3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Nonlinear MHD modelling of helical self-organization in the RFP: effect of a realistic boundary and predictions for RFX-mod2

D. Bonfiglio[1], S. Cappello[1], L. Chacón[2], D. F. Escande[3,1], G. Di Giannatale[1], A. Kryzhanovskyy[1], M. Veranda[1], L. Marrelli[1], P. Zanca[1]

[1] Consorzio RFX (CNR, ENEA, INFN, Università di Padova, Acciaierie Venete SpA), Padova, Italy

[2] Los Alamos National Laboratory, Los Alamos, NM, USA

[3] Aix-Marseille Univ, CNRS, PIIM, Marseille, France

e-mail (speaker): daniele.bonfiglio@igi.cnr.it

The reversed-field pinch (RFP) is a configuration for the magnetic confinement of fusion plasmas, in which most of the toroidal field is generated by the plasma itself through a self-organized dynamo process, instead of being produced by external coils as in the tokamak. In the RFP, the nonlinear saturation of resistive-kink/tearing modes brings to the spontaneous emergence of helical states with improved confinement. This is observed both in nonlinear magnetohydrodynamics (MHD) modelling [1] and in RFP devices, especially at high current [2,3].

A major advance in the predictive capability of nonlinear MHD modelling for RFP plasmas was made possible by allowing helical perturbations of the radial magnetic field at the plasma boundary, which was suggested by analytical study of helical equilibrium equations [4].

A proper use of helical magnetic perturbations (MPs) in MHD modelling allowed to obtain experimental-like helical states [5] and to predict new helical states with chosen helical twist, successfully produced in RFX-mod [6]. The amplitude of the helical component and sawtooth frequency can be "tuned" as well, thus opening new routes to configuration optimization in several respects (ion heating, thermal and fast particle transport processes).

Here, we discuss the effect of a more realistic magnetic boundary recently included in the modelling: a thin resistive shell and a vacuum layer between the plasma and the ideal shell are considered, similarly as in [7,8].

We present two main results:

1) The decrease of secondary modes by increased shell-plasma proximity (see Figure 1). This is of interest in view of the upgraded RFX-mod2 device (starting operation in 2021), in which the shell-plasma proximity will change from b/a=1.11 to b/a=1.04 [9].

2) With a proper choice for the resistivity of the thin shell at the plasma boundary, helical states do emerge in a self-consistent way, as in the experiment, without the need to impose a fixed helical MP (see Figure 2).

Finally, further extensions of the realistic boundary implementation, in order to take into account a double resistive shell and an active feedback control system, will be discussed.

References

[1] S. Cappello and D.F. Escande, Phys. Rev. Lett **85**, 3838 (2000)

[2] R. Lorenzini, et al., Nature Physics **5**, 570 (2009)

[3] J.S. Sarff, et al., Nucl. Fusion **53**, 104017 (2013)

[4] D. Bonfiglio, D.F. Escande, P. Zanca and S. Cappello, Nucl. Fusion **51**, 063016 (2011)

[5] D. Bonfiglio, M. Veranda, S. Cappello, et al., Phys. Rev. Lett **111**, 085002 (2013)

[6] M. Veranda, D. Bonfiglio, S. Cappello, et al., Nucl. Fusion **57**, 116029 (2017)

[7] D. D. Schnack and S. Ortolani, Nucl. Fusion **30**, 277 (1990)

[8] R. Paccagnella, et al., Nucl. Fusion **47**, 990 (2007)

[9] L. Marrelli, R. Cavazzana, et al., Nucl. Fusion **59**, 076027 (2019)

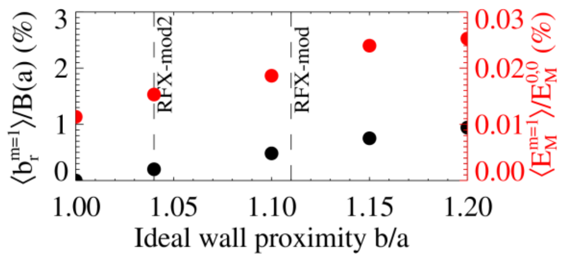

Figure 1. Time-averaged edge b_r amplitude (black) and total energy (red) of m=1 modes in nonlinear MHD simulations of the RFP with varying ideal wall proximity.

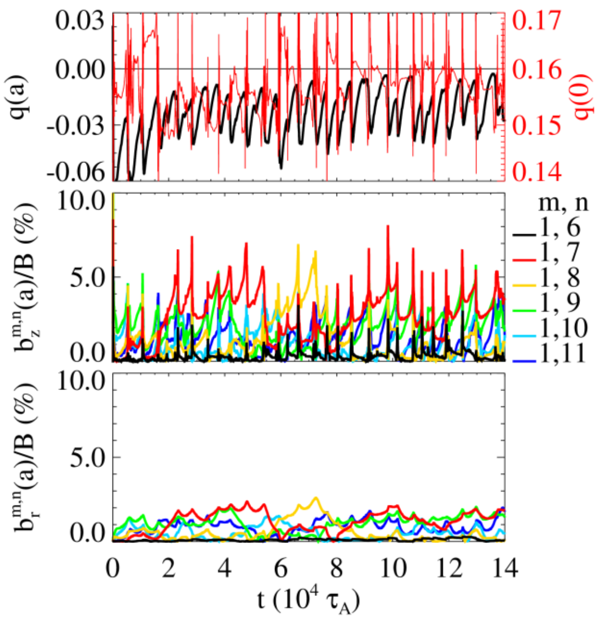

Figure 2. Nonlinear RFP simulation with resistive wall at r=a (with $\tau_W/\tau_A=10^4$) and ideal wall at b/a=1.2, showing the self-consistent emergence of the m=1, n=7 mode as in RFX-mod.