Viscosity profile studies in 3D non-linear MHD modeling of RFP fusion plasmas

N.Vivenzi[1,2], D. Bonfiglio[1,3], S. Cappello[1,3], and M. Veranda[3]

[1]Consorzio RFX (CNR, ENEA, INFN, Università degli Studi di Padova, Acciaierie Venete SpA), C.so Stati Uniti 4, 35127 Padova, Italy
[2]CRF – University of Padova, Italy
[3]CNR - ISTP Padova, Italy

The strong uncertainty related to the estimate of the viscosity coefficient represents an important challenge in the application of magneto-hydrodynamics (MHD) simulation results to laboratory plasmas [1]. This is particularly relevant in the contest of the reversed-field pinch (RFP) configuration, where the viscosity together with the resistivity jointly rules the transition between different dynamical plasma regimes in non-linear MHD simulations, by means of the dimensionless Hartmann number [2] and the rise of helical self-organized states, exploiting non-ideal boundary conditions [3].

In the SpeCyl non-linear MHD code [4], the modelling of the viscosity is quite simple, considering a constant and scalar viscosity coefficient. In this work, we present a sensitivity study concerning the impact of different viscosity radial profiles. In particular, a profile inspired by the Braginskii perpendicular viscosity is implemented in SpeCyl. This choice is motivated by the fact that the MHD field instabilities relevant for the RFP configuration dynamics (resistive-kink / tearing modes) are active in the direction perpendicular to the magnetic field. Moreover, the analysis of a wide database of RFX-mod shots [5] has highlighted that the perpendicular Braginskii coefficient (with a suitably anomaly factor [6]) represents the contribution to the plasma viscosity which provides the best agreement, in the comparison of SpeCyl numerical simulations and RFX-mod data [7].

The non-monotonous viscosity displays the existence of local effects specifically due to the profile, in addition to the more consistent ones, due to the absolute value of the viscosity [8]. In particular, the Braginskii-like viscosity profile causes a localized damping of plasma flow in the regions where the viscosity is stronger, close to the plasma edge. This results in the reduction of the flow shear, in turn allowing the enhancement of 'intermediate-resonant' magnetic field modes amplitude, confirming a basic picture of interplay where the plasma flow counteracts the growth of magnetic instabilities [9]. Furthermore, a preliminary analysis on the magnetic topology is carried out, highlighting (as main result) the lowering of the connection length, interpreted as consequence of the higher MHD activity caused by the non-uniform profile.

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion).

References:

[1] D. Montgomery, *Plasma Physics and Controlled Fusion*, **34**, 1157 (1992)
[2] S. Cappello, D.F. Escande, *Physical Review Letters*, **85**, 3838 (2000)
[3] D. Bonfiglio, M. Veranda et al., *Physical Review Letters,* **111** 085002 (2013)
[4] S. Cappello, D. Biskamp, *Nuclear Fusion*, **36**, 571 (1996)
[5] G. Spizzo et al., *Nuclear Fusion,* **55**, 043007 (2015)
[6] R. Fridström et al., *Physical Review Letters*, **120**, 225002 (2018)
[7] N. Vivenzi et al., *Journal of Physics: Conference Series* **2397**, 012010 (2022)
[8] M. Veranda et al., *Nuclear Fusion,* **60**, 016007, (2020)
[9] R. Fitzpatrick, *Physics of Plasmas*, **5**, 3325, (1998)