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Comprehensive magnetohydrodynamic hybrid simulations of fast ion losses due to the fast ion driven instabilities in the Large Helical Device

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In the LHD, the fast ion confinement has been investigated by using three tangentially injected neutral beams (NBs) with 180 keV fast ions and/or two perpendicularly injected NBs with 40-80 keV fast ions. The Alfvén eigenmodes (AEs) are observed during the tangential-NB injections. The fast ion driven instabilities enhance the fast ion losses. It is important to identify the instabilities and clarify the properties of the lost fast ions due to the instabilities.
A hybrid simulation code for nonlinear magnetohydrodynamics (MHD) and energetic-particle dynamics, MEGA, has been developed to simulate recurrent bursts of fast ion driven instabilities including the energetic-particle source, collisions and losses. In order to identify the instabilities and to clarify the process of the fast ion losses in the LHD experiments, MEGA is applied to the LHD plasmas, where fast ion driven instabilities and lost fast ion properties are investigated by using tangential-NBs, with the realistic conditions close to the experiments. In a plasma with tangential-injected neutral beams (NBs), the Alfvén eigenmode (AE) bursts with m/n=2/1 occur recurrently. As a result, the stored fast ion energy is saturated at a lower level than that of a classical slowing down calculation where the magnetohydrodynamic (MHD) perturbations are neglected. Fast ion losses occur during the AE bursts. The fast ion losses brought about by the AE bursts are proportional to the square of AE amplitude, which reproduces well the LHD experiment. This indicates the emergence of stochasticity in the fast ion loss process. The fast ions deposited well inside the plasma up to the magnetic axis are significantly lost for the counter-injected fast ions. We present the first self-consistent simulations that reproduce and clarify the fast ion loss properties in the LHD experiments.

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Author: Dr SEKI, RYOSUKE (National Institute for Fusion Science)

Co-authors: Dr OGAWA, Kunihiro (National Institute for fusion science); Prof. OSAKABE, Masaki (National Institute for Fusion Science); Dr ISOBE, Mitsutaka (National Institute for Fusion Science); Dr SUZUKI, Yasuhiro (National Institute for Fusion Science); Dr TODO, Yasushi (National Institute for Fusion Science)

Presenter: Dr SEKI, RYOSUKE (National Institute for Fusion Science)

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