Contribution ID: **1047** Type: **Regular Poster**

Modeling of Basic Physics Issues in Toroidal Pinches and Tools for Performance Control

Friday 14 May 2021 12:10 (20 minutes)

In the last few years, nonlinear modelling and data analysis tools have improved in several respects, in particular to deal with physics issues encountered in magnetically confined toroidal pinches, such as the Reversed Field Pinch and Tokamak configurations. Benchmark-verified codes for 3D nonlinear MHD basic modelling find a reasonable comparison (validation) against a number of experimental observations in the RFX-mod and other devices. Here, we present recent results concerning helical self-organization processes, formation of internal transport barriers, temporary loss of operational point, relaxation-reconnection events, excitation of Alfvèn waves, and a possible fundamental mechanism for ion heating in plasmas. Starting from physics processes in Reversed Field Pinch plasmas, we discuss several similarities with Tokamaks too. The realistic description obtained within our basic modeling may provide a useful set of means to train and validate advanced data analysis tools, like machine learning techniques, with the aim of understanding and optimizing magnetic configurations (i.e., in the RFP case, steady helical regime, sawtooth mitigation, prevent transport barrier disruption, optimize ion heating by tuning relaxation events⋯).

Helical self-organization in 3D nonlinear modeling; on the role of boundary conditions. After highlighting the key role of helical shaping of the magnetic boundary in RFPs [r1] and Tokamaks [r2] (see example in Fig.1), and the discovery of new RFP helical states excited by suitable seed edge magnetic perturbations [r3], the implementation of more realistic boundary conditions (including resistive shell and vacuum layer) provided two additional results relevant for RFPs. First, intermittent helical regimes similar to medium current RFX-mod [4] discharges self-organize for given thin shell resistivity values [5] (Fig.2). Then, the decrease of secondary modes is predicted when increasing the shell-plasma proximity, as expected in the upgraded RFX-mod2 device, starting operation in 2021 [6].

Lagrangian Coherent Structures (LCS) and temperature gradients in chaotic domains. The development of refined techniques to detect Lagrangian Coherent Structures (LCS), i.e. surfaces ruling the "motion"of magnetic field lines inside a chaotic domain [7, 8], allowed explaining the formation of temperature gradients even in regions characterized by chaotic fields [9]. Such gradients lie where LCS locate, as seen in Fig.3. The technique will be applied to experimental data for the understanding of internal electron transport barrier formation observed in RFX-mod.

3D nonlinear MHD studies of RFP and Tokamak sawtoothing. Besides the boundary conditions impact on favoring or stimulating the transition to helical regimes in RFPs and circular Tokamaks, it has been recently confirmed the crucial role played by the Hartmann dimensionless parameter, $H \sim (\eta\nu)^{-1/2}$ (with η and ν dimensionless resistivity and viscosity) [11]. Indeed, in both Tokamaks and RFPs, the transition to quiescent helical regimes ("snakes"in the tokamak case) is somehow preceded by a sawtoothing behaviour emerging at low dissipation and mitigated by suitable small edge magnetic field applied at the boundary. The sawtoothing period in the simulations is shown to depend on the Hartmann number for both tokamaks and RFPs: $\tau_{RFP} \sim H^{0.76}P^{-0.01}$, $\tau_{TOK} \sim H^{0.32}P^{-0.07}$ (with $P = \nu/\eta$ the magnetic Prandtl) [9], a result to be validated in RFX-mod2[6]. For RFP configurations, a significant quantitative agreement is already available, when comparing in the SpeCyl simulation and RFX-mod databases the scaling (decrease) of m=0 modes amplitude with H, consistently with the reinforcement of quasi-single helical states in that region [12]. Again, in both Tokamak and RFP simulations, the sawtoothing activity is characterized by magnetic energy convertion in kinetic one, formation of localized structures (intense current sheets, mode phase locking) and excitation of **Alfvén waves**. The spectrum of the Alfvén eigenmodes excited in RFP configurations is in reasonable quantitative agreement with experimental findings in the RFX-mod device [13, 14]. **Adiabatic and non-adiabatic effects during low-frequency-wave-particle interactions**. Provided that the amplitude of the forcing wave is large enough, we have demonstrated, in terms of Hamiltonian dynamics, that irreversible energy transfer from the wave to the particle takes place even out of the resonance condition. This result has been applied to the long-standing problem of the solar corona heating, and we showed it can be due to ion heating by low-frequency Alfvén waves upwardly propagating from the chromosphere [15]. We propose here that it might be at the basis of the ion heating during reconnective phases in RFPs.

References.

[r1] Bonfiglio et al, PRL 111, 085002 (2013) DOI: 10.1103/PhysRevLett.111.085002
[r2] Piovesan et al., Nucl. Fusion 57 116029 (2017) doi: 10.1088/1741-4326/aa700b
[r3] Veranda et al., Nucl. Fusion 57 116029 (2017) doi: 10.1088/1741-4326/aa7f46
[4] Valisa et al, PPCF 50 124031 (2008) doi: 10.1088/0741-3335/50/12/124031
[5] Bonfiglio et al. 46th EPS Plasma Physics P1.1049 (2019) http://ocs.ciemat.es/EPS2019PAP/pdf/P1.1049.pdf
[6] Marrelli, et al., Nucl. Fusion 59, 076027 (2019) doi: 10.1088/1741-4326/ab1c6a

[7] Di Giannatale et al, Phys. of Plas., 25(5) 052306, (2018). doi: 10.1063/1.5020163
[8] Pegoraro et al, PPCF 61 044003 (2019) doi: 10.1088/1361-6587/ab03b5
[9] Veranda, et al Nucl. Fus. 60 016007 (2020) doi: 10.1088/1741-4326/ab4863
[10] Chacón, et al Jour. of Comput. Phys., 272, 719 (20 14) doi:10.1016/j.jcp.2014.04.049
[11] Cappello et al, PRL 85, 3838 (2000) doi: 10.1103/PhysRevLett.85.3838
[12] Vivenzi MS degree thesis Università di Padova (2019) http://tesi.cab.unipd.it/63083/
[13] Spagnolo et al, NF 2011 doi:10.1088/0029-5515/51/8/083038
[14] Kryzhanovskyy et al (2019) http://www.eftc2019.ugent.be/docs-upload/Book_of_abstracts_EFTC_2019_final.pdf P1-10
[15] Escande et al. Sci. Rep. 9, 14274 (2019) doi: 10.1038/s415 98-019-50820-x

Indico rendering error

`Could not include image: Cannot read image data. Maybe not an image file?`

Indico rendering error

`Could not include image: Cannot read image data. Maybe not an image file?`

Indico rendering error

`Could not include image: Cannot read image data. Maybe not an image file?`

Affiliation

Consorzio RFX - CNR

Country or International Organization

Italy

Authors: CAPPELLO, Susanna (Consiglio Nazionale delle Ricerche - Consorzio RFX); Dr BONFIGLIO, Daniele (Consorzio RFX, Padova, Italy); Mr DI GIANNATALE, Giovanni (Consorzio RFX); Dr ESCANDE, Dominique (Laboratoire PIIM, UMR 7345 CNRS-Aix Marseille Université, France); Mr KRYZHANOVSKYY, Artur (Consorzio RFX); Dr MANDUCHI, Gabriele (Consorzio RFX); Mr RIGONI, Andrea (Consorzio RFX); Dr SATTIN, Fabio (Consorzio RFX); Mr SPINICCI, Luca (Consorzio RFX); Dr SPIZZO, Gianluca (Consorzio RFX, Associazione EURATOM-ENEA sulla Fusione, Padova, Italy); Dr VERANDA, Marco (Consorzio RFX); Mr VIVENZI, Nicholas (Consorzio RFX); Dr CHACÒN, Luis (Los Alamos National Laboratory); Dr GRASSO, Daniela (CNR-ISC PoliTo); Dr FALESSI, Matteo Valerio (ENEA); Prof. PEGORARO, Francesco (Pisa University)

Presenter: CAPPELLO, Susanna (Consiglio Nazionale delle Ricerche - Consorzio RFX)

Session Classification: P7 Posters 7

Track Classification: Magnetic Fusion Theory and Modelling