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Plasma Response to Resonant Magnetic Perturbations in LHD
LHDにおける共鳴摂動磁場のプラズマ応答

Satoru Sakakibara, Yasuhiro Suzuki, Katsumi Ida, Kiyomasa Watanabe, Yoshiro Narushima, Yuki Takemura, Satoshi Ohdachi, Ichihiro Yamada, Kenji Tanaka, Tokihiko Tokuzawa, Hiroshi Yamada, LHD Experiment Group
榊原　悟, 鈴木康浩，居田克巳，渡邊清政，成嶋吉朗，武村勇輝，大舘　暁，山田一博，田中謙治，徳沢季彦，山田弘司，LHD実験グループ

National Institute for Fusion Science
322-6 Oroshi-cho, Toki-shi, Gifu 509-5292, Japan
核融合科学研究所　〒509-5292　岐阜県土岐市下石町322-6

Resonant magnetic perturbation (RMP) experiments have been made in the Large Helical Device (LHD) in order to clarify magnetic configuration dependence of an error field mode penetration. The m/n = 1/1 RMP field was ramped up to different magnetic shear configurations. The experimental results show that the magnetic island appeared when the RMP field exceeds a threshold, and the threshold linearly increased with an increment of the magnetic shear. The island size increased larger than that given by RMP.

1. Introduction

The error field mode, which degrades a plasma confinement property and triggers other MHD instabilities, is the common problem in the magnetic confinement systems. In tokamaks, the error field provides cause of a locked mode by slowing down the bulk plasma flow. The appearance of the error field mode (so-called mode penetration) has been quantitatively estimated through a lot of experiments of tokamaks and RFPs and an empirical scaling has been constructed for ITER operation [1]. Several attractive models have been proposed for an interpretation of experimental results.

In the Large Helical Device (LHD), the natural error field was identified in the electron beam mapping [2], which makes m/n = 1/1 and 2/1 magnetic island. The threshold of the error field strength was confirmed in the standard configuration [3], and the appearance of magnetic island during discharges depends on not only the beta value and collisionality [4], but also the magnetic shear [5]. However, the physical mechanism of the mode penetration is one of unsolved subjects in stellrators/heliotrons. Here we have made the experiments with the resonant magnetic perturbation (RMP) system so as to find the magnetic shear dependence of the mode penetration.

2. Experimental Set-up

The LHD is a heliotron device with a pair of helical coils and three pairs of poloidal coils, and all coils are superconductive. The major and minor radii in the standard configuration are 3.9 m and 0.65 m, respectively. In the experiments, the magnetic axis, R_{ax}, was set at 3.6 m and the plasma aspect ratio, A_p, was increased from 6.6 to 8.3 in order to change the magnetic shear on the m/n = 1/1 resonance. Figure 1 shows the rotational transform profiles in different A_p configurations. The A_p is 5.8 in the “standard” configuration. The rotational transform increases with an increment of A_p, which decreases the magnetic shear on the $\iota/2\pi$ = 1 resonance. The LHD is equipped with ten pairs of perturbation coils and the m/n = 1/1 component is dominantly produced by this RMP system. The RMP current was ramped up to ±0.84 kA/T in this experiments.

The 24 saddle loops were used to identify the size and the location of magnetic island [6] and

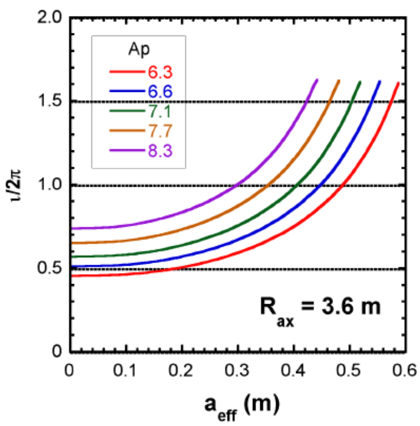

Fig.1　Rotational transform profiles in different A_p configurations.

profiles of electron temperature and density were measured with Thomson scattering system.

3. Experimental Results

The RMP ramp-up experiments were done in the configurations with A_p = 6.6, 7.1, 7.7 and 8.3. Figure 2 shows typical RMP ramp-up discharges in A_p = 8.3 (low shear) and 6.6 (high shear) discharges. The co- and one counter neutral beam injection (NBI) were applied at 1.3 to 3.3 s, and an additional co- NBI was used at 1.3-1.8 s for a production of target plasma. The plasma currents were negligible because of balanced NBI. The RMP current was ramped up to 0.84 kA/T in both cases. In the A_p =8.3 (low-shear) configuration, the magnetic island appeared before RMP current was applied. The island size increases and started to decrease after one NBI was turned off. After that, the island grew with RMP field. In the cases of no RMP, no magnetic island appeared in the configurations with A_p = 7.7, 7.1 and 6.6. In the A_p = 6.6 (high-shear) configuration, the magnetic island was not observed at the beginning of the discharge and appeared at 2.5 s. Then averaged beta was lost by 45 % and the island width was almost the same as the A_p = 8.3 case.

The magnetic shear dependence of the mode penetration is summarized in Fig.3. The error bar corresponds to the results of static RMP experiments. The threshold linearly increased with the enhancement of the magnetic shear. There is an offset of positive and negative threshold data, which is expected to be due to the natural error field. The size and location of the "offset" island are consistent with those of the natural island within the measurement error.

4. Summary

The RMP experiments were made in order to investigate the magnetic shear dependence of the mode penetration. In the lowest magnetic shear configuration with $(1/\iota)d\iota/d\rho \sim 1.08$, the m/n = 1/1 magnetic island appeared even in no RMP discharges, whereas it disappeared when the magnetic shear was increased. In the high magnetic shear case, the RMP field was shielded if it is lower than the threshold. The threshold of shielding of the error field given by RMP linearly increased with the enhancement of the magnetic shear. The positive and negative RMP experiments showed the existence of the natural error field. The results are consistent with the observation in previous mapping experiments.

Acknowledgments

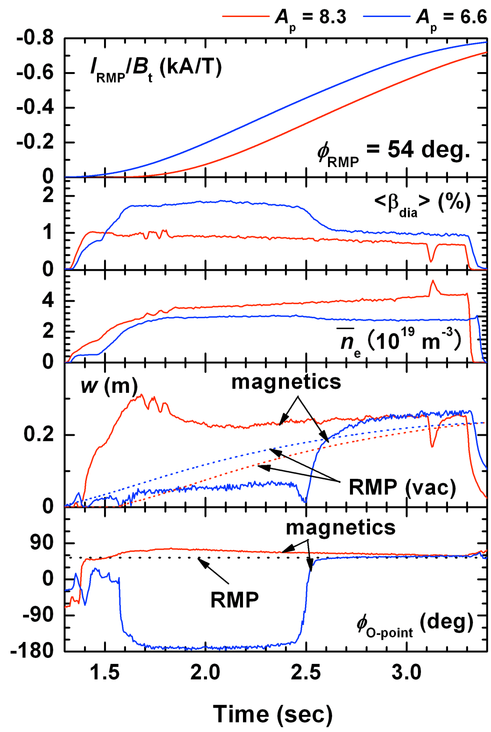

Fig.2 A_p = 6.6 and 8.3 discharges with RMP.

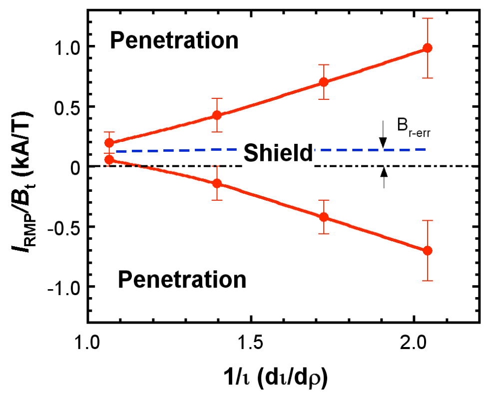

Fig.3 Change of mode penetration as a function of magnetic shear on $\iota/2\pi$=1 resonance.

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