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Flow damping due to the stochastization of magnetic field in Large Helical Device

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Abrupt damping of toroidal flow associated with a transition from nested magnetic flux surface to a stochastic magnetic field is observed when the magnetic shear at the rational surface decreases to 0.5 in the Large Helical Device (LHD). 1) This flow damping and resulting profile flattening is much stronger than that expected from the Rechester-Rosenbluth model. 2) The stochastization starts from the rational surface and expands radially, and then propagates to the magnetic axis rapidly. 3) The toroidal flow shear shows a linear decay, while the ion temperature gradient shows an exponential decay, which suggests that the flow damping is due to the change in non-diffusive term of momentum transport.

The LHD is a heliotron- type device for magnetic confinement of high-temperature plasmas. When the direction of neutral beam injection (NBI) is switched from co-injection to counter-injection (parallel to anti-parallel to the equivalent plasma current that gives the poloidal field produced by the external coil current), the edge rotational transform decreases due to the beam driven current and the central rotational transform increases due to the inductive current. Then the magnetic shear at the q = 2 rational surface decreases and finally the magnetic field becomes stochastic due to the overlapping of magnetic islands with higher modes.

After the stochastization of the magnetic field, the increase of chi_e is much larger than that of the ions (chi_e/chi_i >15) because of the difference in thermal velocity, which is consistent with the Rechester–Rosenbluth model (~ 40). In contrast, the large effective Prandtl number observed during stochastization (mu_phi/chi_i = 3) is inconsistent with the prediction of the Rechester–Rosenbluth model (~1). Furthermore, there are clear differences in the decay between ion temperature and toroidal flow velocity. The toroidal flow shear shows a linear decay, while the ion temperature gradient shows an exponential after the stochastization of the magnetic field. This result suggests that the damping of flow is due to the change in the non- diffusive term of momentum transport associated with the stochastization of the magnetic field.

References

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