§27. Estimation of the Effect of Fast Ions on Pellet Ablation

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To date gas puffing has been successfully used as a fundamental fueling tool. However, for larger devices there is a concern that the fueling efficiency of gas puffing becomes worse because most of fueled gas is ionized by a hot and thick scrape-off layer before it penetrates into the confinement region. Injection of cryogenic solid pellets which is an alternative approach of fueling has been attracting interests because of advantage of deeper and more efficient fueling than gas puffing. In LHD, pellet fueling is performed by two pellet injectors to demonstrate high fueling efficiency and capability to control the electron density. It is necessary for prediction of fueling performance to clarify physical mechanisms in two stages, i.e., ablation process of pellets and subsequent drift motion of ablated plasmoid. We have estimated the pellet ablation with the use of measured and predicted pellet penetration depths.

In LHD, fast ions produced by NBI heating affect the pellet ablation due to their high energy up to 180 keV though the contribution of thermal electrons to the ablation is still predominant. Here the stored energy of fast ions is introduced as the indicator of the effect of fast ions on the ablation, $W_{f0} = P_{dep} \times \tau_{slowdown}$, where P_{dep} is the NBI deposition power and $\tau_{slowdown}$ is the slowing-down time estimated by plasma parameters at the center. In Fig. 1, the penetration depth becomes shallow as a increase of the energy of fast ions and the curve is saturated at ~ 27 kJ, thus we define it the critical value (i.e. High W_{f0} means the energy is more than this value). Figure 2 shows the comparison of the NGS scaling, which accounts for only the effect of thermal electrons on the ablation with measured pellet penetration depth. In the case of low W_{f0}, the trend agrees well with the NGS scaling even for deep penetration while it shows slightly offset from the NGS scaling. In contrast to this result, the difference between measured and predicted pellet penetration is large for deep penetration in the case of high W_{f0} although there is no difference between measured and predicted penetration depth in two cases for shallow penetration. We conclude that the discrepancy of experimental results from the NGS model is evidence of the effect of fast ions on the pellet ablation since the NGS scaling considers only thermal electrons.

The pellet penetration depth is calculated by means of the ABLATE-code [1] including contributions of not only thermal electrons but also fast ions to the ablation for profiles of measured electron temperature, electron density and calculated density of fast ion [2]. Figure 3 shows the comparison of the penetration depth calculated by the ABLATE with measured pellet penetration depth. The penetration depth of the ABLATE results from the ablation model of consideration of the effect of both electrons and fast ions. Although a systematic discrepancy between dataset of high and low W_{f0} is mitigated, disagreement between experimental observation and the model calculation still exist.

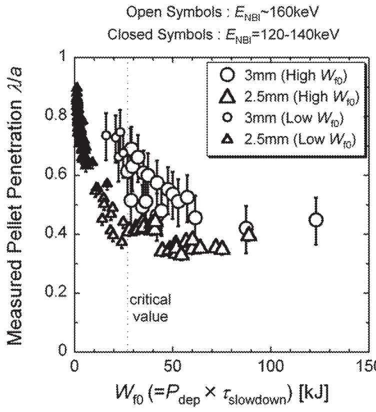

Fig. 1. The relationship between the measured pellet penetration λ/a and the energy of fast ions W_{f0} in LHD pellet fueled discharges.

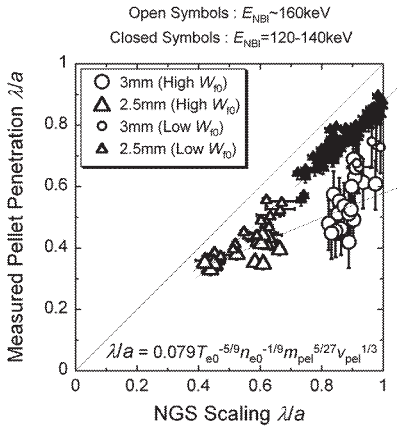

Fig. 2. Comparison of the NGS scaling which accounts for only the effect of thermal electrons on the ablation with measured pellet penetration depth at same magnetic configuration (R_{ax} = 3.6 - 3.7 m, $B_t \geq 2$ T).

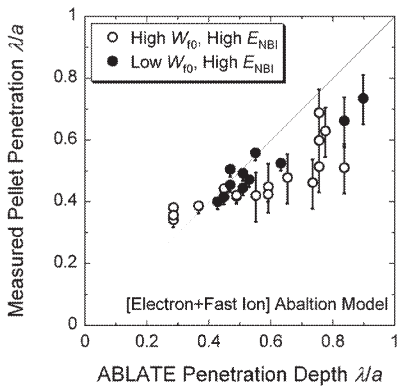

Fig. 3. Comparison of the penetration depth calculated by the ABLATE-code with measured pellet penetration depth.

Reference

[1] Nakamura, Y. *et al.*, Nucl. Fusion **26**, (1986) 907.
[2] Murakami, S. *et al.*, Fusion Eng. Des. **26**, (1995) 209.