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Energetic Ion Transport due to Energetic Particle Continuum Mode in Deuterium LHD Plasmas

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Energetic particle transport due to the energetic-particle-driven magnetohydrodynamic (MHD) instabilities in existing fusion devices has been intensively studied in order to find a way to control/reduce the energetic deuterium-tritium fusion born alpha particle transport in a future fusion reactor. In the hydrogen Large Helical Device (LHD) plasma experiment, a study of energetic ion transport/loss due to energetic-particle-driven MHD instabilities such as toroidal Alfvén eigenmode and energetic particle continuum mode (EPM), has been performed using comprehensive energetic particle diagnostics [1, 2]. By starting the deuterium plasma experiment in LHD, information of the energetic particles confined in the plasma core region can be obtained by neutron diagnostics because neutrons are mainly created by the so-called beam-thermal reactions. The transport of helically-trapped beam ion due to the energetic-particle-driven resistive interchange mode has been visualized using the vertical neutron camera and orbit following numerical simulation [3].
Energetic particle transport due to EPM, whose frequency is sufficiently low compared with toroidal Alfvén frequency, has been studied in relatively low-field conditions. The energetic particle diagnostic, i.e., the fast ion loss detector [4], and neutron diagnostics, i.e., neutron flux detector [5] are simultaneously utilized to understand the transport and loss of energetic particles. Three intensive negative-ion-based neutral beam injectors inject the deuterium beam into the low-density LHD deuterium plasma in these discharges. The bursting EPM excited by significant beam ion pressure gradient having the mode number of m/n of 2/1 and the magnetic fluctuation amplitude of $\sim 3{\times}10^{-5}$ T is observed by the magnetic probe position located on the vacuum vessel. The frequency of EPM sweeps from 40 kHz to 20 kHz within 1 ms. The neutron flux detector shows that EPM induces approximately a 10% decrease in total neutron emission rate, suggesting ~10% loss of the beam ions. The fast ion loss detector measurement shows that fast ions rate corresponds to energy/pitch angle of 60-180 keV/~35 degrees and 120-180 keV/~55 degrees increases significantly due to EPM. The EPM enhances the transport of energetic ions having co-going transit and transition orbits.

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[2] M. Isobe et al 2010 Contrib. Plasma Phys. **50** 540.
[3] K. Ogawa et al 2020 Nucl. Fusion **60** 112001.
[4] K. Ogawa et al 2009 J. Plasma Fusion Res. Ser. **8** 655.
[5] K. Ogawa et al 2018 Plasma Fusion Res. **13** 3402068.

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