3D boundary flow impact in modelling free-boundary instabilities with resistive-shell-based boundary conditions in the nonlinear MHD code SPECYL

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Advanced numerical tools play a determinant role in the understanding of plasma dynamics. The nonlinear three-dimensional magneto-hydrodynamic (3D MHD) code SPECYL [1] investigates magnetic self-organisation processes in fusion plasmas in the Reversed Field Pinch (RFP) and in the tokamak configurations. In the past, SPECYL has been used to investigate the Quasi Single Helicity states (QSH) in the RFP devices [2], where the dominance of a single component in the magnetic field spectrum sustains dynamo currents [3] and fosters the plasma confinement: QSH states in RFP plasmas are strongly influenced by the magnetic boundary [4]. Analogous self-organised helical structures have also been studied with SPECYL in the hybrid equilibria of tokamak plasmas [5,6].

We present the implementation and verification against the independent 3D MHD nonlinear code PIXIE3D [7,8] of more realistic boundary conditions, featuring fully 3D boundary flow and including with increasing complexity a thin shell of variable resistivity in contact with the plasma, surrounded by an arbitrarily wide vacuum region that separates it from an outer ideal conductor [9]. This is a versatile formulation, capable of reproducing different experimental conditions: from an ideal wall attached to the plasma, to a free interface between plasma and vacuum, to a physical wall of finite resistivity at plasma boundary.

In the free plasma-vacuum interface regime, the 3D boundary flow is proven to have an essential role in reproducing free-boundary instabilities, such as the external kink modes in the tokamak configuration. Remarkably, the new implementation of SPECYL's BCs is indeed shown to be capable of achieving robust and self-consistent agreement with the theoretical figures of merit of linear MHD [10], with great freedom of choice in the initial equilibrium and without the need of a pseudo-vacuum boundary region.

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