The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Direct gradient-based design of non-axisymmetric coil systems with excellent charged particle confinement properties

Andrew Giuliani[1], Florian Wechsung[1], Georg Stadler[1], Antoine Cerfon [1] and Matt Landreman [2]

[1] Courant Institute of Mathematical Sciences, New York University, 251 Mercer St, New York NY 10012, giuliani@cims.nyu.edu, wechsung@nyu.edu, stadler@cims.nyu.edu, cerfon@cims.nyu.edu, https://math.nyu.edu/dynamic/

[2] Institute for Research in Electronics and Applied Physics, University of Maryland, College Park MD 20742, United States of America, mattland@umd.edu, https://terpconnect.umd.edu/ mattland/

Keywords: *Magnetic confinement fusion, coil design, particle confinement, gradient based optimization, adjoint method*

Non-axisymmetric coil systems can produce steady-state magnetic fields with excellent particle confinement properties. They are therefore promising candidates for magnetic confinement fusion reactors, which would not require the generation of a strong plasma current to achieve high performance, and would be inherently steady-state.

However, finding coil systems with these desirable properties is a difficult matter. The number of degrees of freedom of the optimization problem is large (of the order of 50 – 100 at least), and most coil systems will lead to very poor confinement properties. The fusion community has historically approached this complicated question by splitting the problem in two stages: in the first stage, one searches for a physically desirable magnetic configuration, and in the second stage, one designs coils which approximately produce this magnetic field. While successful, a crucial limitation of that approach is its decoupling of the physics and engineering objectives, and therefore its tendency to lead to coils which are expensive to manufacture and position.

In order to address this issue, we present a new single-stage paradigm for coil design, in which one directly optimizes the coils to achieve high physics performance [1]. Our objective function combines physics targets and engineering constraints, which allows a more thorough exploration of the trade-offs between confinement and engineering constraints. Furthermore, we rely on an adjoint method to compute the analytical gradient of the objective, leading to efficient gradient-based optimization with good convergence properties. We highlight several coil systems we obtained with this new approach and demonstrate their good physics performance.

REFERENCES

[1] A. Giuliani, F. Wechsung, A. Cerfon, G. Stadler, and M. Landreman, "Single-stage gradient-based stellarator coil design: Optimization for near-axis quasi-symmetry", *submitted to the Journal of Computational Physics*, arXiv:2010.02033