Rapid Communications

The Configuration Dependence of Ripple Transport in LHD

YOKOYAMA Masayuki, WATANABE Kiyomasa and NAKAJIMA Noriyoshi

National Institute for Fusion Science, 509-5292 Toki, Japan

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The GIOTA code [1] has been applied to clarify the configuration dependence of ripple transport properties in LHD. The effective helical ripple ($\varepsilon_{\rm eff}$), as a measure of the level of ripple transport, is calculated with a wide range scan of magnetic axis position, ($R_{\rm ax}$) and plasma beta value (β). Our results show that $\varepsilon_{\rm eff}$ takes a minimum value in a wide radial portion around the configuration with $R_{\rm ax}$ = 3.53–3.55 m at vacuum. It is also revealed that $\varepsilon_{\rm eff}$ decreases as β is increased for configurations with $R_{\rm ax}$ of less than the above mentioned range.

Keywords:

GIOTA code, ripple transport, effective ripple, LHD

As introduced in Ref. [1], GIOTA code is a easy-to-use code for evaluating ripple transport properties in helical systems. The magnetic topography can be rigorously treated through the magnetic field spectrum and also the finite rotational transform. To clarify the configuration dependence of ripple transport in LHD by utilizing this capability of the GIOTA code, the effective ripple ($\varepsilon_{\rm eff}$) has been evaluated in a wide range of LHD equilibria. The $\varepsilon_{\rm eff}$ has been frequently considered to estimate the level of ripple transport in helical systems as the comparative parameter among different configurations [2]. This parameter reflects the effect of the multiple helicity of the magnetic configuration on ripple transport. The definition of the effective ripple [2] is

$$\varepsilon_{\rm eff} = \left[\frac{9\sqrt{2}\pi}{16} \frac{\nu}{v_{\rm d}^2} D \right]^{2/3} ,$$

where ν, $v_{\rm d}$ and D are the collision frequency, drift velocity and particle diffusion coefficient, respectively.

Figure 1 shows the contour of $\log(\varepsilon_{\rm eff}^{3/2})$ on the ($R_{\rm ax}$, β) plane for the radial positions of (a) ρ = 0.2, (b) ρ = 0.5 and (c) ρ = 0.8. Here, $R_{\rm ax}$ denotes the magnetic axis position at vacuum configuration, and β the volume averaged beta value. The MHD equilibria for these calculations are based on the fixed-boundary VMEC calculations [3]. This condition corresponds to an operation with a feedback control of the vertical field to keep the plasma position identical to that used in the vacuum configuration. The pressure profile employed for these VMEC calculations is $P(\rho) = P(0)(1\text{–}\rho^2)(1\text{–}\rho^8)$.

This kind of parameter scan calculations in a wide range of configuration space can be relatively easily done by the GIOTA code. This is a significant advantage of this code. The designated numbers denote the value of $\log(\varepsilon_{\rm eff}^{3/2})$ for each contour. The minimum of $\varepsilon_{\rm eff}^{3/2}$ appears around $R_{\rm ax}$ of approximately 3.53–3.55 m regardless of radial position, ρ,

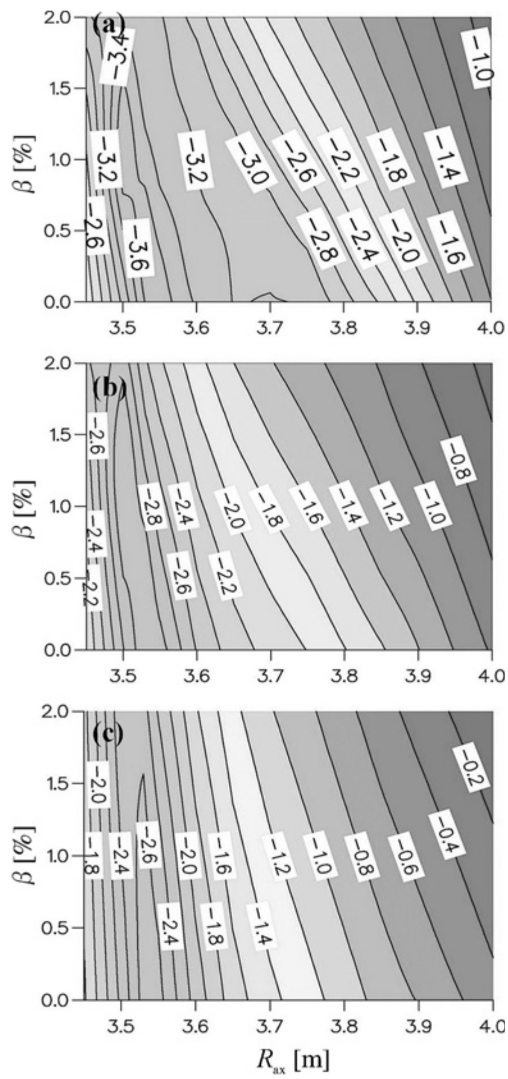

Fig. 1 Contour of $\log(\varepsilon_{\rm eff}^{3/2})$ on the ($R_{\rm ax}$, β) plane for the radial position of (a) ρ = 0.2, (b) ρ = 0.5 and (c) ρ = 0.8, respectively in a wide range of LHD fixed-boundary equilibria.

author's e-mail: yokoyama@nifs.ac.jp

under vacuum conditions. This feature accurately reproduces previous finding of the "neoclassical-optimized configuration in LHD" with the DCOM code [4]. The $\varepsilon_{eff}^{3/2}$ increases as β is increased for configurations with $R_{ax} \geq 3.53$ m. This is not the case, however, for configurations with a smaller R_{ax} value; in such configurations, $\varepsilon_{eff}^{3/2}$ decreases as β is increased in this β range. It is also recognized that this property appears regardless of ρ from plasma core to edge region. This interesting feature indicates the possibility of improving ripple transport in finite-β situations by carefully tailoring the magnetic field structure. No comprehensive understanding has yet been reached of this characteristic. The GIOTA code is an appropriate for this extensive study, since the contribution of each Fourier component of the magnetic field to ripple transport can be systematically specified to clarify the dominant contributor.

For reference, the magnetic axis positions of various VMEC equilibria (from vacuum to finite-β cases) are shown as contour plots on the (R_{ax}, β) plane in Fig.2. A monotonous increase of the magnetic axis position (outward shift) is seen as β is increased, looking in the vertical direction starting from vacuum axis position, R_{ax}. It is interesting to note here that the variation of $\varepsilon_{eff}^{3/2}$ on the (R_{ax}, β) plane is similar to that of the magnetic axis position. Specifically, the minimum region of $\varepsilon_{eff}^{3/2}$ is well aligned with the region whose magnetic axis position is approximately 3.5 to 3.6 m. This fact implies that ripple transport in LHD is strongly correlated with the position of the plasma column. This remarkable feature remains to be investigated in detail.

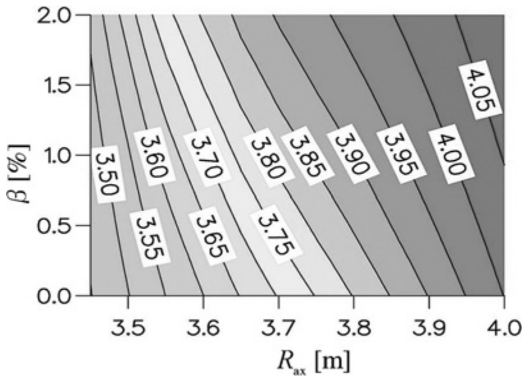

Fig. 2 Contour of the magnetic axis position on (R_{ax}, β) plane in a wide range of LHD fixed-boundary equilibria.

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