§5. Integrated Simulation of C-pellet Injected High Ion Temperature Plasma of LHD

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i) Introduction High ion temperature, T_i, experiments have been performed applying the tangential and perpendicular NBI heating systems in LHD[1]. The high T_i plasma up to 7.3keV has been obtained during the decay phase of the density after rapid increase due to a carbon pellet injection. Simple heat transport analysis of these high T_i plasma has been done but the rapid change of density effect on the NBI heat deposition and the multi-ion species effects on the heat transport is not treated accurately. In order to analyze the transport property of the time evolving plasma, we have to use NBI heat deposition analysis code including the effect of plasma time evolution. Also the plasma contains sufficient impurities due to the He gas puff and C pellet injection and the heat transport simulation should take care the multi-ion species. In this paper we study the high T_i plasma with C pellet injection of LHD applying the integrated simulation code GNET-TD+TASK3D.

ii) NBI heating analysis of C-pellet injection plasma In order to analyze the NBI heat deposition profile of time evolving plasma we have developed GNET-TD[2] including the finite drift orbit and complex motion of trapped particles extending the 5D drift kinetic equation solver GNET[3]. We perform NBI heating simulation of high-T_i discharge (# 110599) plasma.The time evolution of density and temperature profiles are based on the experimental measurements. There are five NBI injectors and one of them #4 is modulated in order to measure the ion temperature. We evaluate the beam ion distributions including time evolutions of density, temperature and beam power modulations. Before the C pellet injection beam ion distribution reaches a steady state slowing down distribution, and just after the pellet injection strong slowing down of energetic beam can be seen at the edge region. But we can not see clear change in the central region. After the density decay phase the beam ion distribution is recovered.

iii) Heat transport simulation of high-T_i plasma We perform the integrated heat transport simulation of high T_i plasma by the improved TASK3D code[4] assuming multi-ion species plasma (e, H, He, C). We assume that the heat transport consists of the neoclassical and turbulent transport. In TASK3D the neoclassical transport database, DGN/LHD, evaluates the neoclassical heat transport for all species and the radial electric field is determined by the am-bipolar condition of neoclassical electron and ion fluxes. For the turbulent transport we assume the gyro-Bohm model for the electron heat conduction and the gyro-Bohm grad-T_i model[4] for the ion one.

The heat transport of high-T_i discharge (# 110599) plasma is investigated. We assume the (e, H, He, C) density profiles based on the experimental measurements, which give us a plausible plasma profiles even though the complex pellet ablation process is not considered in this simulation. We obtain that electron temperature drops rapidly by the pellet injection and backed to near the previous values. This shows similar behavior with the experimental one. On the other hand, the change of T_i after pellet injection, ΔT_i, is about 0.5keV just after the pellet injection and gradually decreases. This indicates that the experimentally observed high-Ti is not simply due to the increase of the ion heat deposition by C-pellet injection and that we need an improvement of the heat transport.

Next, we assume a simple improvement model of the turbulent heat transport just after the pellet injection as $\chi_i^{TB} = \gamma_{TB}\chi_i^{TB(L-mode)}$, where γ_{TB} is a constant. Figure 1 shows the time evolution of ΔT_i varying γ_{TB}. The ΔT_i value increases as γ_{TB} decreases and we obtain a similar value of ΔT_i with the experimental one at γ_{TB}=0.2. This indicates that a factor about five of the turbulent transport improvement is necessary to explain the obtained high-T_i plasma.

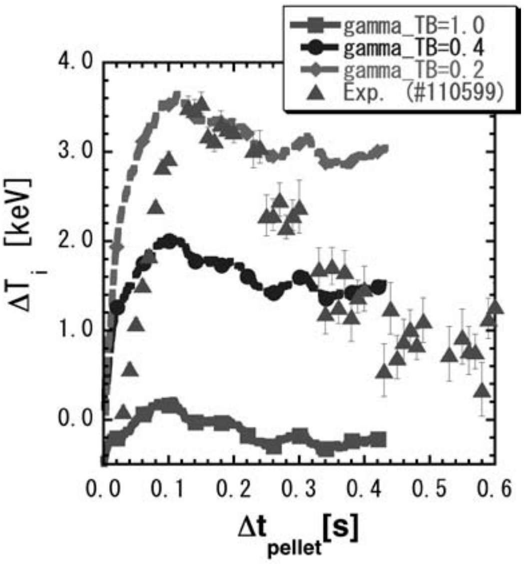

Fig. 1: Time history of ΔT_i with a simple improvement model (top) and with a Z_{eff} depending improvement model (bottom).

1) H. Takahashi et al., Nucl. Fusion **53** (2013) 073034.

2) H. Yamaguchi et al., Plasma Fusion Res., **8** (2013) 2403099.

3) S. Murakami et al., Nucl. Fusion **46** (2006) S425.

4) A. Wakasa, et al., Proc. 39th EPS Conf. and 16th Int. Cong. Plasma Phys., 2012, **P2.028**.