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LHDにおける共鳴摂動磁場印加実験
RMP Experiments in LHD

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The existence of an error field is one of the common problems in magnetic confinement systems because it may degrade plasma confinement and trigger MHD instabilities. The RMP experiments have been done in many tokamaks and RFPs to identify the threshold of error field penetration, which is required for estimating the tolerance to the error field in ITER. Here we have investigated the threshold of the perturbation field strength by changing the RMP field in varying magnetic shear and magnetic hill of LHD so as to find the common physics of the effect of an error field in both tokamaks and helical devices [1]. The magnetic shear can be changed by controlling helical coil pitch parameter, γ_c, where γ_c is defined as $1.282a_c$ and a_c is minor radius of helical coil. When the γ_c decreases from 1.20 to 1.13, the magnetic shear, $(1/\iota)\mathrm{d}\iota/\mathrm{d}\rho$, is reduced from 2.03 to 1.08. The magnetic well/hill is changed by shifting the magnetic axis position (R_{ax}). In the experiments, toroidal field at R_{ax} was set at 0.9 T and balanced neutral beams were applied for plasma heating because of suppression of net toroidal current and toroidal plasma flow. The γ_c and R_{ax} were set at 1.13-1.20 and 3.6-3.75 m, respectively. The RMP field with m/n = 1/1 was ramped-up to 0.8 kA/T during a discharge and both polarity was applied in the experiments.

In the weak magnetic shear configuration with γ_c = 1.13, the magnetic island with m/n = 1/1 appeared even in the case of no RMP, and flattening structure of electron temperature profile was observed around the resonance. The island width increased with negative RMP field. When the positive RMP was applied, the island was suppressed once and increased again with the RMP field. In the strong magnetic shear configuration, RMP field is shielded till RMP current exceeded a threshold. After the penetration, the island had larger size than given RMP field and reduced the total stored energy. Results of different shear experiments indicate that (1) the threshold of the mode penetration linearly increases with the magnetic shear, (2) the size of penetrated island is larger than that given by RMP and (3) the thresholds obtained from both polarity RMP field have an offset. The offset is almost constant in any magnetic shear configurations and corresponds to an error field in LHD. The plasma flow was measured with Charge Exchange spectroscopy in the experiments, and there is no significant difference between different shear discharges.

In order to investigate the effect of magnetic well/hill on the penetration, the magnetic hill was mitigated by shifting R_{ax} to the outward with keeping the strength of the magnetic shear (γ_c = 1.13). The experiments show that the error field was shielded in the mitigated hill configuration (R_{ax} = 3.75m), whereas it appeared in the enhanced hill case (3.6 m). When the R_{ax} was shifted from 3.75 m to 3.6 m during a discharge, the island appeared at R_{ax} < 3.61 m. Finally, the RMP field was ramped up in the mitigated hill configuration and RMP field was not penetrated in the range of I_{RMP}/B_t < 0.8 kA/T, which means that the threshold of the mode penetration is much higher than the enhanced magnetic hill case.

These experiments show that the threshold of the mode penetration has clear dependence of the magnetic shear and/or magnetic well/hill, which suggests that the stability parameter of the interchange stability index (D_I etc.) is one of candidates for the threshold of the penetration in addition to the plasma flow.

[1] S.Sakakibara et al., Proc. Of 24th IAEA Fusion Energy Conference (San Diego, USA, 8-13 Oct. 2012) EX/P4-30.