Multiscale approach toward numerically modelling Soft magnetic composites

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Soft magnetic composites(SMCs) consist of a ferromagnetic powder, with particle sizes which range from 1 to 100 μm, which is coated by an electrical insulating material. The goal of this work is to accurately model these materials through numerical simulations and to help better understand them in order to improve the power-loss. The power which is lost during one cycle is made up of different contributions

$$W(f) = W_{\text{hyst}} + W_{\text{eddy}}(f) + W_{\text{res}}(f) \tag{1}$$

where W_{hyst} is the static hysteresis loss, W_{eddy} is the classic eddy current loss and W_{res} is the residual loss.

To accurately calculate these losses we will utilize micromagnetic numerical simulations and Maxwell solvers. The micromagnetic model can resolve the structure of magnetic domains and domain walls, this yields accurate static hysteresis computation, with which W_{hyst} can be predicted. Additionally it is possible to resolve the time dependent magnetic switching processes and domain-wall movements. This is crucial due to the fact that applied frequencies of the external field are in the high-frequency regime($\sim$ 1MHz), where the residual loss W_{res} becomes relevant. A part of the residual losses originate in the increase of the hysteresis, which results from the fact that the magnetization lags behind the applied magnetic field due to its high frequency. It is also required to solve Maxwells equations in order to calculate the induced current densities responsible for W_{eddy}.

Periodic boundary conditions(PBCs) are vital for simulating SMCs, due to the fact that the magnetic samples are very large(mm-range), however only a small part of the structure can be calculated. Simply truncating the magnetic domain would lead to a strong shape anisotropy and therefore to a much smaller permeability. To implement the PBCs we were inspired by [1,2] for the micromagnetic simulation and the Maxwell solver respectively. Figure 1 shows a schematic which is supposed to convey how the simulation cell relates to the actual torus core.

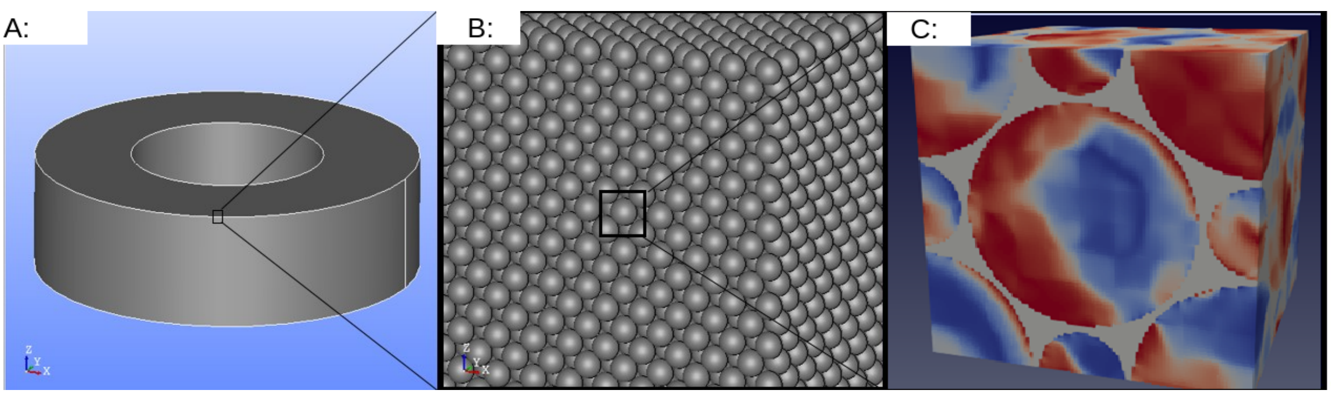

Figure 1: A schematic of the simulation cell and how it relates to the lattice and the magnetic core A: A toroidal magnetic core, as it would be produced from SMCs. B: Zooming into the core reveals, that the magnetic particles form a ffc-lattice, where the particles are not exchanged coupled but have an interparticle layer between them. C: The simulation cell is the primitive cell of the ffc-lattice, with the final result being the magnetization configuration.

References

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