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Integrated Discharge Scenario for High-Temperature Helical Plasma on LHD

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Study of high-temperature plasma is a key for realizing helical fusion reactor, because helical plasmas have good confinement properties in high density regime and a significant advantage in steady state operation. Recently, after the last IAEA-FEC 2012, discharge scenarios for high-temperature helical plasma have been developed in LHD.
An ion ITB was formed in neutral beam injected (NBI) plasmas with wall conditioning and carbon pellet injection. It was observed with a newly installed high-dynamic-range Balmer-alpha spectroscopy that the wall conditioning reduced the neutral density even in the core plasma. The ion heat transport in the ion ITB core is further improved due to reduction of charge exchange loss of fast ions. The carbon pellet injection also enhances the ion ITB formation and enlarges the width of ion ITB. Repetitive helium discharges with duration over 10s were carried out more than 30 times with electron cyclotron heating (ECH) and ion cyclotron heating (ICH) for wall recycling, and central ion temperature of 8keV was achieved with enhanced ion ITB formation.
An ion ITB and an electron ITB were successfully combined with application of localized on-axis ECH to ion ITB with wall recycling and carbon pellet injection, and $T_{e0} \sim T_{i0} \sim 6$keV were achieved. The width of ion ITB is larger than that of electron ITB. The scale length of temperature gradients for ion and electron, R/L_{Ti} and R/L_{Te}, are over 10, indicating simultaneous improvement of ion and electron heat transports. The positive radial electric field was observed in the combined ITBs plasma, while the ion ITB in NBI plasma was formed with negative electric field. The ion temperature gradient at the barrier is observed to decrease with the local temperature ratio (T_e/T_i). It is noted that the improvement of ion heat transport was attributable to the reduction of anomalous transport [1], and it does not depend so much on the radial electric field, but on the temperature ratio (T_e/T_i). As a result of this dependence, the combination of the wide ion ITB and the narrow electron ITB is realized.
This study demonstrated that the profile control is a key to combine ion ITB and electron ITB and have a potential to improve the performance of helical plasmas.

[1] H. Takahashi et al., Nuclear Fusion. 53 (2013) 073034.

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Japan

Author: Mr NAGAOKA, Kenichi (Japan)

Presenter: Mr NAGAOKA, Kenichi (Japan)

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