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Piecewise-Beltrami MHD equilibria[1]

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An algorithm for constructing 3-dimensional toroidal MHD equilibria that converged rapidly to arbitrary accuracy would be useful not only for design and experimental interpretation purposes but as a constructive solution to the fundamental mathematical existence problem [H. Grad, Phys. Fluids **10**, 137 (1967)]. A construction based on minimizing the pressure + magnetic energies cannot converge to arbitrary accuracy if ideal MHD constraints (frozen-in flux) are imposed everywhere because of the generic existence of islands and chaotic field line regions between invariant (KAM) tori. Instead we freeze the topology only on selected surfaces with irrational rotational transforms and, in between, impose only conservation of magnetic helicity, leading to piecewise-flat-pressure Beltrami ($\nabla \times \mathrm{B} = \mu \mathrm{B}$) equilibria. Little generality is lost, because, if KAM surfaces are of full measure a smooth pressure profile can be approximated with arbitrary accuracy by increasing the number of "barrier" surfaces. To this end, cylindrical stepped equilibria have been constructed semi-analytically, and the Beltrami field between two nested 3-D toroidal flux surfaces solved numerically using the method of lines.

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