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Neoclassical Transport in Helical Magnetic Axis System Controlled by Effective Toroidal Curvature

M. Aizawa, K.H. Saito, I. Kawakami and S. Shiina

Atomic Energy Research Institute, College of Science and Technology, Nihon University, Tokyo, 101-8308, JAPAN

Abstract

The neoclassical transport in the L=1 helical axis stellarlator is investigated. The effective toroidal curvature term ε_T defined as the sum of usual toroidal curvature and one of the nearest satellite harmonics of helical field, determines the confinement properties of localized trapped particle. As one of the methods to control ε_T, we impose the toroidal bumpy field to the L=1 torsatron. We found this field to improve the low collisionality regime particle confinement as same as the negatively pitch modulation method.

1. Introduction

There are two important notices for the helical magnetic axis system to consider good confinement properties. The first is the formation of the largest magnetic islands at the lowest-order rational surfaces because they couple nonlinearly most readily to the non-resonant vacuum magnetic Fourier components, the helical magnetic axis field and toroidal field, which cause indirect resonant pressure driven currents at every rational surface and form the islands [1]. This result requires the large periodic field number *N*. The second is the role of the effective toroidal curvature term for localized trapped particles defined as the sum of the toroidal field and bumpy field. It determines the collisionless confinement conditions of helically trapped particles. We have reported that this small effective term leads to the good collisionless confinement of helically trapped particles [2,3]. Then, we have controlled this effective term by two methods. The first method is the pitch modulation of winding law for helical coil, the second is applying the bumpy field by the toroidal field creation coils (circular loop coils). In this paper we apply the second case to reduce the effective toroidal curvature.

2. Effective Toroidal Curvature and Toroidal Bumpy Field

The magnetic field strength B in magnetic coordinates (ψ, θ, ϕ) on a given flux surface

Fig.1 The L=1 torsatron with no pitch modulation. The main field components and the effective toroidal curvature ε_T .(upper) The transport integral S

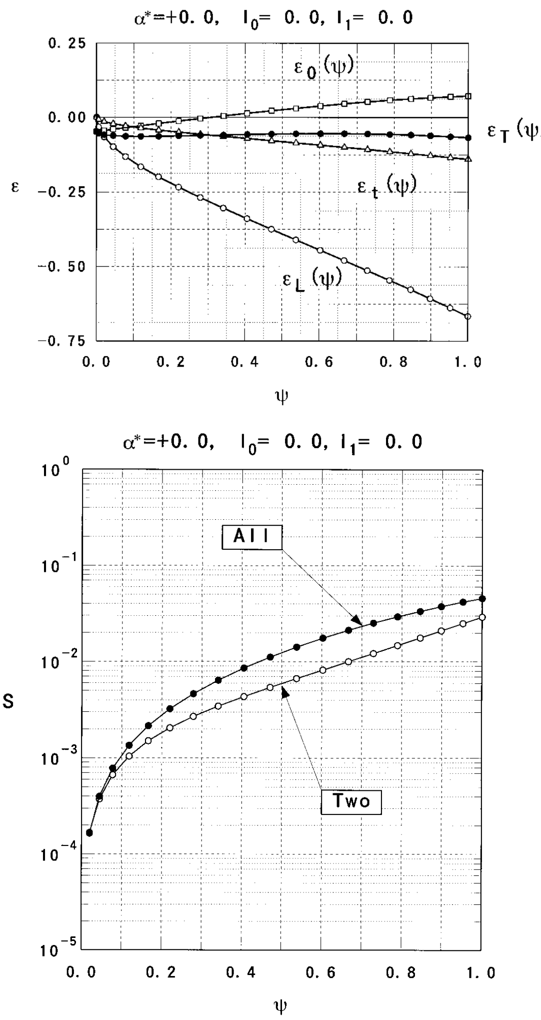
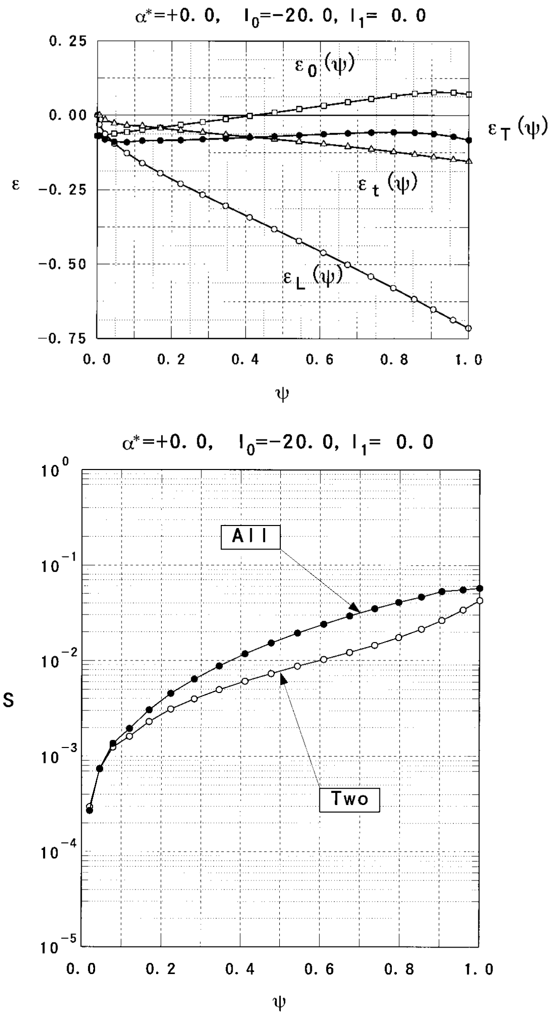


Fig.2 The toroidal field is increased.



ψ =const. is represented by its Fourier components $B_{n,m}(\psi)$ as follows,

$$B(\psi,\theta,\phi) = B_{0,0} + 2 \sum_{(n,m)\neq(0,0)} B_{n,m}(\psi)\cos(n\phi - m\theta) .$$

With the rotational transform $\iota / 2\pi << N$ in present case (N=17, R/a=8.4), we can set $\theta \sim N\phi$ [3], so that the main L=1 field is rewritten by

$$B \sim B_{0,0}\left[1 + \varepsilon_T \cos\theta + \varepsilon_L \cos(N\phi - \theta) + \cdots\right].$$

Here, ε_T is defined as $2(B_{0,1} + B_{N,0}) / B_{0,0}$, which gives an effective toroidal curvature term for localized trapped particles rather than usual toroidal curvature term $\varepsilon_t (\equiv 2B_{0,-1} / B_{0,0} < 0)$. The term ε_L represents $2B_{N,1} / B_{0,0}$. Defining ε_0 as $2B_{N,0} / B_{0,0}$, we obtain the relation

Fig.3 The toroidal field and mirror ratio are increased.

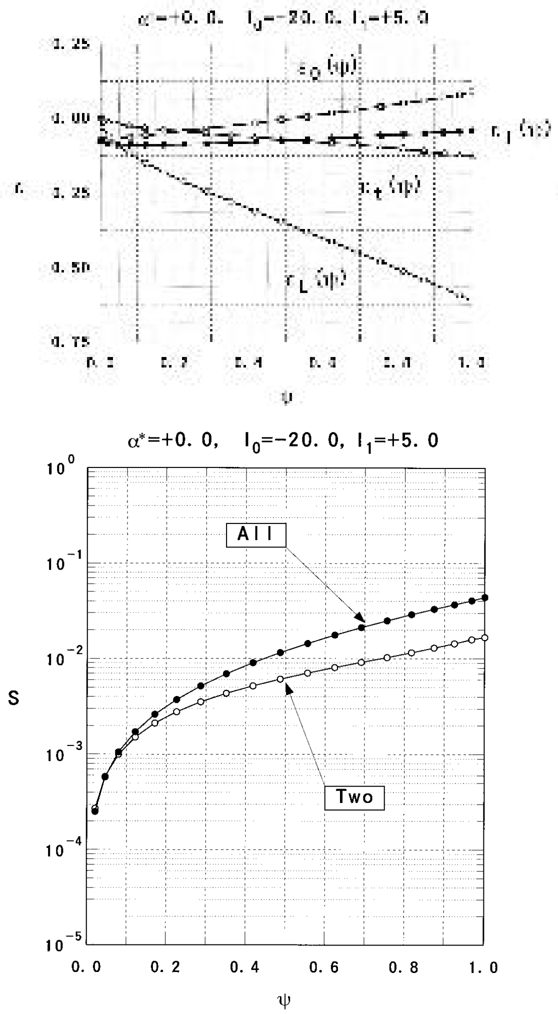
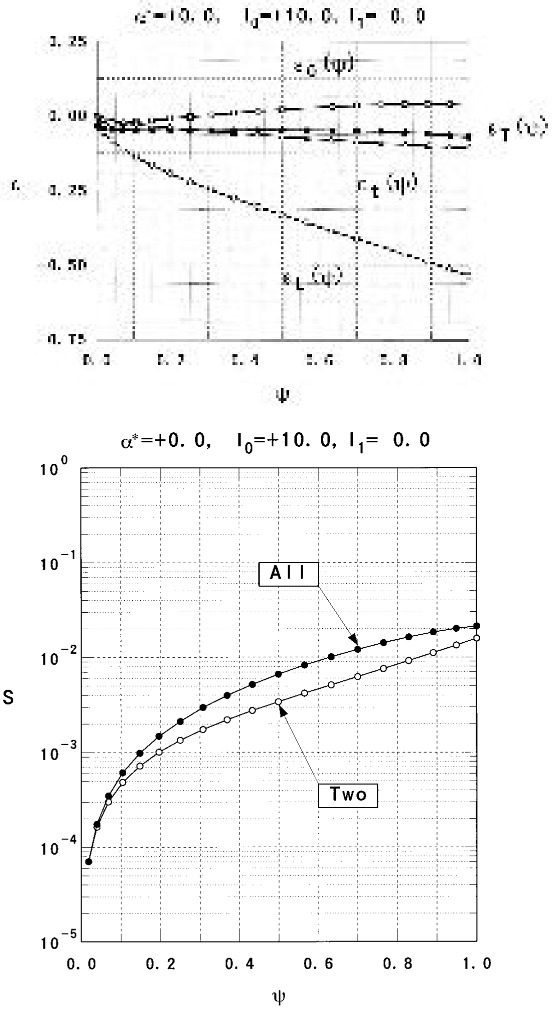


Fig.4 The toroidal field is decreased. (The loop current direction is opposite against Fig.2-3.)



$\varepsilon_T = \varepsilon_t + \varepsilon_0$. These field components are shown in each upper part of Fig.1-4, where ψ is normalized to the outermost flux surface $\psi = 1$. Figure 1 shows the case of L=1 torsaton with no pitch modulation($\alpha^* = 0.0$). On this configuration, we have imposed the toroidal field by N loop coils with current(I_0) of 1/5 of helical coil current(Fig.2). The mirror ratio of bumpy field is also changed (30% up) by adjusting the current(I_1) in the supplementary loop coils between main loop coils(Fig.3). Figure 4 shows the case of reversed toroidal field direction produced by main N loop coils. It is noteworthy that ε_0 becomes positive in the outer region in each case, hence ε_T becomes small in the outer region. The reduction of ε_T is clear in case of Fig.3.

3. Neoclasical Transport

When we consider the collisional plasma, the $1/\nu$ collisionality regime, is characteristic for standard stellarators due to the symmetry break effect of satellite harmonics (B_{N0} etc.). In this regime, both particle and heat fluxes are proportional to the neoclassical transport surface integral S [4], which depends only on the geometric parameters ε_t , ε_L and ε_{L+i} ($i \neq 0$, satellite harmonics). The lower parts of Fig.1-4 show these transport integrals. The word Two in these figures means that we evaluate integral by using only two harmonics ($i = 0, -1$) and ε_t . On the other hand, All means that all terms in the theory are used. Each Two case suggests good transport properties in all cases (Fig.1-4). In the case of Fig.4, all Fourier components are decreased and S is the smallest. The consistency of this result with decreasing uniform field(B_{00}) is now under studying.

4. Conclusion

The first method by the negative pitch modulation can attain low transport and confine helically trapped collisionless particles, where the effective toroidal curvature term becomes flat and small value in the whole confinement region, especially in case of $\alpha^* = -0.2$ [3]. We confirmed that the second method which described in this article, also reduce the effective toroidal curvature term. As contrasted with first method, the second method can t flatten this term usually. However, when we consider compact system with low aspect ratio and small N value, this method would plays important role on ε_T control keeping the compatibility with magnetic well formation.

References

[1] K.H.Saito,M.Aizawa,K.N.Saito,I.Kawakami and S. Shiina.;
17th IAEA Fusion Energy Conference(Yokohama) IAEA-CN-69/THP1/09(1998).
[2] M.Aizawa,K.H.Saito,I.Kawakami and S.Shiina;
Proceedings of the 26th EPS Conference on Controlled Fusion and Plasma Physics
(Maastricht, 1999), 449(1999).
[3] M.Aizawa and S.Shiina; Phys. Rev. Lett. **84**, 2638(2000).
[4] K.C.Shaing and S.A.Hokin; Phys. Fluids **26**, 2136(1983).