Numerical solutions of resistive finite-pressure magnetohydrodynamic equilibria for quasi-axisymmetric stellarator CFQS and non-axisymmetric toroidal plasmas

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A hybrid spectral/finite-element code, NTEC, is developed to numerically solve the resistive finite-pressure magnetohydrodynamic equilibria in non-axisymmetric toroidal systems. The adopted approach integrates a hyperbolic parallel damping equation for pressure updating, along with a dynamic resistive relaxation for the magnetic field. A pseudo flux mapping is employed to relate the axisymmetric computational domain to the physical domain, and an isoparametric C1-continuous triangular element is utilized to discretize the poloidal plane, which is complemented with a Fourier decomposition in the toroidal direction. For the calculation results, we first benchmark the NTEC solutions with a fixed-plasma-boundary classic stellarator equilibrium from SIESTA and the free-plasma-boundary CFQS equilibria from HINT [1, 2]. Figure 1 shows the Poincare plots of the equilibria calculated using NTEC with different artificial resistivities. We then show the NTEC results in the standard CFQS equilibria, the TCV-like tokamak helical-core equilibria, and the KTX-like RFP quasi-single-helicity equilibria. Ongoing numerical updates are dedicated to achieving more precise MHD equilibria. A recent NTEC application is that of evaluating the robustness and resilience of good flux surfaces in high β free-plasma-boundary equilibria within standard and non-standard CFQS configurations modulated by additional toroidal/poloidal field coils or other externally driven currents. Our study could provide a useful indication for further high β CFQS experiments where the confinement may degrade due to the finite-pressure-relevant stochastization of the nested flux surfaces.

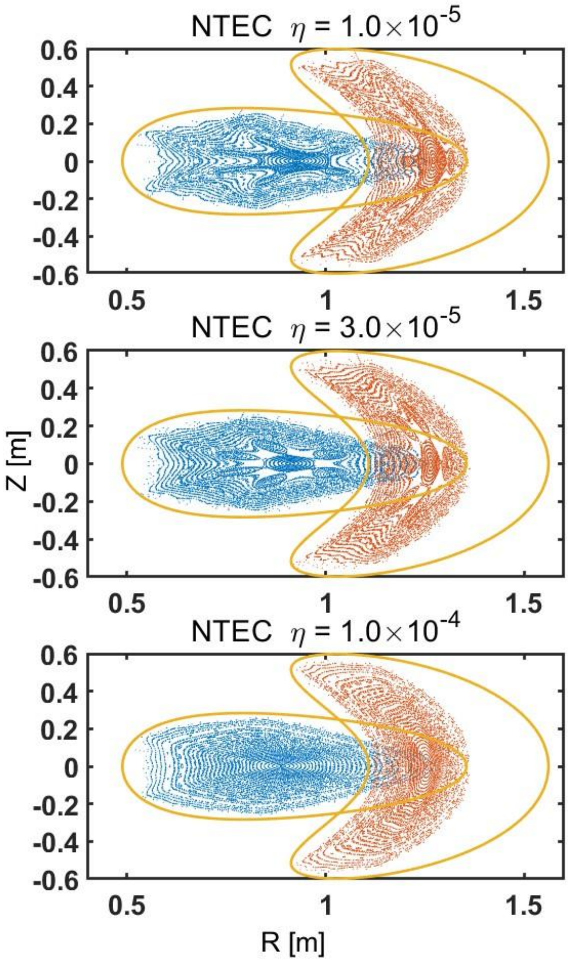

Figure 1. Poincare plots of equilibria at two cross sections $\boldsymbol{\varphi} = \mathbf{0}$ (red), $\boldsymbol{\pi}/\mathbf{2}$ (blue)

References

[1] S. P. Hirshman *et al*, Phys. Plasmas 18 (2011) 062504
[2] X. Wang *et al*, Nucl. Fusion 61 (2021) 036021