2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Modeling research of isotopic effect on H-mode threshold power for tokamak plasma

Xingquan WU[1], Guosheng XU[1]
[1]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031
e-mail (speaker): xqwu@ipp.ac.cn

Since the ITER requirement for H-mode operation in the initial phase with only limited power available, the study on low-to-high (L-H) confinement transition still attracts significant attention. After decades of research, the database shows that the H-mode threshold power depends on many plasma parameters such as density, magnetic field, isotopes and so on[1-2], but the mechanism behind is not fully understood. In order to be in close compliance with relevant experiment results, it is challenging and necessary for a dynamic model to capture the dynamics of turbulence suppression during L-H transition and predict the threshold power at the same time.

If the saturated turbulence intensity would be the balance between the effective growth rate and the nonlinear damping rate, there are theories indicate the sheared ExB flow has effect both on growth rate[3] and damping rate[4] to induce the turbulence suppression. Those theories may belong to the paradigm of turbulence reduction induced by radially sheared ExB flow but lack of the information to explain the H-mode threshold power scaling law. Inspired by the recent observation on EAST that a turbulence radial wave number spectral shift and turbulence structure tilting prior to the L-H transition[6], a dynamical model of the L-H transition based on Edge-Instability Stabilization by ExB flow shear has been developed, where the L-H transition has been treated as a collapse event of edge instability[5]. With the typical plasma parameters of the EAST tokamak, the dominant instability in L-mode at plasma edge is analyzed for the turbulence growth rate, which indicates the weak ExB flow shear in L mode is able to increase the ion inertia of the electrostatic motion by increasing the radial wave number of the tilted turbulence structures, which play an important role for accelerating the trigger process of stabilization of edge instability rather than directly to suppress the turbulent transport. It is found the instability pressure driven term is inversely proportional to the ion mass which induces an isotope effect of mode growth rate. With the scrape-off-layer (SOL) boundary condition applied, the results of the modelling reveal the threshold power would decrease with increasing the isotopic mass, which is reasonable consistent with the $P_{L-H} \propto A_{eff}^{-1}$ scaling in the experimental database. And the preliminary results are shown in Fig1. The model is keep optimizing and may help to understand the connection between the microscopic turbulence suppression and H-mode power threshold in magnetically confined plasma.

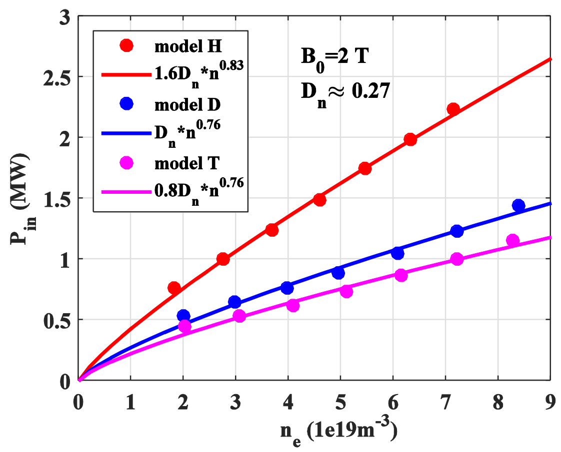

Fig1. (Preliminary results) The dependence of H mode threshold power on the density of the pedestal top region and isotopes, where the Hydrogen, Deuterium and Tritium shown in red, blue and purple respectively, where the power scaling coefficient D_n for the deuterium plasma is about 0.27 in value especially for this EAST tokamak parameters

References:

[1] Martin Y R, et al. J. Phys.: Conf. Ser. 2008 123 012033
[2] Takizuka T, et al. Plasma Phys Contr F 2004 46 A227
[3] Gurcan O D Phys Rev Lett 2012 109 155006
[4] Staebler G M, et al. Phys. Rev. Lett. 2013 110 055003
[5] Itoh S I, Itoh K, Zushi H, et al. Plasma Phys Contr F 1998 40 879
[6] Xu G S, et al. Phys. Rev. Lett. 2016 116 095002