Control of Energetic-particle-driven MHD Instabilities by External Actuators in Heliotron J and LHD

K. Nagasaki[1], K. Nagaoka[2], J. Varela[3], S. Kobayashi[1], S. Kado[1], T. Minami[1], Y. Nakamura[4], A. Ishizawa[4], S. Ohshima[1], S. Konoshima[1], T. Mizuuchi[1], H. Okada[1], N. Maruchchenko[5], Á. Cappa[6]

[1] Institute of Advanced Energy, Kyoto University, Uji, Kyoto, Japan
[2] National Institute for Fusion Science, Toki, Gifu, Japan
[3] Universidad Carlos III de Madrid, 28911 Leganes, Madrid, Spain
[4] Graduate School of Energy Science, Kyoto University, Uji, Kyoto, Japan
[5] Max-Planck-Institute for Plasma physics, Greifswald, Germany
[6] National Laboratory for Magnetic Fusion, CIEMAT, Madrid, Spain

Energetic alpha particles generated by D-T fusion reaction and beam ions for plasma heating interact resonantly with shear Alfvén waves through damping/driving processes when their velocity is comparable with Alfvén velocity, resulting in excitation of energetic particle (EP)-driven MHD instabilities. Control of the MHD instabilities is required for good plasma performance and protection of in-vessel components. Interaction between EP-driven MHD instabilities and turbulence has also been pointed out recently. Several types of EP-driven MHD instabilities, including toroidicity-induced AEs (TAEs), helicity-induced AEs (HAEs), global AEs (GAEs), energetic particle modes (EPMs), have been observed in NBI-heated plasmas of stellarator/heliotron devices. We have successfully demonstrated that electron cyclotron heating (ECH) and current drive (ECCD) are effective tools to mitigate and suppress the EP-driven MHD instabilities in Heliotron J, LHD, and TJ-II [1-4]. The experimental and theoretical results suggest that the mode excitation in the shear Alfvén continua and the continuum damping related to magnetic shear have a crucial role in mode suppression. In Heliotron J and LHD, we have recently studied the ECH effect by scanning the EC power, power deposition location, and magnetic configuration [5]. In Heliotron J, the modes are mitigated with an increase in ECH power at a low-bumpiness configuration, while they are not a monotonic function of ECH power in other configurations. In LHD, the response of AEs to ECH depends on the modes and the EC deposition location. The stability of EPMs and AEs with ECH has been analyzed with a numerical simulation by using the FAR3d code [6]. The simulation results show that the stabilization/destabilization depends on the balance among the continuum damping, EP pressure, and thermal pressure. We will discuss the EP response to ECH to clarify the excitation and damping mechanisms.

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