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Effects of Aspect Ratio on Confinement Properties of L=1 Helical Systems

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Introduction

The L=1 compact helical magnetic axis system has a high magnetic shear, and also a local magnetic well by its modifications [1]. The L=1 torsatron has some advantages over other stellarators; in addition to the simple coil structure and a local magnetic well keeping a positive magnetic shear, a negative pitch modulation ($\alpha^* < 0$) of coil winding law $\theta = N\varphi + \alpha^* \sin N\varphi$ leads to the complete confinement of helically trapped collisionless particles, where θ, φ and $N(=17$, coil aspect ratio $A_C = R/a$ =major radius/minor radius of coil=7.0) are the poloidal and toroidal angles and field period number, respectively[2,3]. We have studied further the confinement properties of these systems with fixed $N\,(=8)$, $a\,(=0.3m)$ and current of helical coil. Some quantities to estimate for confinement properties have been evaluated as changing A_C and α^*, and we have found the optimum values for each parameter.

Estimations of Physical Quantities for Confinement Properties

In this paper, we have considered the four physical quantities to estimate for confinement properties. The first one is an average radius $\bar{r}$ of poloidal cross section for the outermost surface and the second one is an effective confinement volume $V/V_C = (\bar{r}/a)^2$, where V is a volume of simple torus with minor radius $\bar{r}$, that is, $V = 2\pi R \cdot \pi \bar{r}^2$ and V_C is a volume of simple torus region surrounded by helical winding coil. The third quantity is a shear defined by $\iota'_{out} \equiv (\iota_{out} - \iota_{axis})/\bar{r}$ at outermost surface, and the last one is an average magnetic well defined by $V''(\overline{r}) \equiv (V_{out}' - V_{axis}')/\overline{r}$, where V_{out}' is a specific volume at outermost surface and V_{axis}' is at magnetic axis. The specific volume V' is defined by $\frac{1}{n}\int d\ell/B$, and this integral is performed along the filed line encircled around a major axis $n(=30 \sim 60)$ times. In any cases, we have decided the coil parameters so that each average magnetic axis position is coincide with geometrical minor axis of helical coil.

Figure 1 shows an average radius $\overline{r}$ versus coil aspect ratio A_C and pitch modulation α^*. The average radius increases with decreasing A_C, and it increases with negative α^*. This result suggests that an amount of $\overline{r}$ can be controlled by pitch modulation α^* like A_C. The maximum value has been achieved incase of $A_C = 2.6$ and $\alpha^* = -0.2$.

Figure 2. shows an effective confinement volume V/V_C against A_C. This quantity is proportional to the square of $\overline{r}$, the maximum value has been achieved in the low A_C case. The compact devices in the L=1 systems are more favorable from a viewpoint of effective confinement volume. On the whole, the pitch modulation makes good contribution to the confinement properties effectively, and it attains its maximum in case of, $\alpha^* = -0.2$ as shown in Fig.2.

The rotational transform $\iota\!\!\!-_{out}$ at outermost surface is also examined, it is dependent A_C linearly, but nearly independent with α^*. In general, the rotational transform becomes large, many magnetic islands occur and then particle transport will become worse. The poincaré plots evaluation by these parameters proves the islands formation. The magnetic shear $\iota\!\!\!-'_{out}$ at outermost surface is shown in Fig.3, but it can be seen that there is no clear interrelation among $\iota\!\!\!-'_{out}$, A_C and α^*.

We have analyzed the magnetic field of systems from MHD stability viewpoints., and Fig.4 shows that a magnetic well configuration ($V''(\overline{r}) < 0$) is performed in case of $A_C = 2.0$, $\alpha^* = 0.2$, and magnetic hill ($V''(\overline{r}) > 0$) configurations are approaching to magnetic well configurations as A_C becomes small, and these tendencies are also observed by controlling positive pitch modulation parameter $\alpha*$. The averaged minimum-B field configurations has been observed in the low A_C region. In case of high A_C region, the pitch-modulation control can approach to the averaged minimum-B field configurations. The optimized values of parameters A_C and $\alpha*$ vary in accordance with those four estimations of physical quantities, as expected. The decision of optimization value needs more consideration about physical quantities to be estimated. We had reported the important playing role on the trapped particle confinement of the 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 [3]. The relations between above results and effective curvature term are now understudying, this will be discussed in a future paper.

Summary

We have examined MHD stability properties for vacuum magnetic field by controlling a coil aspect ratio A_C and pitch-modulation parameter $\alpha*$. The estimations by many parameter suggest many optimization condition, these overall estimations will lead to the best condition of L=1 systems.

References

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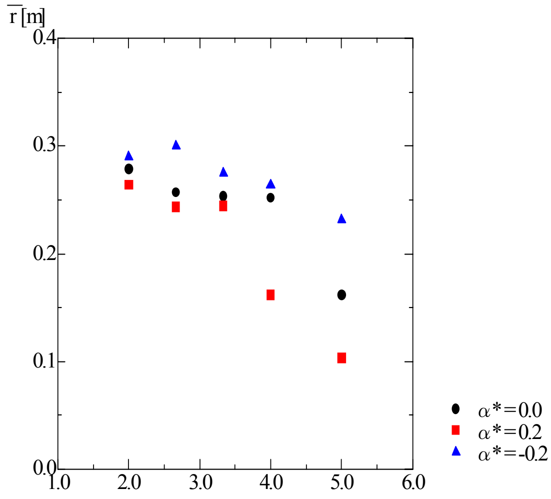

Fig.1 : Average radius ($\bar{r}$) versus coil aspect ratio A_C .

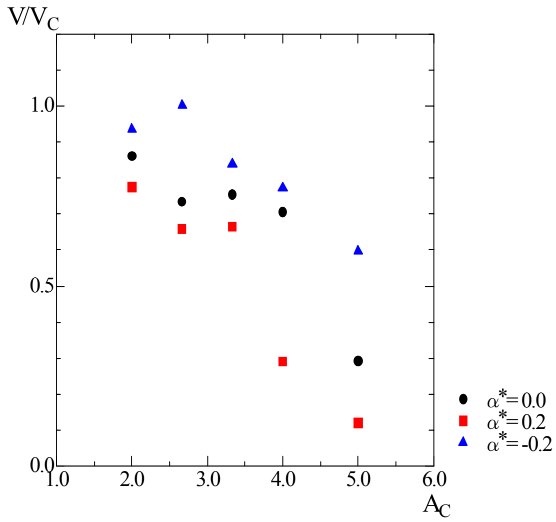

Fig.2 : Effective confinement volume V/V_C versus coil aspect ratio A_C .

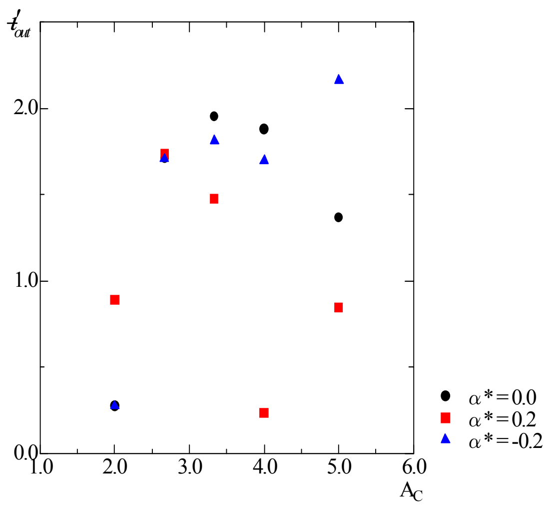

Fig.3 : Outermost magnetic shear (ι'_{out}) versus coil aspect ratio A_C .

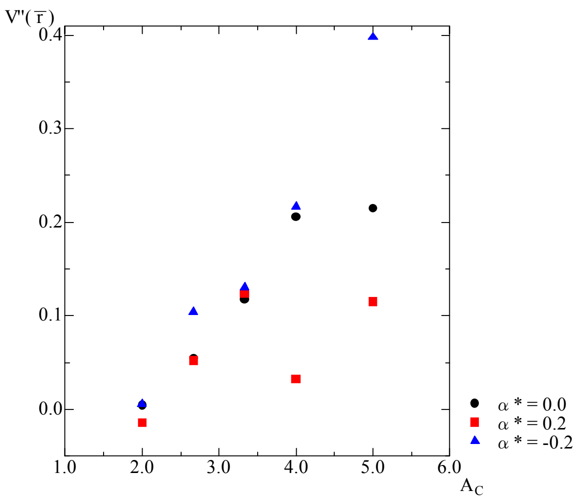

Fig.4 : Magnetic well ($V''(\bar{r})<0$) and hill versus coil aspect ratio A_C .