3D nonlinear MHD studies at Consorzio RFX:
Achievements and challenges in macroscopic modelling of fusion plasmas

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As comprehensively reviewed in [1], enormous volume of work has been carried out in understanding and control of various MHD instabilities, in particular in the Tokamak configurations and significant progress has been achieved. Yet, unresolved issues remain, where the MHD description is expected to play important contributions. We here present a survey of our activity focussed to the macroscopic helical self-organization occurring in pinch configurations, eminently in Reversed Field Pinches, which characterize Tokamak scenarios too, for example when dynamo/flux pumping effects play a role. Our simplified 3D visco-resistive full-MHD model (**SpeCyl code**, collaboration with Dr. Biskamp MPI-IPP 1991 [2]) has been very effective in favoring a paradigm change, anticipating the potentiality of RFP helical ohmic equilibria which result from resistive-kink/tearing modes nonlinear saturation. It provided a framework for understanding and exploring the emergence of Quasi helical regimes (QSH) featuring magnetic chaos healing in RFX device(s) (the largest RFP). Nonetheless, with the aim of growing the comprehension of the basic processes, we advanced our numerial capabilities by acquiring the *extended-full*-MHD **PIXIE3D** code (benchmark-verified against SpeCyl, a collaboration started in 2007 with Dr. L. Chacòn LANL-USA [3]). Since 2011, The collaboration with Dr. Grasso and Borgogno (PoliTo) made possible the development of an advanced technique for magnetic field transport analysis: the **LCS-fusion tool** [4]. Finally, we gained access to the *extended*-MHD **JOREK code** thanks to collaboration with its team at MPI-IPP under EUROfusion, since 2018 [5]. We believe the comparison in between different advanced numerical codes is mandatory, given the need to fill the existent gap in fusion to achieve predictive and quantitave modelling capabilities.The present survey of main achievements and perspectives in 3DMHD studies relates the following aspects: i) Transition to Quasi Helical regimes in RFP (QSH)[6]; ii) Boundary Conditions extension toward realistic RFX-mod2 front-end (RFP and Tokamak) [7,10]; iii) Formation of Internal Transport Barriers in RFP (eITB), (Lagrangian Coherent Structures)[8]; iv) Large scale modes (dynamo/flux pumping effect), their control and characterization of plasma flow: Magnetic Reconnection events in current carrying plasmas: RFPs and tokamaks, and interplay with Alfvén waves (possible RFP ion heating mechanism) [9]; v) Assessment of SPI technique to mitigate disruptions in DTT, also in comparison with the MGI approach; vi) initial assessment about ELM physics and correlation with 3D fields in view of DTT [11]. These lines of research are naturally interconnected with nonlinear MHD activities under EUROfusion (TSVV, WP) and DTT programme.

References:

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