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JT-60Uの逆方向トロイダル回転とセパラトリクスパワーによる Type-I ELM特性に対する統合的効果

Unified effects of counter toroidal rotation and power across the separatrix on type-I ELMs in JT-60U

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Type-I ELMs are spontaneous periodic relaxations of the pressure gradient at the pedestal of H-mode plasmas, occurring in a repetitive manner once the edge pressure gradient and current density exceed the stability boundary. In present understanding on type-I ELMs, the peeling-ballooning instability driven by both edge pressure gradient and current density has described the experimentally observed limit of edge pressure profiles in tokamaks. In recent ELM studies, it has been prevalently recognized that the edge toroidal rotation plays a significant role in determining the ELM feature. The effects of toroidal rotation on the stability boundary of edge MHD modes have also been detected in recent theoretical studies.

One of the most general features in type-I ELMs is the proportionality between ELM frequency f_{ELM} and the power crossing the separatrix P_{sep}, which is also utilized in many cases for validation of ELM type. The ELM characteristics are strongly influenced by the edge pedestal structure just before an ELM crash occurs. Therefore, in case the toroidal momentum source is input by NBs in ELMy H-mode plasmas whether those are tangential NBs or perpendicular NBs, the composition of ELM characteristics becomes suddenly complex. This is because the edge pedestal structure itself could be modified directly or indirectly when the toroidal rotation and heating power are changed. An increase of β_p due to the application of increased heating power could improve the stability of the plasma edge in the low magnetic field side. At the same time, this also causes the increase of ELM frequency because of increased heat flux across the separatrix. Besides, the stability boundary is modified by the edge toroidal rotation.

In this study, the influence of toroidal rotation and heating power is examined using the variety of NB injections in JT-60U. ELM frequency f_{ELM} during the type-I ELMy H-mode phase increased monotonically together with P_{sep} for all the cases of tangential NBs. In addition, f_{ELM} became higher in case of counter-tangential NB at a given P_{sep}. However, dependence of f_{ELM} on P_{sep} for each case of tangential NB was explicitly stronger than a proportional relation when the perpendicular NBs were injected. The toroidal rotation velocity at the H-mode pedestal V_T^{ped} shifted continuously in counter-direction when P_{sep} was increased by the perpendicular NBs. Fig. 1 shows the dependence of f_{ELM} on P_{sep} for two cases of fixed V_T^{ped}. At fixed values of V_T^{ped}, f_{ELM} increased clearly in proportion to P_{sep}. In addition, this proportionality between f_{ELM} and P_{sep} holds regardless of the mixture of dataset with the toroidal momentum inputs [1]. The proportional coefficient decreased as V_T^{ped} shifted in co-direction. The ELM frequency observed in the H-mode experiments with power scan becomes higher than the value expected in proportion to P_{sep} when V_T^{ped} shifts toward counter. This is explained as a result of the unified effect of V_T^{ped} and P_{sep} on ELM activity.

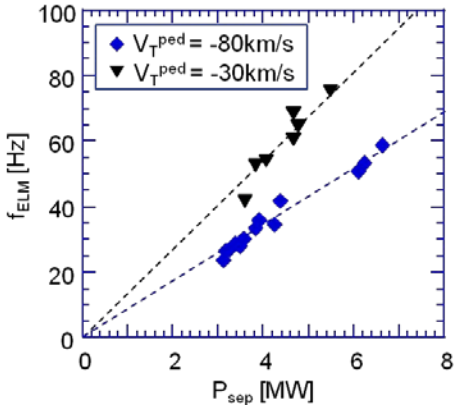

Fig. 1. Dependence of f_{ELM} on P_{sep} for two cases of fixed V_T^{ped} in type-I ELMy H-mode plasmas.

[1] H. Urano, et al., Nucl. Fusion **52** (2012) 103012.