Predicting the stability of alpha-particle–driven Alfvén Eigenmodes in burning plasmas

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Plasma heating in the burning regime of tokamak reactors will be provided mainly by an isotropic population of fusion-born alpha-particles with energy in the MeV range. However, their free energy can drive Alfvén eigenmodes (AEs) unstable. If destabilized, AEs may enhance alpha-particle transport away from the fusing core, thereby eliminating the dominant heating source and causing damages to the vessel walls. Therefore, understanding and predicting the complex interplay between supra-thermal particles and AEs has emerged as one of the most significant research topics in support of the fusion effort in magnetic-confinement devices.

In future tokamak reactors, for which no experiments have been performed yet, there is no experimental guidance about which AEs interact most with fusion alpha-particles. To address this issue, a systematic approach was recently developed to intensively scan a parameter-space range (frequency and wave number) in order to find all AEs allowed by a given magnetic equilibrium and rank them by their linear growth rate [1]. Numerical simulations carried out for an ITER baseline scenario [2] found that the most linearly unstable modes expected are core-localized Toroidicity-induced AEs with a large toroidal mode number ($n \approx 30$) [1]. It was also found that alpha particles in resonance with such modes were strongly passing ones, with large parallel velocity and small (but not vanishing) pitch angle. In these circumstances, the drift-velocity term $k_\perp v_\perp$ becomes comparable with the AE's angular frequency and the wave-particle resonance condition must be revisited.

In this talk, new developments concerning the resonance mechanism between AEs and fusion-born alpha-particles with large parallel velocity are discussed. In particular, the effects of the drift-velocity contribution to the resonance condition are addressed in order to explain the results of recent numerical simulations. The new elements brought into the discussion will aid one to understand why specific AEs pair with the most energetic alpha-particles available in the population, becoming thus the most unstable ones. The consequences of the gained insight for stability predictions of alpha-particle–driven AEs in burning plasmas are also discussed.

References

[1] P. Rodrigues *et al.*, Nucl. Fusion **55**, 083003 (2015).

[2] S. D. Pinches *et al.*, Phys. Plasmas **22**, 021807 (2015).