A modular workflow for the optimisation and simulation of tokamak plasma in equilibrium

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The objective of this work is to aid in the design of next-generation magnetically confined reactors, whose success depends on stable and efficient plasma confinement while satisfying a variety of mechanical, stability, and efficiency constraints. Currently, various reactor design frameworks use numerical optimisation to determine viable values for parameters such as the positions of the poloidal and toroidal coils, the geometry of the reactor, and the divertor design [1]. This work presents and validates a fast optimisation workflow that explores the hardware component parameter space of a tokamak for an axisymmetric plasma in equilibrium. The modular workflow is subdivided into two substeps: First, parameter optimisation is coupled to a free-boundary Grad-Shafranov solver to generate optimised plasma configurations on a Cartesian grid. Second, due to seamless integration with extended MHD codes [2], the plasma configurations are evolved in time using finite volume schemes to perform stability analysis for quick assessment of design viability. In the current workflow version, the plasma is assessed for vertical stability by running an MHD simulation under perturbation. To show a full run of the workflow, results from case studies for a range of optimisation parameters will be presented.

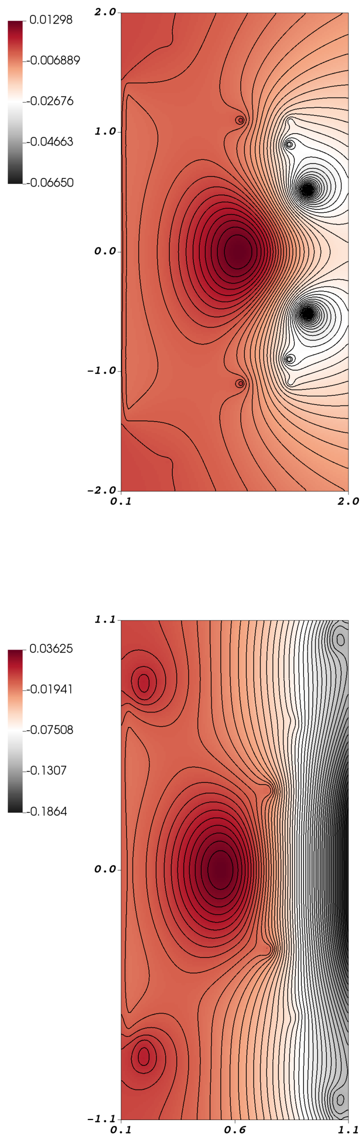

Figure 1: *Example of optimised Ψ profiles for MAST (top) and ST40 (bottom) tokamak.*

References

[1] Coleman, M. & McIntosh, S. BLUEPRINT: a novel approach to fusion reactor design. *Fusion Engineering And Design*. **139** pp. 26-38 (2019)

[2] Dematté, R., Farmakalides, A., Millmore, S. & Nikiforakis, N. An all Mach number scheme for visco-resistive magnetically-dominated MHD flows. *Journal Of Computational Physics*. **514** pp. 113229 (2024)