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# Resistive stability of cylindrical MHD equilibria with radially localised pressure gradients

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To be physically observable, MHD equilibria must at least be ideally stable and sufficiently stable to fast growing resistive instabilities not to change significantly over some non-trivial timescale. The existence of at least one `nearby' ideal equilibrium, however, should be a prerequisite for any kind of physically meaningful resistive stability analysis.

Grad [1] argued that 3D MHD equilibria with continuous, non-uniform pressure could exist only if pressure gradients were avoided at every rational surface within the plasma volume. As the rationals are dense on the real line, the corresponding pressure profile, however, seemed unnatural or 'pathological'.

More recently, Bruno and Laurence [2] proved the existence of 3D MHD equilibria with non-uniform, but discontinuous, stepped pressure profiles. The pressure jumps occur at surfaces with highly irrational values of rotational transform and generate singular current sheets. If physically realisable, the dynamical mechanism of formation of these states remains to be understood.

We present a new cylindrical equilibrium model with alternating regions of constant and smoothly changing pressure, such that pressure gradient is *continuous*. An example of a 4-volume equilibrium with tokamak-like parameter values is shown in Figure 1.

Our equilibria have continuous total pressure (with no singular current sheets) but do have discontinuities in the parallel current density.

Our model allows for a direct comparison of the linear stability properties of smooth and non-smooth equilibria, since discontinuous pressure profiles are accessible as a configurational limit.

We examine how the resistive stability characteristics of the model change as we increase the localisation of pressure gradients at fixed radii and approach a discontinuous pressure profile in the zero-width limit. Equilibria with continuous pressure profiles are found to be unstable to moderate/high-m modes and tend towards ideal instability in some cases.

We propose that additional geometric degrees of freedom may increase the parameter space on which equilibria of our model are physically realisable, while preserving localisation of the pressure gradients. This is consistent with the possibility of realising, in practice, 3D MHD equilibria which support both nested flux surfaces and chaotic field regions.

References

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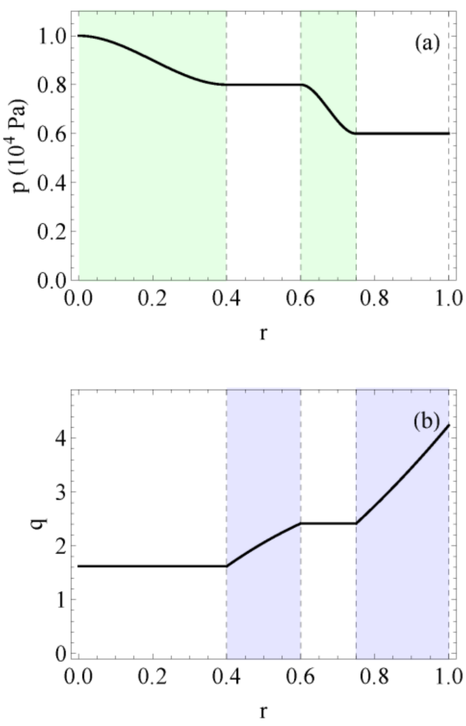


Figure: Example of a 4-volume equilibrium with tokamak-like parameter values. (a) Pressure profile with the non-zero pressure gradient regions shaded in green. (b) q-profile with the constant pressure regions shaded blue. Note that there are no resonances in the regions where $\nabla p \neq 0$ (green), since the q-profile is constant and an irrational value.