§43. Magnetic Island Formation in LHD

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Magnetic islands can be generated due to the error field in magnetically confined plasmas. It is critical to clarify the physics how the magnetic island grows or shrinks to realize the helical fusion reactor. In the neoclassical tearing mode, which is one of the most critical MHD instabilities in tokamaks, the bootstrap current enlarges a seed island in the same manner of the tearing mode. It has been considered that the bootstrap current also causes the enlargement or reduction of the seed island in LHD [1]. The direction of the bootstrap current can be changed by changing the radius of the magnetic axis R_{ax} in LHD, because the bootstrap current has the geometric factor G_{bs}, as

$$\left\langle j_{bs}B\right\rangle_s \propto \frac{f_t}{f_c} G_{bs}^{1/\nu} P\left(\frac{n'}{n} + c_1\frac{T_i'}{T} + c_2\frac{T_e'}{T}\right) \qquad (1)$$

At iota=1 surface, the direction of the bootstrap current is reversed at R_{ax}=3.575 m in vacuum as shown in Fig. 1(a). Theoretically, the magnetic island width is enlarged as the β is increased due to the bootstrap current if R_{ax} is less than 3.575 m. In the previous experiment, however, the island width is reduced as the electron temperature increases [2].

In order to observe the effect of the magnetic axis position, the error field is applied to the high β plasma with low R_{ax} and low B_{ax}. The n=1 error field is generated by the LID coil current. Fig.1(b) shows the island width (w) versus the normalized LID coil current (I_N) in the case of B_{ax}=1.5 T and β~1 %. Here,

$$I_N = I_{LID}/B_{ax}$$

The island width is increased as the I_N is increased. The island is generated when the I_N exceeds the critical value (I^*_N). Fig. 2(a) shows I^*_N versus R_{ax} in the case of β~1 %. I^*_N is reduced as R_{ax} is reduced.

Interestingly, in the case of R_{ax}=3.53 m and β~1 %, the island width is larger than that in the vacuum field as shown in Fig. 1(b). So, the high β experiment is done in order to clarify the effect of β and the island width is plotted versus I_N in Fig. 2(b). In the case of β~3 %, I^*_N is two times higher than that in the case of β~0.85 %. Since the electron temperature is lower when β~3 % due to lower magnetic field, the electron temperature effect on the island width does not work. This experiment shows that the β has the effect reducing the island width even in R_{ax}=3.53 m, which is almost lower limit of R_{ax} in LHD.

In order to clarify the effect of bootstrap current on the island width, the precise profile of the geometric factor in the higher β should be obtained both in the experiment and in the theory.

[1] N. Ohyabu, et al., Phys. Rev. Lett. **88**, 55005 (2002).
[2] Y. Nagayama, et al., Nuclear Fusion **45**, 888 (2005).

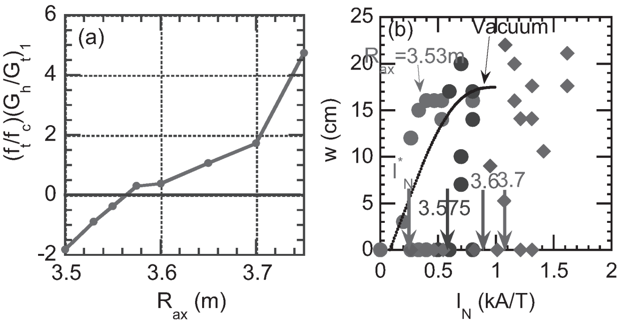

Fig.1 (a) Theoretical geometric factor of the bootstrap current at the iota=1 surface vs the major radius of plasma axis (R_{ax}) in LHD. (b) Island width (w) vs normalized LID coil current (I_N).

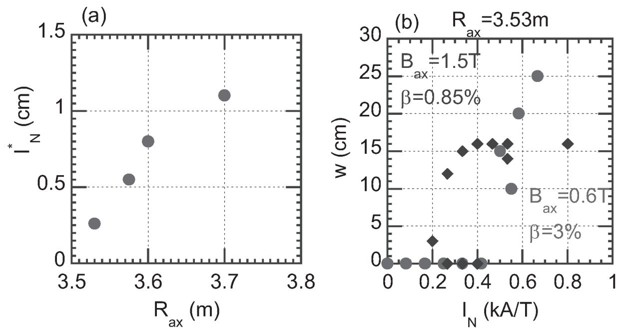

Fig.2 (a) Critical normalized error current (I^*_N) vs R_{ax}. (b) Island width vs. normalized LID coil current R_{ax}=3.53 m.