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Effect of neoclassical poloidal viscosity and resonant magnetic perturbation on the response of the m/n=1/1 magnetic island in LHD

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In this work we employ FORTEC-3D to investigate the dependence of neoclassical ploloidal viscosity(NPV) on magnetic configuration of LHD, and the effect of resonant magnetic perturbation (RMP) on NPV. From LHD experiments, the threshold of RMP amplitude to penetrate depends on magnetic axis position in LHD. Since the NPV also correlates to magnetic axis position, we investigate how NPV varies in LHD plasmas using measured plasma profiles and taking account of ambipolar electric field. NPV becomes larger as Rax moves outward. We found that m/n=1/1 RMP less than 1% cannot effects NPV.

1. Introduction

Recently the LHD group performed the experiment with m/n=1/1 resonant magnetic perturbation (RMP).[1][2] They observed a response of plasma as increasing/decreasing the RMP amplitude. In the beginning, RMP is shielded. Then, RMP penetrates the plasma when its amplitude exceeds the threshold. The experiment showed that RMP threshold depends on magnetic field configuration. In other words, the threshold correlates to the magnetic axis position in LHD. [3]

In neoclassical theory, the neoclassical poloidal viscosity (NPV) is also related to the magnetic axis position. As a reason, we expected that the RMP threshold, in the procedure, is dominated by the poloidal force balance between electromagnetic force and the drag force, from poloidal rotation.

In this work we employ FORTEC-3D to investigate the dependence of NPV on magnetic configuration of LHD, and the effect of RMP on NPV. This is a basic study toward investigation of the correlation between the threshold of RMP and NPV. Here, poloidal rotation $\vec{E}\times\vec{B}$, from the ambipolar radial flux, is considered in evaluating NPV. In this study, we concentrated on the cases only in which RMP is shielded, and effect of RMP is studied by applying model RMP field.

2. The calculation method

We employ the kinetic equation for plasma distribution function $f(\vec{x},\vec{v})$ and we obtain

$$\frac{\partial f}{\partial t}+\vec{v}\cdot\frac{\partial f}{\partial t}+\frac{e}{m}(\vec{E}+\vec{v}\times\vec{B})\cdot\frac{\partial f}{\partial\vec{v}} = \sum_{a,b} C_{a,b}+S_a \quad (1)$$

Here, $C_{a,b}=C(f_a,f_b)$ is Coulomb collision term and S_a is particle source. Taking moment of (1) yields

$$\frac{\partial}{\partial t}(mn\vec{v})=-\nabla\cdot\vec{\vec{P}}+en(\vec{E}+\vec{u}\times\vec{B})+\vec{R}+\vec{S} \quad (2)$$

In (2) u is mean flow velocity, $\vec{P}$ is pressure tensor, $\vec{R}$ is friction force and $\vec{S}$ is momentum source. [3]

For the poloidal momentum, taking the dot product of (2) and flux-surface average, then we obtain

$$\left\langle\frac{\partial}{\partial t}mn\vec{u}\cdot\hat{e}_\theta\right\rangle = -\langle\hat{e}_\theta\cdot\nabla\cdot\vec{\vec{P}}\rangle+e\langle n\vec{u}\cdot\nabla\psi\rangle+\langle R_\theta+S_{m,\theta}\rangle. \quad (3)$$

In (3) the average flux surface poloidal viscosity $\langle\hat{e}_\theta\cdot\nabla\cdot\vec{\vec{P}}\rangle$ is expanded as

$$\langle\hat{e}_\theta\cdot\nabla\cdot\vec{\vec{P}}\rangle=\frac{1}{2}\left\langle\frac{\partial\delta P}{\partial\theta}\right\rangle=\left\langle\frac{\delta P}{B}\frac{\partial B}{\partial\theta}\right\rangle. \quad (4)$$

Furthermore, $\delta P=\delta P_\perp+\delta P_\parallel$. $\delta P_\perp$ and $\delta P_\parallel$ are respectively defined as

$$\delta P_\perp=\int d^3v\,\frac{m}{2}v_\perp{}^2\delta f \quad (5)$$

and

$$\delta P_\parallel=\int d^3v\,mv_\parallel{}^2\delta f. \quad (6)$$

3. Simulation Result

We scan the magnetic axis form 3.55 to 3.80 for ramped-up and ramped-down RMP experiments respectively as we show in the Figs.1 and 2. Excluding a case, these NPV amplitude correlates to magnetic axis position as the exception from neoclassical theory, as shown in Fig.3. In the Figs.

1 to 4, we investigate NPV amplitude without RMP. In Fig. 5 and 6, we investigate the NPV with different RMP amplitude using a simple model $\delta B \propto (r/a)^2$. Following the simulation result, we are able to see the influence near the resonant surface ($\iota \simeq 1$) if the RMP amplitude $\delta B / B_0$ is larger than one percentage. However, below 0.1% RMP we cannot see any positive correlations between RMP and NPV so far.

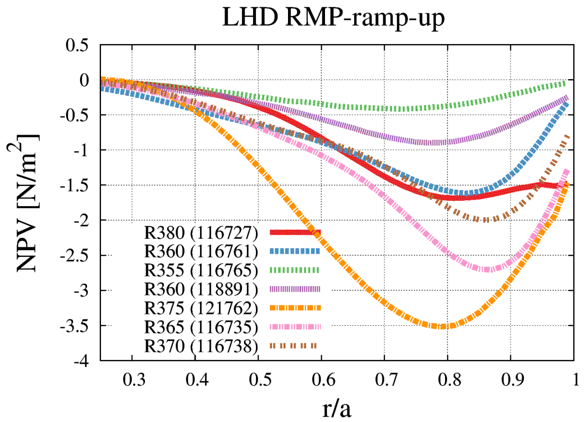

Fig.1 Radial profile of NPV in ramp-up cases

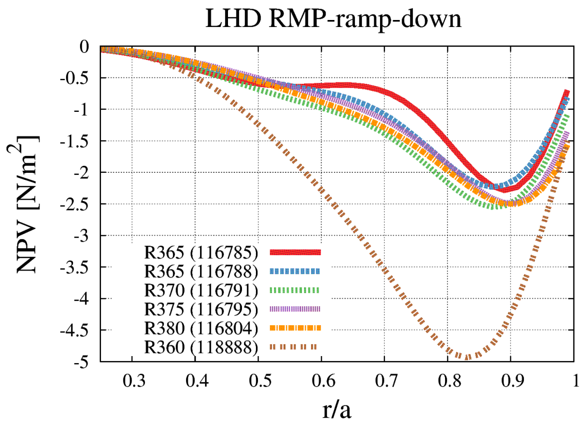

Fig.2 Radial profile of NPV in ramp-down cases

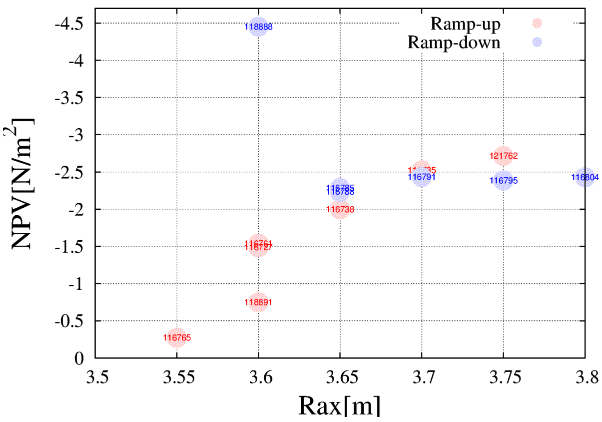

Fig.3 Dependence of NPV on Rax

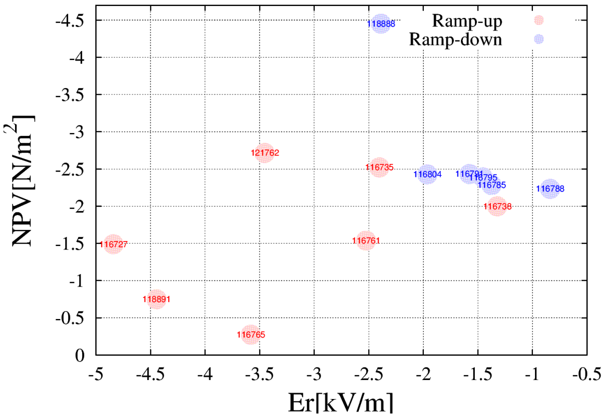

Fig.4 Dependence of NPV on Er

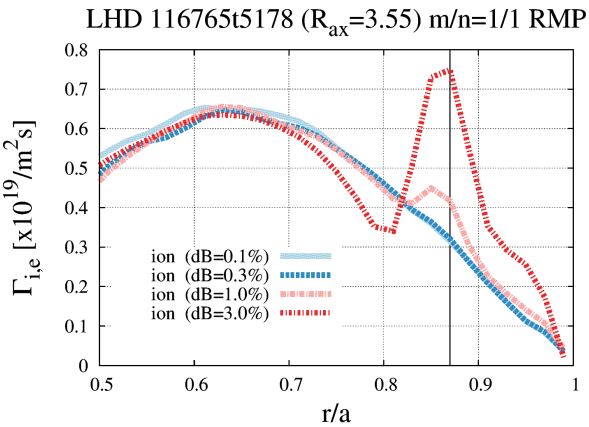

Fig.5 Radial profile of NPV with RMP in a case Rax = 3.55

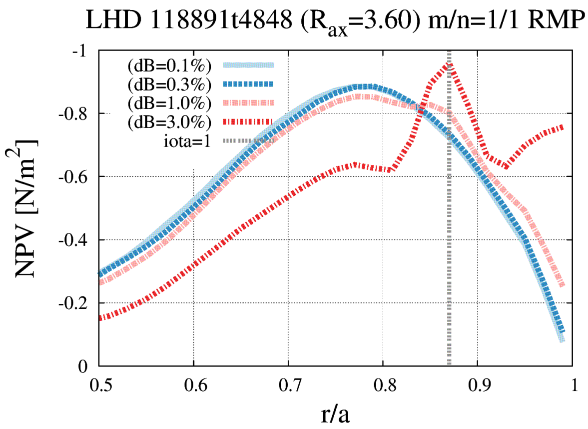

Fig.6 Radial profile of NPV with RMP in a case Rax = 3.60

References

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