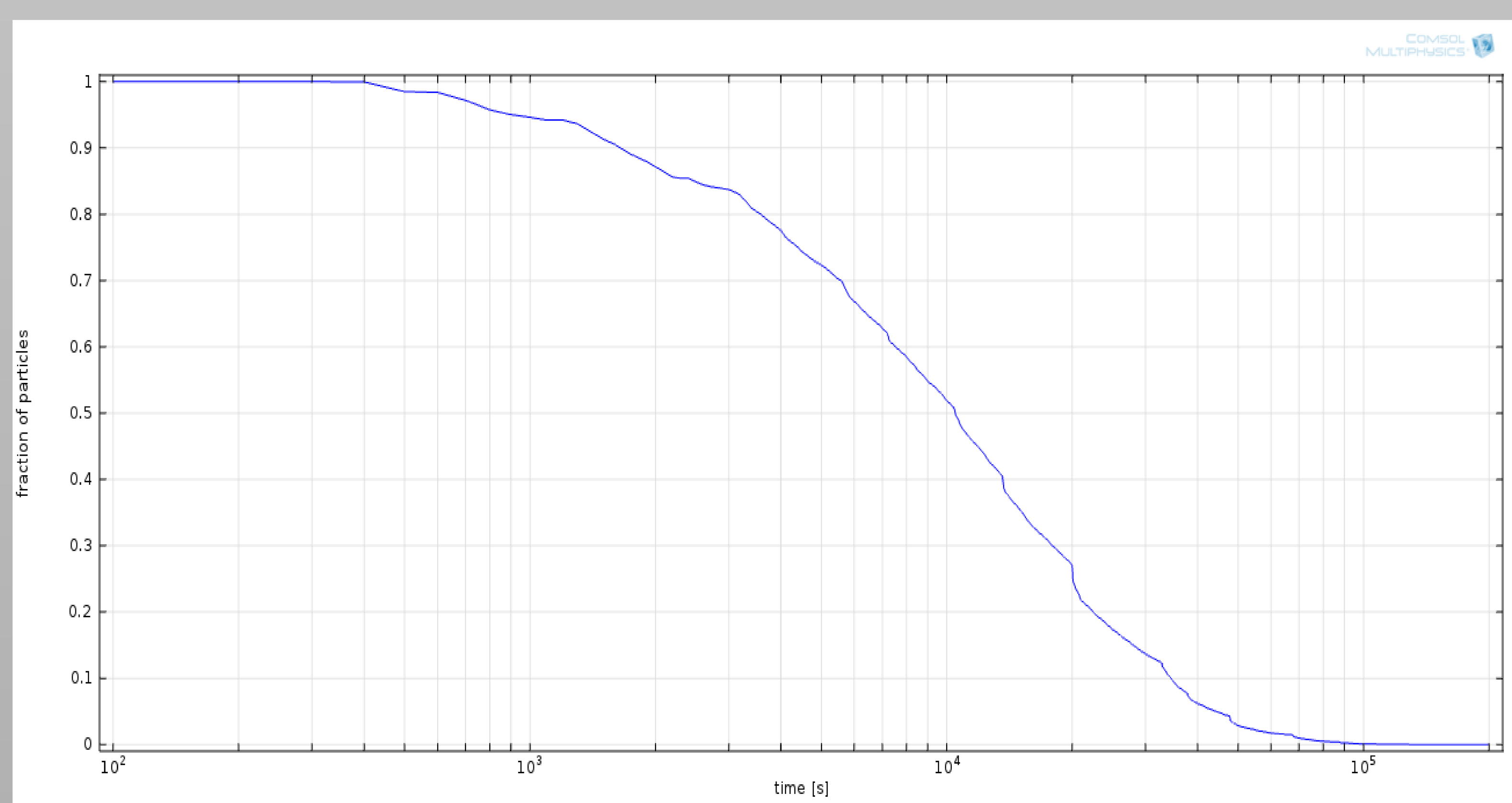

Figure 3. Fraction of particles remaining in the liquid as a function of time.

Conclusions: We have shown that COMSOL Multiphysics’ Particle Tracing Module can be used to study noncooperative magnetophoretic separation of superparamagnetic dispersions. We currently investigate the possibility to include particle-particle interactions.

References:

[1] J.S. Andreu *et al.*, “Simple analytical model for the magnetophoretic separation of superparamagnetic dispersions in a uniform magnetic gradient”, Phys. Rev. E **84**, 021402 (2011)

[2] SEPMAG Technologies [http://sepmag.eu]