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Advanced Equilibrium Models for Anisotropy, Flow and Chaotic Fields

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The purpose of this topical review [1] is to present the state of the art in diagnosis, interpretation and modelling of waves, particles and the magnetic configuration in fusion plasmas. A focus of the review, detailed in this abstract, is the physics and validation of magnetic configuration, which underpins all confinement, stability and transport physics.
As the effect of fast particles become important enough to modify the macroscopic variables of the plasma, the macroscopic fluid equations for equilibrium need to be modified to encapsulate the effects of pressure anisotropy, particle and heat flow. A recent advance has been the development of EFIT TENSOR [2], to solve tokamak equilibrium problem with toroidal flow and anisotropy. EFIT TENSOR solves MHD equations with a bi-Maxwellian closure model neglecting poloidal rotation. The code is a modification of the existing force balance solver EFIT++. We show that for sufficiently anisotropic plasma, the parallel transport model can be compared against measured current profiles, providing a novel measure of heat flow from equilibrium constraints. A companion code, HELENA-ATF has been written to enable physics studies with anisotropy and flow, and provide a finely converged equilibrium solution for ongoing stability physics studies. We have identified the different components of the toroidal current, and examined the impact of the widely applied p*approximation to anisotropy. This study shows that an isotropic reconstruction can infer a correct p*, only by getting an incorrect toroidal flux function.
We also report on progress in the modelling of fully 3D (non toroidally axis-symmetric) fields with a new physics model, Multiple Relaxed region MHD, a generalisation of Taylor's theory, in which the plasma is partitioned into a finite number of nested regions that independently undergo Taylor relaxation. This approach has had recent success in modelling the spontaneous formation of single helical axis and double helical axis states in the reverse field pinch [3].
Finally, we report on developments of a force balance validation framework based on Bayesian inference [4].

[1] M. J. Hole and M. Fitzgerald, accepted, Plasma Phys. Con. Fus.
[2] M. Fitzgerald et al , Nuc. Fus. 53, 113040, 2013
[3] Dennis et al, Phys. Rev. Lett. 111, 055003, 2013
[4] G T von Nessi, et al J. Phys. A: Math. Theor. 46, 185501, 2013

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