Improved Particle Confinement by Magnetic Field Controll
in Low Aspect Ratio L=1 Helical Systems

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Abstract

The L=1 torsatron systems having a spatial magnetic axis are described. The trapped particle confinement in the L=1 helical system with a large pitch number of the helical magnetic field N is considerable satisfactory by the particle orbits tracing 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. The transport properties of this compact system have been studied, and we have improved a particle transport by controlling the effective curvature term.

1. Introduction

The L=1 helical axis systems applying the control of effective toroidal curvature term 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[1]. The trapped particle confinement in the L=1 helical system with a large pitch number of the helical magnetic field N is considerable satisfactory by the particle orbits tracing, the longitudinal adiabatic invariant J method and calculating the neoclassical transport particle and heat fluxes[2]. If we consider a compact system, a small N and low aspect ratio system is desirable[3]. The transport properties of these compact systems have been studied.

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 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.

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.

So, we have investigated the 410 test particles confinement under the assumption of

no-collision. The maximum test particles energy is set at 10KeV. The particle loss

boundary is set by the surface of simple torus region with major radius R_0 and minor

radius $0.95a$, and starting point is set at magnetic axis in any cases. The devices

considered in this study are all aligned that each average magnetic axis is positioned on a

minor axis of toroidal shape container. So 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 number of confined particles after long time particles

tracing. We can see that the particle confinement becomes worse in low N (low A_C) case

as expected. But, the particle confinement properties can be controlled by the pitch modulation parameter. The confinement properties in N=5 case are improved by the negative pitch modulation. 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 low aspect ratio coil device, especially $N = 5$ device, the effect of a negative pitch modulation improves the trapped particle confinement properties against the pitch modulation parameter $\alpha *$ as shown in Fig.2. The initial conditions are all same $(v_\perp, v_{//}) = (3.08, 0.243[\text{keV}])$ in these calculations. It is favorable for trapped particle to acquire the velocity component v_r toward the minor axis of helical coil system. The value of v_r is oscillating rapidly in time. The effective value is calculated by taking a short time average. This short time average is evaluated as the average of a bottom and peak value through one cycle. The time dependency of this effective value against each $\alpha *$ value explains the particles behavior in Fig.2.

4. Conclusion

We have examined the test particle confinement properties in the zero-beta magnetic field of low coil aspect ratio devices. The transport properties are worse than the large aspect device because of relatively large toroidal curvature effect in the low aspect case. 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.

N	$R_0\,[m]$	Circular vertical field coil current I_c [kA]						
		$\alpha^* = -0.5$	$\alpha^* = -0.4$	$\alpha^* = -0.2$	$\alpha^* = 0.0$	$\alpha^* = 0.2$	$\alpha^* = 0.4$	$\alpha^* = 0.5$
17	2.1	386.60	347.70	271.0	192.0	116.0	41.63	5.88
12	1.482	440.43	400.30	321.0	243.0	167.0	94.01	59.04
8	0.988	507.01	466.11	386.0	308.7	234.7	164.78	131.74
5	0.617	564.13	523.57	445.8	372.5	304.8	243.15	214.76

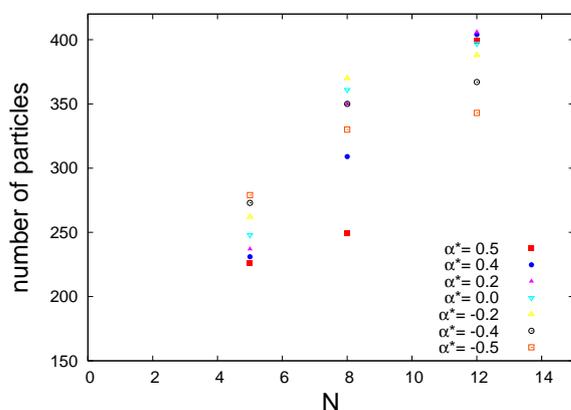Table.1   The parameters and their values which are dependent on N value.

Fig.1 : The number of test particle which are confined after long time particles tracing against N and α^*.
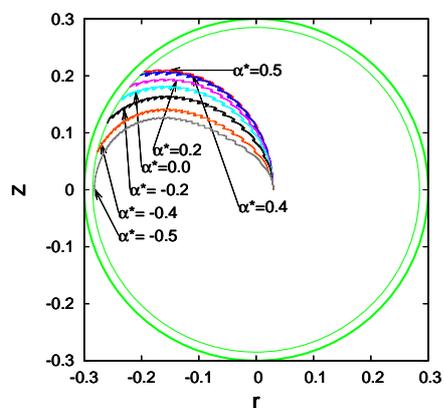
Fig.2 : The trapped particle orbits for $N = 5$ devices. Each orbit trajectory is projected into a poloidal plane. The minor axis of helical coil system is set by $r = 0$.

References

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