§24. Bifurcation of Equilibria with and without a Large Island in the LHD

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Figure1 shows how the island width (n/m=1/1) changes when externally imposed resonant field and hence w_{ex} (the width of the vacuum island in terms of ρ) increase. When w_{ex} is below 0.17, an island structure is undetectably small in the observed Te-profile. Uncertainty in the profile measurement means that the width must be below 0.04. Plasma dynamics suppresses the island width from 0.17 down to below 0.04, proving existence of a surprisingly strong suppression mechanism. When w_{ex} exceeds a critical value (w_{ex}^*) of 0.17, plasma suddenly can not suppress the island any more and the island grows and becomes 0.22, even larger than the vacuum island. It is a rapid bifurcation of the equilibrium with and without a large magnetic island.

Figure 2 shows density dependence of the island suppression with fixed input power (P). The widths are taken in the discharges with gradual increasing phase of the density ($dn/dt \sim 2\times10^{19}m^{-3}s^{-1}$). The external perturbation field (and hence w_{ex}) is fixed during each discharge. When the perturbation field is high (▼: w_{ex}=0.158), no suppression of the island is seen at any density. For the case with w_{ex} = 0.144 (O), strong island suppression occurs suddenly when the density exceeds a critical value of $2\times10^{19}m^{-3}$, exhibiting a sharp transition from an equilibrium with a large island to non-island equilibrium. This critical value of the density decreases when the external perturbation field becomes weak (see the cases with ⊞: w_{ex}=0.132, ●: 0.118).

The other dependences of the width are : (1) When P is increased with fixed n, island suppression becomes stronger and hence w_{ex}^* increases, (2) For fixed P and n, w_{ex}^* increases with decreasing B. For physics understanding of the mechanism, it may be more appropriate to use dimensionless parameters such as β, ν^*, ρ^* at the surface with ι/2π =1. In the standard LHD operational regime, the shape of the temperature profile is nearly independent of plasma conditions and the temperature (T) at any location $\propto n^{-0.35}P^{0.43}B$ and thus the dimensionless parameters approximately scales as: $\beta \propto n^{0.65}P^{0.43}B^{-1}$, $\nu^* \propto n^{1.7}P^{-0.86}B^{-2}$, $\rho^* \propto n^{-0.17}P^{0.22}B^{-0.5}$.

We find that higher power, higher density and lower magnetic field leads to stronger island suppression. This dependence means that higher β leads to stronger suppression and hence larger w_{ex}^*.

In Fig.3, we combine data with various magnetic field (B) and plot w_{ex}^{*2} as a function of beta. The critical width (w_{ex}^*) is found to almost proportional to $\sqrt{\beta}$. The β-value is that of the bulk plasma. For low density regime ($n<1.5\times10^{19}m^{-3}$), w_{ex}^* tends to become higher than predicted value by the above $\sqrt{\beta}$ scaling. In this regime, however, the beam beta is not small, probably contributing island suppression.

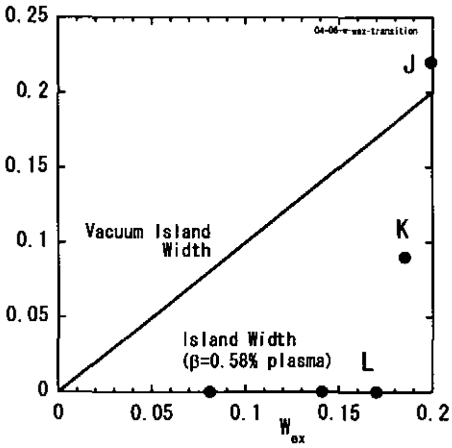

Fig. 1 When w_{ex} (vacuum island width) is increased by increasing external resonant field, the island width is nearly zero and suddenly increases for w_{ex} > 0.17.

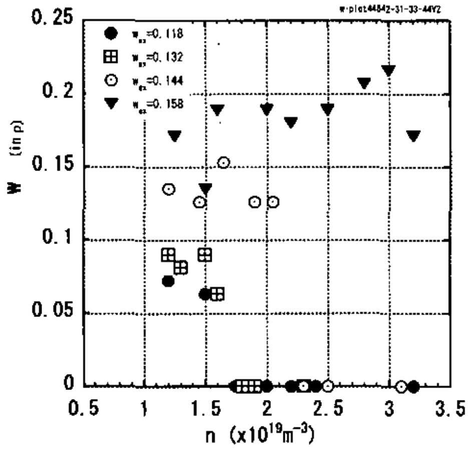

Fig.2 Island width as a function of density for various w_{ex}.

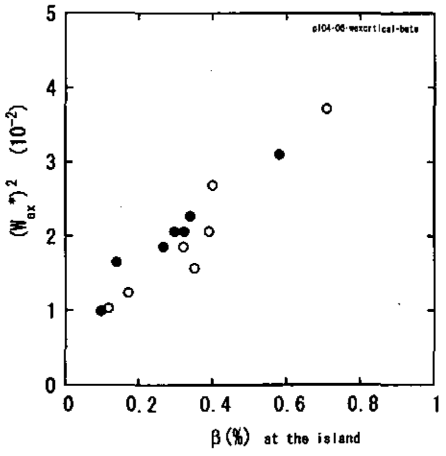

Fig. 3 The critical island width (w_{ex}^*), below which the island is suppressed is plotted as a function of β-value at the island.