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# Improved Magnetic Field 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. If we consider a compact system, the small field periods number and low aspect ratio system is desirable. In generally, particles transport properties of compact system become worse due to usual toroidal effect. We have been studied by the same methods described above, and we have improved particles transport.

## 1. Introduction

The L=1 helical axis systems applying the control of effective toroidal curvature term $\varepsilon_T$ defined as the sum of usual toroidal curvature term $\varepsilon_t$ and one of the nearest satellite harmonics of helical field term $\varepsilon_0$, 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.

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## 2. Consideration of different coil aspect ratio devices

We have examined mainly 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 $\Delta$ (=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. Magnetic field properties of low aspect system

For L=1 case, the magnetic field strength $B$ is approximately

$$\frac{B}{B_0} = 1 + \varepsilon_T \cos\theta + \varepsilon_L \cos(N\varphi - \theta),$$

where $\varepsilon_T = \varepsilon_t + \varepsilon_0$, $\varepsilon_t = 2B_{0,1} / B_{0,0}$, $\varepsilon_0 = 2B_{N,0} / B_{0,0}$, $\varepsilon_L = 2B_{N,1} / B_{0,0}$ and $B_{n,m}$ are the amplitudes of the corresponding harmonics $\cos(n\varphi - m\theta)$.

In L=1 case, helicaly trapped particle feels effective toroidal curvature $\varepsilon_T$ rather than usual toroidal curvature $\varepsilon_t$. 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. This phenomena are clearly seen in N=17 large aspect ratio case[1]. Compared with the bumpy field control methods, the pitch modulation method is easy and effective to control $\varepsilon_T$. When we consider collisional plasma, the $1/\nu$ collisionality regime is characteristic for standard stellarators due to the symmetry break effect of satellite harmonics. In this regime, both particle and heat fluxes are proportional to the neoclassical transport surface integral $S(\psi)$ [3], where $\psi$ 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. So, we have investigated the collisionless test particles confinement in both Cartesian and Boozer coordinates systems. The velocity space loss regions have been studied 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 $0.95a$ in Cartesian case, and $\psi = 0.95$ in Boozer case, and starting point is set at magnetic axis in any cases. The Cartesian case results were shown in the following Figures. We can see that the particle confinement becomes worse in low *N* ( low $A_C$) case as expected in Figure 1. But, the low *N* case, especially *N*=5 case, the particle confinement is influenced by the pitch modulation parameter $\alpha *$. And the confinement properties of negative $\alpha *$ cases are improved as shown in Figure 2. These results are consistent with the above mentioned neo-classical theory, and the reduction of neo-classical transport in the entire $\psi$ region in case of negative pitch modulation.

## 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. In this situation, we have also examined magnetic field structure and its desirable properties through mode analysis. The Hamiltonian properties of magnetic field line are now understudying.

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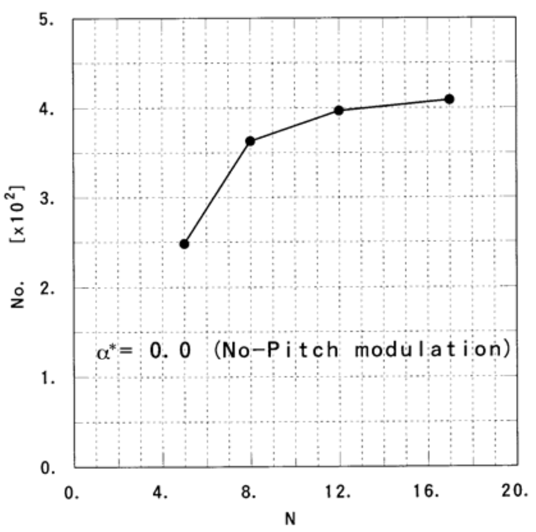


Fig.1 : Confined particles number against a field period number N and a pitch modulation parameter $\alpha$*.

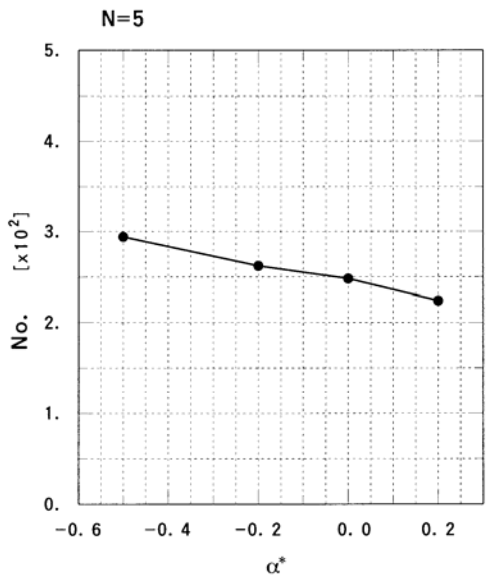


Fig.2 : Confined particles number against a pitch modulation parameter $\alpha$* for N=5 system devices.

References

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