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Recent Progress of Experiment Studies for Advanced Plasma Physics in the HL-2A Tokamak

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As an important part of the fusion research program of China, the key mission of the HL-2A tokamak is to explore physics issues involved in advanced tokamaks and to address the physic and technologic issues relevant to ITER. Most of the important issues of fusion plasmas physics, such as energy confinement improvement, pedestal physics, MHD instabilities and energetic particle physics, divertor and scrape-off layer physics, heating and current drive have been investigated through the progressive improvement of the many subsystems [1,2]. This contribution will highlight the latest progresses in HL-2A programs, including high performance scenarios for the study of advanced plasma physics, ELM control physics and technology development, abnormal event mitigation and prediction, and nonlinear physics [3-10].

In recent H-mode experiments of HL-2A, a high-performance operation regime (β_N>3.0 and H_{98y2}~1.3) with both edge and internal transport barriers has been realized by using the upgraded NBI and LHCD systems. Moreover, these experiments provide an important platform for studying MHD physics, such as neoclassical tearing mode, Alfvén modes and so on. Regarding to the L-H transition, a critical $E \times B$ velocity shear has been found. Statistical results indicate that the velocity shear threshold is independent of the plasma density and the total heating power. Moreover, it has been found that non-linear interactions between shear flows and turbulence can be enhanced by the fueling pulse via supersonic molecular beam injection (SMBI). The enhanced regulation dynamics can quench the turbulence and maintain the turbulence collapse. The effective reduction of the H-mode power threshold by SMBI is demonstrated, as shown in Fig.1 [10]. The H-mode performance can be further improved by impurity seeding (Ne or Ar) via SMBI. The result suggests that the seeded impurity changes the core thermal transport, resulting in a higher ion temperature and an enhanced energy confinement.

ELM physics understanding and its mitigation, as well as the development of control technique have been investigated intensively in HL-2A. Recently, type-I ELM suppression by applying n=1 resonant magnetic perturbation (RMP) in HL-2A is explained by the enhancement of turbulence during RMP. Further improvement of the reliability and robustness of the ELM control approach is the high priority of the research. Issues concerning abnormal event such as disruption needs to be resolved in future fusion devices. The effects of LHCD and LBO on runaway electrons (RE) dynamics during disruptions have been investigated. RE generation during disruptions has been avoided for the first time by the LBO-seeded impurity. To predict disruption, a predictor based on deep learning method has been developed in HL-2A. It reaches a true positive rate of 92% and a true negative rate of 97% with 30ms before the disruption. This model interpretation method can be used to automatically give the disruption causes, which will be helpful for the active avoidance of disruption.

Regarding the progress on nonlinear physics, a new experiment evidence about the EPM avalanche is demonstrated in the HL-2A tokamak. A profound influence of the island size on the nonlinear effect of turbulence on transport has been studied. The results indicate that there are strong nonlinear interactions between the tearing mode (TM) island and turbulence.

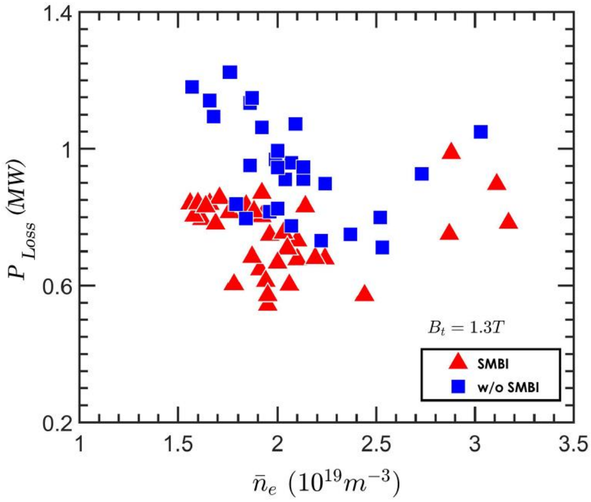

Figure 1 The loss power dependence on the line averaged electron density for the SMBI-stimulated H-mode (red triangles) and the H-mode without SMBI (blue squares).

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