Analysis of particle orbits in spherical tokamak-stellarator hybrid system (TOKASTAR), and experiments in Compact-TOKASTAR device

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A tokamak magnetic configuration system is widely accepted as a future attractive toroidal fusion reactor, because of axisymmetric simple coil configuration and good plasma confinement properties. However, to operate in steady state, external power for plasma current drive is required and the risk of plasma current disruption should be considered.
On the other hand, helical magnetic confinement systems are superior to tokamaks for steady-state operation and possible disruption-free operations, but the non-axisymmetric configuration gives rise to the loss of fast ions.

Here, TOKASTAR (tokamak-stellarator) which is a compact spelical tokamak and stellarator hybrid system was proposed by K.Yamazaki.[1,2] But confinement performance of plasma in TOKASTAR have not been proved. Then in this research, we evaluated characteristics of plasma confinement in TOKASTAR using a Compact-TOKASTAR device (C-TOKASTAR).

In the configuration analysis, magnetic field tracing code HSD (helical system design) is used to define vacuum magnetic surfaces and guiding-center orbit theory is used to calculate the confinement of fast ions. The guiding-center model which we used in this research is as follows;

$$\frac{dv_{//}}{dt} = -\frac{v_{\perp}^{2}}{2B}(\vec{b} \cdot \nabla) B \qquad \frac{1}{v}\frac{d\vec{r}}{dt} = \frac{v_{//}}{v}\vec{b} + \rho(\frac{\beta^2}{2}\frac{B}{B_0} + \frac{v_{//}^{2}}{v^2})\frac{B_0}{B}(\vec{b} \times \frac{\nabla B}{B})$$

Moreover, we proposed an improved TOKASTAR adding helical component on the inboard-side of a system. By this helical component modification, we can increase the inboard-side rotation transform and therefore can increase averaged rotational transform. We showed that confinement of fast ions in improved TOKASTAR is superior to normal TOKASTAR.

In the experiment, we might prove using an impedance method that magnetic surface is made in TOKASTAR system. From now on, we will try to produce plasma in C-TOKASTAR and improved TOKASTAR.

[1]K. Yamazaki and Y. Kubota, Proceedings of Plasma Science Symposium 2005 and the 22nd Symposium 2005 and the 22nd Symposium on Plasma Processing (PSS2005/SPP-22) (2005) P3-094.
[2]K. Yamazaki and Y. Abe, Research Report of the Institute of Plasma Physics, Nagoya, Japan, IPPJ-718 (1985).