# Magnetic Field Structures of Improved Low Aspect Ratio L=1 Helical Systems

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**Abstract**

The L=1 torsatron systems having a spatial magnetic axis have been studied. If we consider a compact system, a small pitch number of the helical magnetic field *N* and low aspect ratio system is desirable. The transport properties of this compact systems with *N*=5 are described. The particles confinements are evaluated by the Boozer coordinate cases and the real space Cartesian coordinates cases. And we have improved a particle transport by controlling the effective curvature term.

## 1. Introduction

The trapped particle confinement in the L=1 helical system with a large *N* is considerable satisfactory by the particle orbits tracing and calculating the neoclassical transport particle and heat fluxes[1]. This helical axis systems applying the control of effective toroidal curvature term $\varepsilon_T$ defined as the sum of usual toroidal curvature term and one of the nearest satellite harmonics of helical field term, have been studied to improve particles confinement properties[2]. If we consider a compact system, a small *N* and low aspect ratio system is desirable. The transport properties of these compact systems have been studied[3].

## 2. Consideration of different coil aspect ratio devices

We have examined several type devices with different coil aspect ratio $A_C \equiv R_0 / a$. A minor radius $a$ is hold constant $(= 0.3[m])$ and a helical coil current is 1000[kA] in each case. The length of one helical field period is also fixed with standard case $N_0 = 17$ device 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 $\Delta$ of magnetic axis around a geometrical center of minor radius is fixed and an average radial position is also at that center. The characteristic parameters are summarized in the reference[3].

**3. Particle confinement**

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. We have investigated the test particles confinements under the assumption of no-collision by two methods, simultaneously. One method is calculated by using Cartesian coordinates in the real space. The particle loss boundary is set by the surface of simple torus region with major radius $R_0$ and minor radius $0.95a$. Another method is calculated by using Boozer coordinates. In this case, the particle loss boundary is set by the outermost magnetic surface. The test particles energy are set at 0.9-10KeV with equal velocity intervals and equal velocity pitch angle distribution from 0 to $\pi$, and starting point is set at magnetic axis in any cases. In the Boozer coordinate, the starting point is slightly away from magnetic axis because of its singularity. It seems that the test particle tracing from the axis informs us the basic radial behavior of core plasma in these devices. The results are shown in Fig.1. This figure shows the confined particle rate defined by the ratio of confined particles number to all test particles number after long time particles tracing.

### 3. Pitch-modulation and effective curvature effects

We can see that the particle confinement becomes worse in low $N$ ( low $A_C$) case as expected, and two methods show similar behavior. But, the particle confinement rate can be controlled by the pitch modulation parameter, and improvements of confinement properties are achieved by the negative pitch modulation. 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 this case, helicaly trapped particle feels effective toroidal curvature $\varepsilon_T$ rather than usual toroidal curvature $\varepsilon_t$. It determines the collisionless confinement conditions of 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]. Figure 2 shows the magnetic surface dependencies of $\varepsilon_T$ against $\alpha *$, and are consistent with confinement rate. We have also evaluated the neo-classical transport coefficients for these devices as described in the ref.[3], and their results explain qualitatively in the core region as shown in Figure 3.

### 4. Conclusion

We have examined the test particle confinement properties in the zero-beta magnetic field of low coil aspect ratio devices. Though absolute value of radial transport is still large, we have found that our methods are effective to decrease a transport as 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. The field line Hamiltonian properties in the low aspect systems are now under constructing.

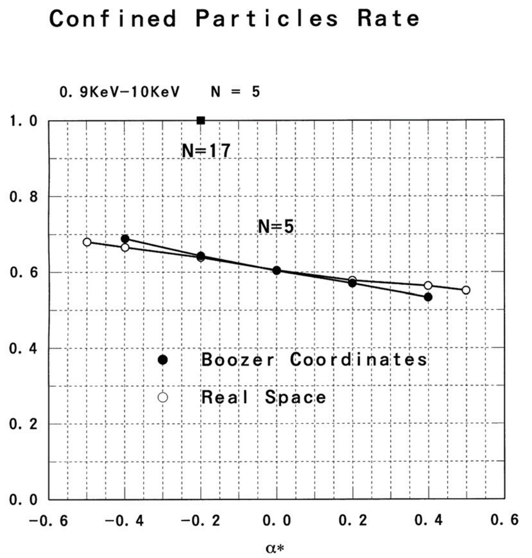


**Fig.1 :** The confined particles rates defined by the ratio of confined particles number to all test particles number after long time particles tracing, are shown against $\alpha*$. The two methods are similar behavior.

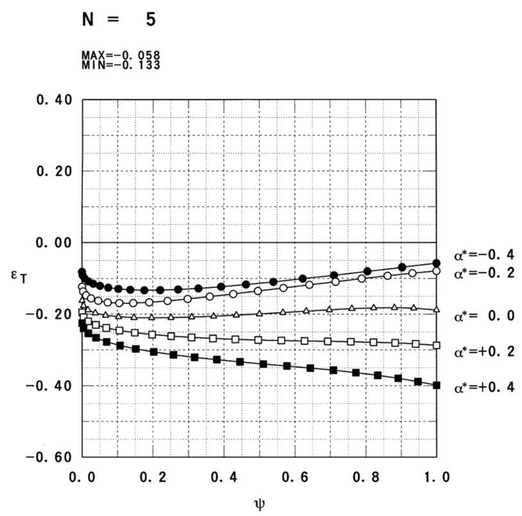


**Fig.2 :** The magnetic surface dependency of effective curvature term against $\alpha*$ in the $N$=5 helical systems.

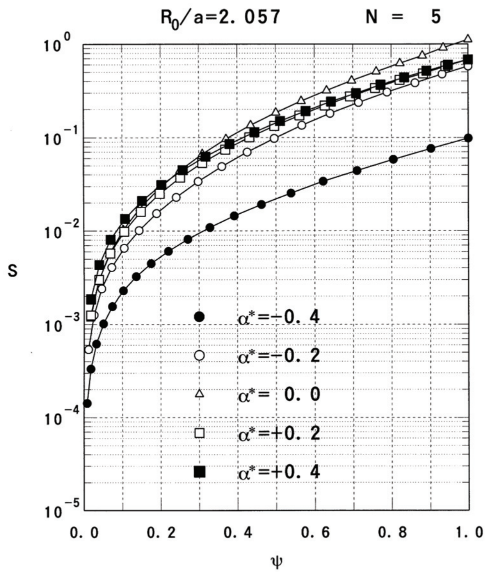


**Fig.3 :** Neo-classical Surface integrals for Five types $N$=5 system devices.

## References

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