Up-down asymmetric tokamaks

J. Ball$^{1,2,3}$, F.I. Parra$^{2,3}$, S. Brunner$^1$, O. Sauter$^1$, M. Barnes$^{2,3}$, and M. Landreman$^4$

1 Swiss Plasma Center, École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland
2 Rudolf Peierls Centre for Theoretical Physics, Oxford University, Oxford, OX1 3NP, UK
3 CCFE, Culham Science Centre, Abingdon OX14 3DB, United Kingdom
4 Institute for Research in Electronics and Applied Physics, University of Maryland, College Park, Maryland 20742, USA

E-mail: Justin.Ball@epfl.ch

Toroidal plasma rotation can reduce turbulent energy transport and is commonly used in experiments to stabilize MHD instabilities. However, the conventional mechanisms that drive rotation are expected to diminish in future, larger devices (e.g. ITER or a reactor). This motivates up-down asymmetric flux surface shaping (i.e. shaping that is not symmetric about the midplane), which enables turbulence to redistribute momentum and create intrinsic rotation that scales well to large devices.

We start by considering all possible flux surface shapes, then use analytic MHD and gyrokinetic analysis to argue that those with both tilted elongation and tilted triangularity will drive the most rotation. Next, we explicitly calculate the turbulent transport in these configurations using nonlinear gyrokinetic simulations in order to find the optimal tilt angles to maximize rotation. These simulations indicate that up-down asymmetry can drive sufficiently fast rotation to stabilize MHD modes in an ITER-like device. Free boundary MHD equilibrium calculations demonstrate that these geometries can be created by the ITER and TCV shaping coils. Lastly, we compare our theoretical results to preliminary TCV experimental results.

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