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Transport Properties of Low Aspect Ratio L=1 Helical Systems

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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 particles. As one of the methods to control ε_T, the negatively pitch-modulation is applied to the low coil aspect ratio and small periodic number system which stands out a toroidal effect, and we have found that our methods are more effective to decrease a neoclassical transport compared with a large aspect ratio case.

1. Introduction

The L=1 helical axis systems applying the control of effective toroidal curvature term ε_T defined as the sum of usual toroidal curvature term ε_t and one of the nearest satellite harmonics of helical field term ε_0, have been studied to improve particles confinement properties[1]. The trapped particle confinement in the L=1 helical system with a large field period number N is considerable satisfactory by the particle orbits tracing, the longitudinal adiabatic invariant J method and calculating the neoclassical transport particle and heat fluxes. If we consider a compact system, a small N and low aspect ratio system is desirable[2]. The transport properties of these compact systems have been studied.

2. Four type different coil aspect ratio devices

We have examined four type devices with different coil aspect ratio $A_C \equiv R_0 / a$, where R_0 is major radius and a is minor radius, respectively. A minor radius is hold constant $(= 0.3[m])$ in each case. The length of one helical field period is also fixed with standard case $N_0 = 17$ device[1] so that new coil aspect ratio will be obtained for an appropriate N by $A_C = NA_{C0} / N_0$. The subscript "0" denotes standard device case. This approach makes the toroidal effect clear in transport studies. The maximum excursion length Δ of magnetic axis around a geometrical center of minor radius is fixed and an average radial position is also at that center. These configurations are attained by controlling a ratio of vertical field coil current to helical coil current. The characteristic parameters are summarized in the Table. 1.

Period Number	$R_0\,[m]$	A_C	$\Delta\,[m]$	$I_V / I_H \quad (I_H = const.)$		
				$\alpha^* = -0.2$	$\alpha^* = 0.0$	$\alpha^* = +0.2$
$N_0 = 17$	2.1	7.0	0.03	0.271	0.192	0.116
$N = 12$	1.482	4.94	0.03	0.321	0.243	0.167
$N = 8$	0.988	3.293	0.03	0.386	0.3087	0.2347
$N = 5$	0.617	2.057	0.03	0.4458	0.3725	0.3048

Table.1 : The characteristic parameters of four type devices.

3. Neoclassical transport and effective toroidal curvature

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 a role of the effective toroidal curvature term ε_T for localized trapped particles. 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. Compared with the bumpy field control methods, the pitch modulation method is easy and effective to control ε_T. When we consider 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 $S(\psi)$ [3]. The transport properties of small *N* systems will be worse than that in the larger *N* systems. But, the magnetic well control is comparatively easy and device becomes compact. So, we have studied the four type devices as described before, and the Fourier components of magnetic field strength are analyzed by constructing the Boozer coordinates to evaluate S. The three surface integral S corresponding to pitch modulation parameter against a normalized magnetic surface ψ, are shown in Fig.1-4, and the reduction of transport is observed in case of negatively pitch-modulation. The large aspect cases Fig.3,4 show that the transport of $\alpha^* = -0.2$ case is the smallest of the three cases in the core plasma region($\psi < 0.5$). We can see also the enlargement of radial transport in the outer region ($\psi > 0.5$), but the total loss is insignificant by consideration of the particle density in the outer region. On the other hand, the low aspect cases Fig.1,2 show that the reduction of radial transport is observed in the entire region.

4. Conclusion

We have examined neoclassical transport for low aspect ratio devices by controlling a pitch-modulation parameter α^*. The transport properties are worse than the large aspect device because of relatively large toroidal effect. Though absolute value of radial transport is still large, we have found that our methods are more effective to decrease a neoclassical transport compared with a large aspect ratio case. When we consider the compact system with low aspect ratio and small N value, it is expected that the effective toroidal curvature would play important roles keeping the compatibility with magnetic well formations.

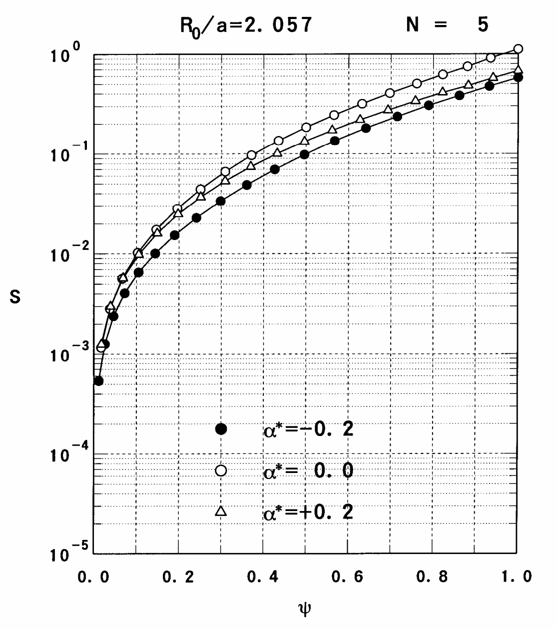

Fig.1 : Three type N=5 system devices.

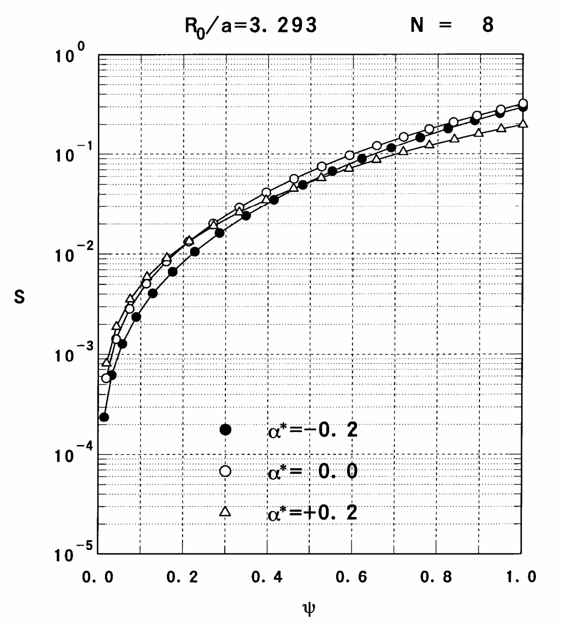

Fig.2 : Three type N=8 system devices.

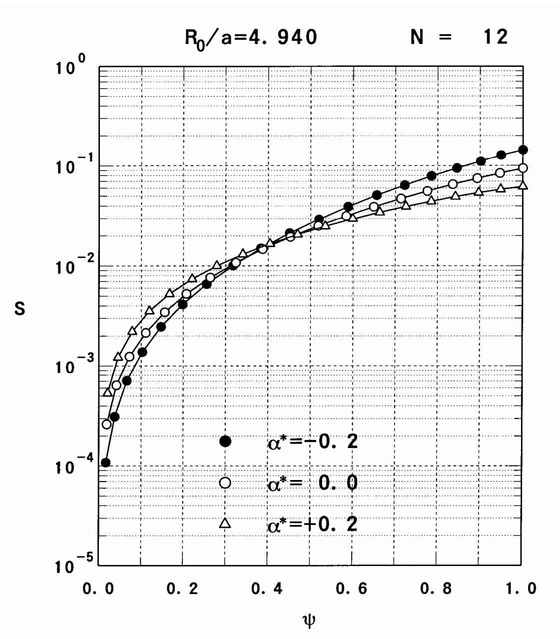

Fig.3 : Three type N=12 system devices.

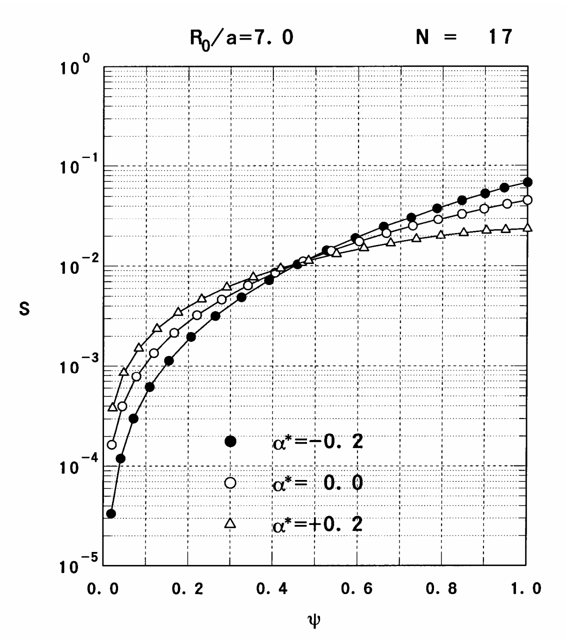

Fig.4 : Three type N=17 system devices.

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