

ELM Control Physics with Impurity Seeding and LHCD in the HL-2A Tokamak

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ELM control is a key issue in the magnetic fusion reactor. Experiments for controlling ELMs have been performed in the HL-2A tokamak with several tools, including lower hybrid current drive (LHCD), laser blow-off (LBO) seeded impurities (Al, Fe, W) and supersonic molecular beam injected (SMBI) impurities (Ar, Ne). A beneficial effect of the pedestal deposited impurity injected by LBO on ELM mitigation/suppression has been demonstrated in a controlled manner. In addition, the dependence of these effects on impurity species and amount has been systematically investigated. Mixture SMBI with impurity was firstly carried out in HL-2A. Experimental results suggest that there exists an optimal impurity ratio for heat load control in H-mode plasmas, and pedestal dynamics can be actively controlled by exciting pedestal instabilities with impurity seeding.

ELM mitigation with LHCD has been also successfully achieved in HL-2A. The divertor peak heat load during an ELM is strongly reduced during the mitigation phase. After the LHCD application, the pedestal velocity shear has undergone a severe decrease, and the radial wavenumber spectrum of the pedestal turbulence is shifted toward the origin. It has been found that the ELM mitigation is not synchronized to LHCD pulse with a significant delay, while it is closely correlated to the enhancement of the pedestal turbulence, indicating that as for impurity injection, the ELM mitigation with LHCD can be directly caused by the enhancement of the pedestal turbulence.

In order to understand the mechanism of the turbulence enhancement during ELM mitigation, a theoretical turbulent heat transport model, based on the regulation of the turbulence amplitude by its radial wavenumber spectral shift caused by external velocity shear, has been developed. This external velocity shear can be from SMBI, impurity injection or LHCD. A critical growth rate γ_0 for the turbulence regulation has been identified in this theoretical model. It has been found that the turbulence enhancement and ELM mitigation occur when the external velocity shear exceeds a threshold value, which directly depends on γ_0 . Qualitatively, ELM mitigation with pedestal turbulence enhancement and radial spectral shift due to the pedestal velocity shear reduction can be simulated with this theoretical model.

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Primary author: Mr XIAO, Guoliang (Southwestern Institute of Physics, China)

Co-authors: Mr LIU, A.D. (USTC); Dr EKEDAHN, Annika (CEA, IRFM); Mr FENG, B.B. (CNSWIP); Mr LU, Bo (SWIP); Dr YU, Deliang (Southwestern Institute of Physics); Dr MAZON, Didier (CEA Cadarache); Dr GIRUZZI, Gerardo (IRFM, CEA); Mr GAO, J.M. (SWIP); Prof. DONG, Jiaqi (Southwestern Institute of Physics); Ms DELPECH, Lena (CEA); Dr GONICHE, Marc (CEA, IRFM); Mr XU, Min (SWIP); Mr SUN, Ping (SWIP); Mr SONG, Shaodong (CnSWIP); Dr HOANG, Tuong (CEA - Institute for Magnetic Fusion Research); Dr ZHONG, Wulyu (CnSWIP); Prof. SONG, Xianming (Southwestern Institute of Physics); Dr BAI, Xingyu (CnSWIP); Prof. DING, Xuantong (Southwestern Institute of Physics); Prof. DUAN, Xuru (Southwestern Institute of Physics); Dr ZHANG, Yipo (Southwestern Institute of Physics); Dr PEYSSON, Yves (CEA); Dr CUI, Zhengying (Southwestern Institute of Physics); Dr SHI, Zhongbing (Southwestern Institute of Physics); Dr ZOU, xiaolan (CEA)

Presenter: Mr XIAO, Guoliang (Southwestern Institute of Physics, China)

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