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Simulation study of the effect of impurities on the ELM dynamics using BOUT++ six-field two-fluid model

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The huge heat load onto divertor is a crucial issue in fusion reactor. While the radiative impurities are necessary for achieving divertor detachment especially for the future tokamak [1], it is also found to have essential effects on ELM control [2]. It implies the possibility of simultaneous control of the transient and steady-state heat load by impurity seeding. Therefore, it is necessary to understand the mechanism how impurities affect the dynamic of ELMs. The "indirect"effects of impurities, such as radiative cooling, profile regulation and fuel dilution, have been investigated in the simulation studies by the linear instability analysis [3-5]. However, it is still insufficient to explain the complicated ELM behaviors observed in experiments [6, 7].
In this work, a systematical simulation study of the dynamical effect of impurities on pedestal stability, ELM evolution and turbulence transport is carried out using BOUT++ six-field two-fluid module [8] combined with the impurity model developed by Li et al. [9]. According to Seto et al.'s work [10, 11], the evolutions of toroidal axisymmetric electric field and parallel current are included. The electron inertia is also considered for self-consistent current dissipation in fast magnetic reconnection.
Based on EAST equilibrium (shot #91616, t = 6s during ELM suppression phase), the nonlinear simulations are performed. It is found that the complete suppression of ELM can be achieved only when including the effect on vorticity distribution due to impurities, which reflects the essential role of impurity dynamics in ELM suppression. Further scan of the impurity density shows the change of ELM size with impurity density and indicates that there could an impurity density "threshold"for ELM suppression, which is qualitatively consistent with experiment result in HL-2A [7].
The impurity effect on the ELM dynamic process is further explored by varying both the impurity mass ratio and the pedestal electron temperature. As the simulated ELM evolution shows the "two-stage burst"[11] feature, it is found that the first stage is related to linear trigger of peeling-ballooning mode and the second stage is nonlinear triggered due to the drift-tearing mode [12]. According to the difference in the "two-stage burst"feature, the two-dimensional parametric plane can be divided into four regions. According to the shift of operation point between different regions, the different effect of impurity on the ELM evolution can be understood.

Reference

[1] A. W. Leonard. Plasma Physics and Controlled Fusion 60 (2018) 044001.
[2] G. S. Xu, et al. Reviews of Modern Plasma Physics 7 (2023) 14.
[3] H. Lan, et al. Nuclear Fusion 60 (2020) 056013.
[4] T. H. Osborne, et al. Nuclear Fusion 55 (2015) 063018.
[5] J. Rapp, et al. Plasma Physics and Controlled Fusion 44 (2002) 639.
[6] X. Lin, et al. Physics Letters A 431 (2022) 127988.
[7] G. L. Xiao, et al. Nuclear Fusion 61 (2021) 116011.
[8] T. Y. Xia, et al. Nuclear Fusion 53 (2013) 073009.
[9] Z. Li, et al. Nuclear Fusion 62 (2022) 076033.
[10] H. Seto, Physics of Plasmas 26 (2019) 052507.
[11] H. Seto, Physics of Plasmas 31 (2024) 032513.
[12] A. B. Hassam, Physics of Fluids 23 (1980) 2493.

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