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TH/7-1: Bifurcated Helical Core Equilibrium States in Tokamaks

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Tokamaks with weak to moderate reversed central magnetic shear in which the minimum of the inverse rotational transform q_min is in the neighbourhood of unity can trigger bifurcated MagnetoHydroDynamic (MHD) equilibrium states. In addition to the standard axisymmetric branch that can be obtained with standard Grad-Shafranov solvers, a novel branch with a three-dimensional (3D) helical core has been computed with the ANIMEC code [1], an anisotropic pressure extension of the VMEC code [2]. The solutions have imposed nested magnetic flux surfaces and are similar to saturated ideal internal kink modes.
The difference in energy between both possible branches is very small. Plasma elongation, current and beta enhance the susceptibility for bifurcations to occur. An initial value nonlinear ideal MHD evolution of the axisymmetric branch compares favourably with the helical core equilibrium structures calculated.
Peaked prescribed pressure profiles reproduce the 'snake' structures observed in many tokamaks which has led to a new explanation of the snake as a bifurcated helical equilibrium state that results from a saturated ideal internal kink in which pellets or impurities induce a hollow current profile. Snake equilibrium structures are computed in free boundary TCV tokamak simulations. Magnetic field ripple and resonant magnetic perturbations in MAST free boundary calculations do not alter the helical core deformation in a significant manner when q_min is near unity. These bifurcated solutions constitute a paradigm shift that motivates the application of tools developed for stellarator research in tokamak physics investigations. The examination of fast ion confinement in this class of equilibria is performed with the VENUS code [3] in which a coordinate independent noncanonical phase-space Lagrangian formulation of guiding centre drift orbit theory has been implemented. This work was supported in part by the Swiss National Science Foundation. We thank S.P. Hirshman for his invaluable contributions.

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[3] M. Jucker et al., Comput. Phys. Commun. 182 (2011) 912.

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