WEEK 6

Article: Gervasoni *et.al.*, A Human-Scale Clinically Ready Electromagnetic Navigation System for Magnetically Responsive Biomaterials and Medical Devices, *Advanced Materials*, 2024.

QUESTIONS 6a

1. The article mentions a magnetic workspace with field strength ranging from 10 to 30 mT in various directions. How is the “magnetic feasible workspace” calculated and why is directional uniformity important for clinical applications? Navion’s electromagnets use laminated silicon steel cores. Why is this material preferred over solid ferromagnetic cores in this application, and how does lamination impact the dynamic response of the field during time-varying actuation?

2. In Figure 3, the new winding technique is highlighted, showing the creation of cooling channels within the winding pack. How does this winding strategy improve thermal management compared to traditional methods, and what impact does the reduced steady-state temperature have on the maximum allowable current and magnetic field strength? The authors claimed that their goal was to increase the current flowing through the windings to increase the magnetic field intensity, following Biot-Savart law. The electromagnets are then claimed to be winded using a new technique, lowering the temperature for the same current compared to a traditional wound electromagnet. For the same amount of current, nominally 70A, the magnetic field difference on the surface of the electromagnets is said to be 0.9%, what causes such a difference? How does this difference scales with the current provided to the electromagnets?

3. In Video S5, the magnetic microparticle swarm loses cohesion during navigation, particularly at bifurcations. What engineering strategies could mitigate swarm dispersion in such scenarios? The particle swarm navigation results show that above a 3 Hz rotation frequency, the swarm becomes uncontrollable, and cohesion does not improve with increasing field magnitude beyond 5 mT. What are the fundamental limiting factors that determine this frequency threshold for swarm stability? What physical or fluidic mechanisms limit the maximum controllable frequency in such a system? Particle swarm navigation, where linear structures form under a magnetic field, is described as a unique feature. How is this feature useful?

4. The article mentions that contact with the wall of the vascular model helps stabilize the locomotion of the ABF and prevents side drift during forward motion. Explain how exactly the wall constrains the ABF’s motion to enhance its stability. In a real biological environment, could this kind of wall-contact strategy be applied safely without risking damage to the vessel endothelium? Are there alternative methods to achieve similar stabilization without relying on physical contact with the vessel wall? For a device such as the helical ABF, how can one derive a full analytical model coupling magnetic torque, viscous drag, and device geometry to predict translational velocity as a function of field amplitude and frequency? Can this be inverted to estimate material or shape properties from in situ motion data?

5. It is stated that the Ni-rich cylindrical device experiences wobbling under a 2 Hz rotating field, while the Co-rich counterparts remains stable at 1 Hz. This seems counterintuitive, as wobbling is often associated with high-frequency actuation where the device can no longer keep up with the rotating magnetic field. How do differences in material composition affect the stability of these devices at different field frequencies, and what magnetic or structural properties might explain this behavior?