3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Radiative divertor study for partial detachment in the grassy ELMy H-mode in EAST

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In future fusion devices such as ITER and DEMO, the power flux in a steady state to the targets is on the order of several 100 MW/m^2[1], which is well above the material limit of 5-10 MW/m^2. To protect the divertor target, one efficient solution is to reduce the heat flux by impurity seeding with elements such as nitrogen (N_2), neon (Ne), and argon (Ar). With the rapid increase in the impurity radiation after gas puff, the detachment is achieved and the j_s is reduced significantly in this scenario as demonstrated in radiative divertor experiments in tokamak [2, 3].

Edge-localized modes (ELMs) are a type of magnetohydrodynamic instability that characterize H-mode plasmas [4]. For giant ELMs, a transient heat load of more than 10 MJ/m^2 on the divertor target poses a substantial threat to the device safety, which makes the type-I ELMy regime less attractive for future fusion reactor operation. For comparison, the grassy ELMs can avoid the high transient heat load of type-I ELMs on the divertor target and the impurity exclusion ability in the grassy ELMy regime is much stronger.

To reduce the steady and transient heat flux on the divertor target, the combination of grassy ELMy regime and radiative divertor operation was proposed and performed in the EAST 2018 campaign. As a result, the first stable partial detached plasma during the grassy ELMy regime has been achieved by Ne seeding from the upper outer divertor target. The detachment of inner and outer tungsten divertor targets was achieved by mixed 5% Ne and 95% D_2 seeding from the upper outer divertor target inlet in upper single null (USN) plasma. The measured ion saturation current (j_s) on the upper outer divertor target was reduced by 45% and the degree of detachment (*DOD*) increased to 2. The total radiation power increased to 1.45 MW, approximately 20% of the total input heating power. The stored energy decreased from approximately 160 kJ to 138 kJ, corresponding to stored energy loss of approximately 14%, which is acceptable for the operation for fusion reactors. After Ne seeding, the frequency of grassy ELMs increased which contributed to impurity expulsion. It was also evident that detachment and grassy ELMs are mutually beneficial. From aforementioned experimental observations, grassy ELMs with partial detachment by impurity seeding will probably be one of the candidate operation systems for the Chinese Fusion Engineering Test Reactor (CFETR) and fusion reactors in the future.

References

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