33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-4.142 (2006)

Improvement of Particle Transport Properties in Low Aspect Ratio L=1 Helical Systems

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Abstract

The L=1 helical axis systems applying the control methods of effective toroidal curvature term, have been studied to improve particles confinement properties. The trapped particle confinement in this helical system with a large field period number *N* is considerable satisfactory by various methods. If we consider a compact system, a small *N* and low aspect ratio system is desirable. In generally, particles transport properties of compact system become worse due to usual toroidal effect. We have improved particles transport by controlling the effective curvature term. It has been found that improving rate of particle confinement has become high in case of low 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 other coil aspect ratio will be obtained for an appropriate N by $A_C = NA_{C0} / N_0$. The subscript "0" denotes standard device case. The basis parameters are a major radius R_0=2.1[m] and an aspect ratio A_{C0}=7.0. The three other devices are $N = 12, 8, 5$. This approach makes the toroidal effect clear in transport studies. The maximum excursion length Δ (=0.03[m]) of magnetic axis around a geometrical center of minor radius is fixed and an average radial position is also at that center in each device. These configurations are attained by controlling a ratio of vertical field coil current to helical coil current [2].

3. Collisionless particle confinement 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], where ψ is a magnetic flux function normalized by the outermost surface flux. 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 investigated the collisionless 410 test particles confinement and velocity space loss region for the four type devices as described before. The maximum test particles energy is set at 10KeV. The particle loss boundary is a surface of torus region with major radius R_0 and minor radius $0.95a$, and starting point is set at magnetic axis in any cases. The results are shown in Fig.1. We can see that the particle confinement becomes worse in low N (low A_C) case as expected. But, the low N case, especially N=5 case, the particle confinement is influenced by the pitch modulation parameter and shows that the transport of $\alpha^* = -0.2$ case is improved confinement properties. These results are consistent with the above mentioned neo-classical theory, as shown in Fig.2. In this figure we can see the reduction of neo-classical transport in the entire ψ region in case of negative pitch modulation. On the other hand, the high aspect ratio cases show that the efficiency of improvement is not so large in our particle tracing calculation.

4. Conclusion

We have examined the collisionless particle confinement properties in the zero-beta magnetic field of low coil aspect ratio devices. The neoclassical transport theory for low aspect ratio devices explains the particle tracing results. 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.

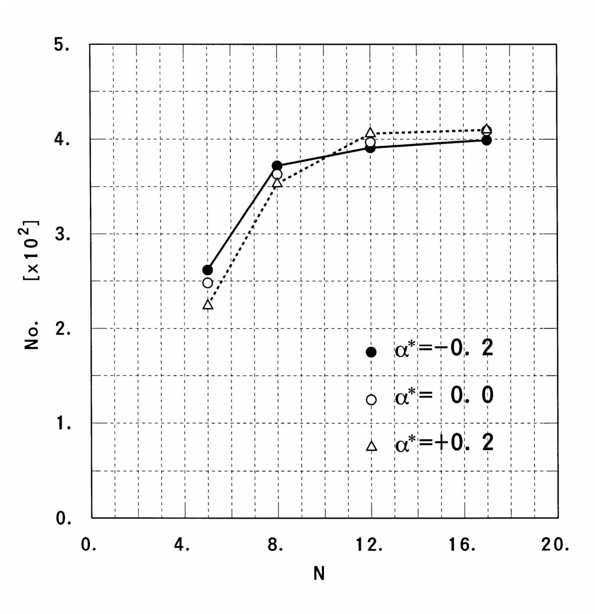

Fig.1 : Confined particles number against a field period number N and a pitch modulation parameter $\alpha *$.

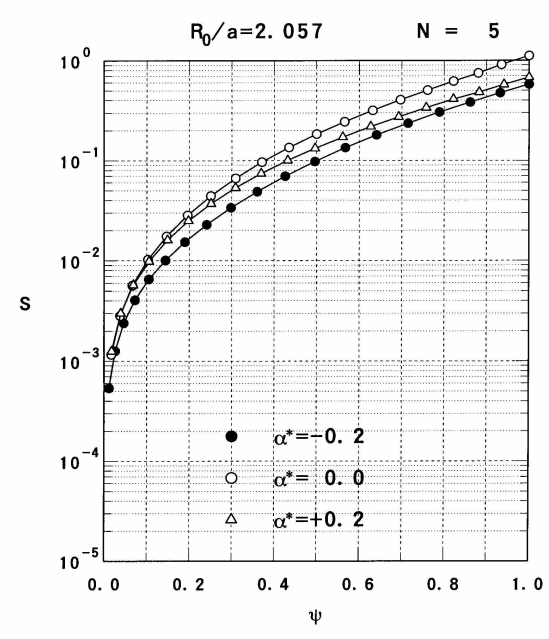

Fig.2 : Neo-classical Surface integrals for three type N=5 system devices.

References

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