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Durable Coils for Concurrent TMS-fMRI Applications

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1 Extended Abstract

Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation technique that interleaved with functional magnetic resonance imaging (fMRI) provides a powerfull tool to evaluate brain activity [1]. However, TMS-fMRI is still not widely employed due to its difficult application: the high magnetic fields present inside MRI scanner can interact with the current pulses in the TMS coil, resulting in extremely high Lorentz forces that may lead to mechanical stresses capable of producing failure and even compromising patient safety. Therefore, concurrent TMS-fMRI application would be enhanced by developing new mechanically stable coils capable of safely operating without breakdown. Recently, a new group of TMS coil design methods based on the incorporation of the stream function of a quasi-static surface current density within an inverse boundary element method (IBEM) has emerged. They allow coil generation of arbitrary geometry subjected to different performance requirements (minimize inductance or Lorentz forces, for instance) [2]. There exist preliminary efforts to design coils for concurrent TMS-fMRI applications in small animals [3], where it has been highlighted the need of controlling the elevated magnetic forces experienced by the TMS coil.

Here, we used the stream function IBEM to produce durable TMS coils capable of working inside a small animal MRI scanners with an improved mechanical behaviour. Three different TMS coils that generate equally focus stimuli were produced. Firstly, for sake of reference, a conventional minimum inductance (Coil 1) was designed, Fig. 1a. Secondly, minimum current density, Fig. 1b, and minimum maximum Lorentz force distribution, Fig. 1c, coils (Coils 2 and 3, respectively) were obtained to study the improvement of the coil durability. The performance of these coils was numerically evaluated using finite element method simulations COMSOL. The maximum von Mises stress of each coil was evaluated when operating within a 9.4 T MRI scanner, Fig. 1c. The obtained results indicate that minimizing the maximum Lorentz force or the current density are strategies to produce coils with significant lower von Mises stress distribution than the reference minimum energy coil. The proposed approach for coil design can be remarkably useful to overcome current limitations for interleaved TMS-fMRI.

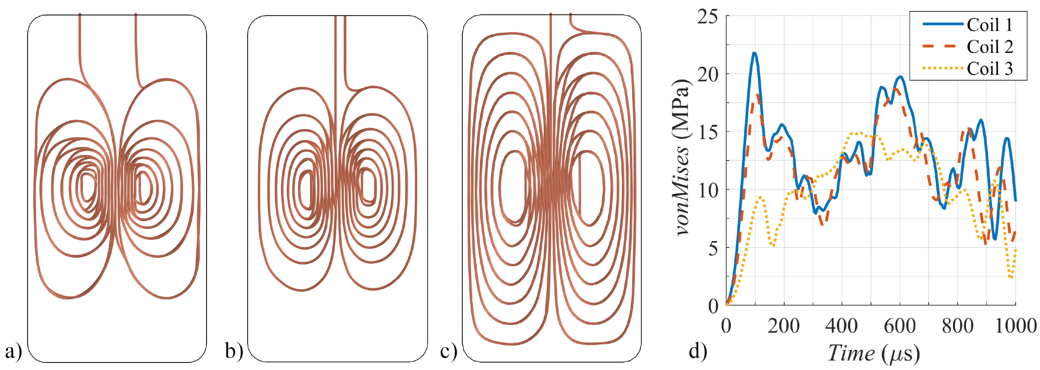

Figure 1. a) Coil 1, b) Coil 2, c) Coil 3 and d) maximum von Mises stress.

References

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