§23. Experiments of Magnetic Island Formation

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Magnetic islands play important roles in fusion and space plasmas. For instance, in tokamaks, a seed island is enlarged due to the neoclassical effect, and it degrades the plasma performance. It has been considered that the magnetic island structure, which is formed by an error field, could grow and degrade the plasma confinement seriously in a helical reactor. In LHD, it has been observed that the island size is sometimes significantly reduced in the plasma. This is called the 'healing' of the island. The object of this experiment is to answer the question how the magnetic island is formed is an important issue for the realization of a fusion reactor.

By adding an $n=1$ field using 10 pairs of modular vertical field coils, a static magnetic island can be formed around the $q=1$ surface. The calculated flux surfaces agree well with those measured in the vacuum field by an electron beam emission diode. The magnetic island can be observed as a flat region in the electron temperature (T_e) profile, which is measured using Thomson scattering installed at $\phi=342°$ and the ECE diagnostics at $\phi=136°$.

In LHD, the heat conductivity inside the island is 10 times less than that outside the island. The island may become warmer because of low heat loss. An experiment has been done to heat the island with additional NBI heating. Before the additional NBI heating, the T_e profile in the island is flat, and after the heating the T_e at the center of island becomes higher than at the boundary of the island. This indicates that the magnetic island is isolated from the main plasma.

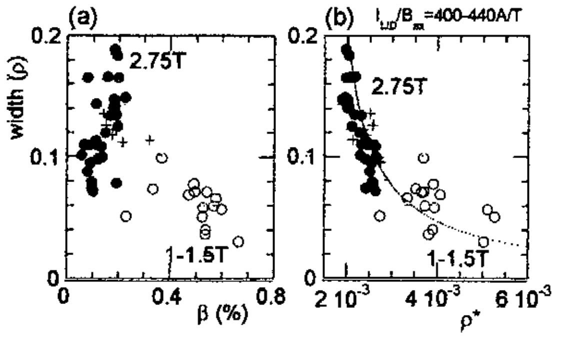

Fig.1 (a) Island width of normalized radius versus beta, (b) island width versus ρ^* in the case of I_{LID}/B_{ax} = 400 - 440 A/T. Closed circles indicate B_{ax}=2.75 T and open circles indicate low field (B_{ax} =1-1.5 T).

The 'healing' phenomenon is as follows: the island is not observed in the plasma, while the island in the vacuum is large. An experiment has been done to cool down the island using the ice hydrogen pellet injection in the case of R_{ax}=3.6 m. The island appears after the pellet injection, but the island width (w) is reduced as the temperature increases. Finally, the T_e profile returns to that before the pellet injection, and the island disappears.

The island width in the plasma depends on the plasma parameters. Fig.1 shows island width of normalized radius versus beta or ρ^* in the case of I_{LID}/B_{ax}=400 - 440 A/T. In the case of high field (B_{ax}=2.75 T), the magnetic island width decreases as the T_e. In the case of low field (B_{ax}=1-1.5 T), the magnetic island width decreases as the beta increases. The island width in vacuum is increased as the n=1 coil current (I_N) increases, but the island in the plasma suddenly appears when it surpasses the threshold of the current. This is another example of 'healing'. Here, the coil current is normalized to B_{ax}. The threshold level is increased as the beta increases.

In the case of lower R_{ax} (such as R_{ax} =3.53 m) the magnetic island is formed from the small residual error field. This is counter phenomenon of the 'healing'. When the island is formed, a large B_r (n=1) is observed. Since the island appears on both sides of the T_e profile, the X-point and the O-point of island are located in the vertical direction on the plasma cross-section at $\phi=342°$. Therefore, the large negative B_r at $\phi=342°$ is made by the (1,1) current flowing at the O-point and/or the X-point. This result may suggest that a sheet current flows on the rational surface and it forms the magnetic island.

The 3-D equilibrium calculation using the 'HINT' code shows that 'healing' of high m island can be due to the Pfirsch-Schlüter currents, but a clear 'healing' of (1,1) island has not been obtained. So the island width is not determined by the MHD equilibrium only. The island width is reduced as R_{ax} increases, in other words, as the magnetic hill reduces in LHD.

In conclusion, the B_r (n=1) is observed when the island grows. This is the first observation of the evidence of the island current in helical systems. The 'healing' effect is more enhanced as the beta or the T_e increases in the case of lower magnetic hill. Further theoretical research is required to understand this result. The magnetic island dynamics should be considered in designing the helical fusion reactor, because of very high values of beta and T_e.