Calculation of Heat Fluxes onto Divertor Plates at Edge Localized Modes in KSTAR Tokamak

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Numerical simulations of ELMs (Edge Localized Modes) have been carried out to predict the characteristics of ELMy H-mode for the KSTAR (Korea Superconducting Tokamak Advanced Research) tokamak. In the H-mode operation, rapid emissions of plasma energy and particles in the core region towards the SOL (Scrape-Off Layer) by ELMs could deliver transient heat loads onto divertor plates above the tolerable limits and cause the H-mode to transfer to the L-mode by cooling the core plasma. A comprehensive understanding of ELMs is, therefore, essential for stable H-mode operations where the pedestal conditions related to ELMs may act as constraints impacting on the global confinement,.

In this numerical work, a 1.5-dimensional core code and a 1-dimensional edge module have been integrated by adapting an iterative method. The temperature and density distributions of core plasma are calculated self-consistently with NBI heating profiles, and edge plasma profiles are calculated by solving multi-fluid equations in the SOL region when the boundary parameters are determined by iterations between the core and SOL values.
In the whole simulation, the NBI heating power is applied after 5 seconds and the H-mode is formed by suppressing the transport of plasmas at the edge pedestal. The ELM crash is assumed to be triggered by an ideal ballooning mode in the first stability region, which is unstable if α_{MHD} exceeds the ballooning mode threshold α_{cr} as expressed in the following:

$$\alpha_{MHD} \equiv -\frac{2\mu_0 R q^2}{B^2}\left(\frac{dp}{dr}\right) > \alpha_{cr} = 0.4s\left(1+\kappa_{95}^2(1+5\delta_{95}^2)\right) \quad (1)$$

Current driven peeling modes are also considered to trigger ELMs at the condition:

$$\sqrt{1-4D_M} < C_k\left[1+\frac{1}{\pi q'}\oint\frac{J B}{R B_p^3}dl\right] \quad (2)$$

Once the ELM crash occurs, the transport coefficients at the edge transport barrier (ETB) are adjusted to imitate the large energy and particle losses observed between neighboring ELMs. At ELM events, the pedestal temperatures are observed to increase rapidly and oscillate in an almost constant frequency, as illustrated in Fig. 1.

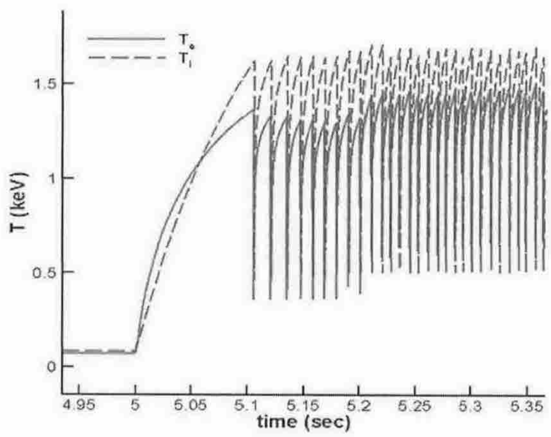
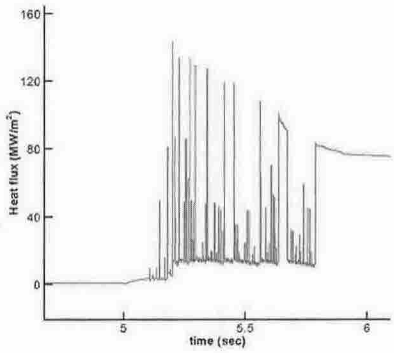


Fig 1. Pedestal temperature at ELM events

Heat fluxes onto the divertor plates are calculated by the equation, $q_d = n_p C_s(\gamma_i T_i + \gamma_e T_e)$, and exhibit very strong peaks over 120 MW/m^3 during ELMs. The maximum heat flux on the target plates at ELMs has a tendency to increase with increasing NBI heating powers as shown in Fig 2.



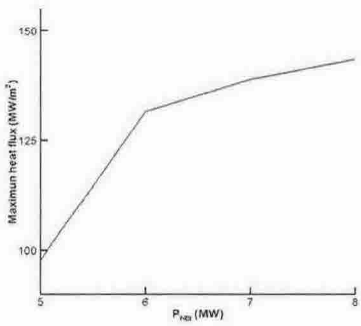


Fig 2. Divertor heat flux (left), and maximum heat flux on the target plates with NBI heating powers (right)

As a result of this numerical simulation, ELM phenomena in the KSTAR tokamak are described for various NBI heating powers, and the maximum heat fluxes onto the divertor plates at the ELM event are given for KSTAR baseline discharges. From the results, it is predicted that both ballooning mode and peeling mode can be sources of ELMs and they transfer intolerable heat spark to the target plates, which could degrade the tokamak confinement. Therefore, control of SOL plasma conditions for stable ELMy H-mode operations is very important and more rigorous modeling of ELMs including MHD effects and theory-based transport models are needed to trace the mechanism of ELMs.