§14. Compact Toroidal Magnetic Concepts in Mirror Magnetic Field

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For the realization of attractive fusion reactors, steady-state high-beta plasmas are required with efficient divertor, compact coil and simple reactor core systems. According to the reactor system analysis, to realize economic tokamak reactors, steady-state operation at high beta (>5%) should be achieved with high bootstrap current fraction (>70%) and efficient current drive methods. The system availability factor should be larger than 70 %, which gives rise to the requirements of only one permissible disruption during several years. For this purpose, reliable active disruption control is required. For compact and low-cost designs, low-aspect-ratio systems without disruptions might be created by some combinations among tokamak, helical and mirror field configurations. Moreover, easy maintenance of reactor system requires a simple coil system and enough plasma-coil space, which can be achieved using mirror field configurations.

Here, we started bidirectional collaboration research program between Nagoya University and Tsukuba University on the toroidal plasma formation in mirror field configurations. Especially, the compact tokamak-stellarator hybrids (C-TOKASTAR) with mirror-type magnetic divertor configuration are investigated.

Historically, a lot of exotic confinement concepts are proposed so far (Fig.1). One of the authors previously proposed the tokamak/stellarator hybrid called TOKASTAR[1)] in 1985 to improve the magnetic local shear near the bad curvature region and to get smooth transition from the first to the second stability regime. At that time a reference system of N=4 system was proposed with outer helical coils.

As an extension of this TOKASTAR, we propose an N=1 or N=2 compact coil system C-TOKASTAR (Compact Tokamak/Stellarator Hybrid). This system has several advantages: (1) probable high-beta by strong magnetic well, (2) steady-state operation by helical coils, (3) no current disruption risk by external helical field, (4) enough divertor space by mirror-type magnetic divertor configuration, (5) compact economic system by spherical configuration, (6) easy maintenance by simple N=1 or N=2 coil system.

The vacuum magnetic surfaces are analyzed for the system with single (N=1) or double (N=2) helical coils in addition to a pair of poloidal field coils. The plasma equilibria and divertor configurations can be clarified by the finite beta analysis and small plasma experiments which are now under preparation. The recent magnetic analysis related to Tokastar is given in Ref 2. These magnetic configurations will be utilized for various industrial plasma applications in addition to future toroidal fusion reactors.

1) Yamazaki, K., Abe, Y., Research Report of the Institute of Plasma Physics, Nagoya, Japan, IPPJ-718 (1985).
2) Sawafuji, T., Yamazaki, K., Mikhailov, M., Arimoto, H., Shoji, T., Proceedings of International Symposium on EcoTopia Science 2007, ISETS07 (23-25 November 2007, Nagoya, Japan.

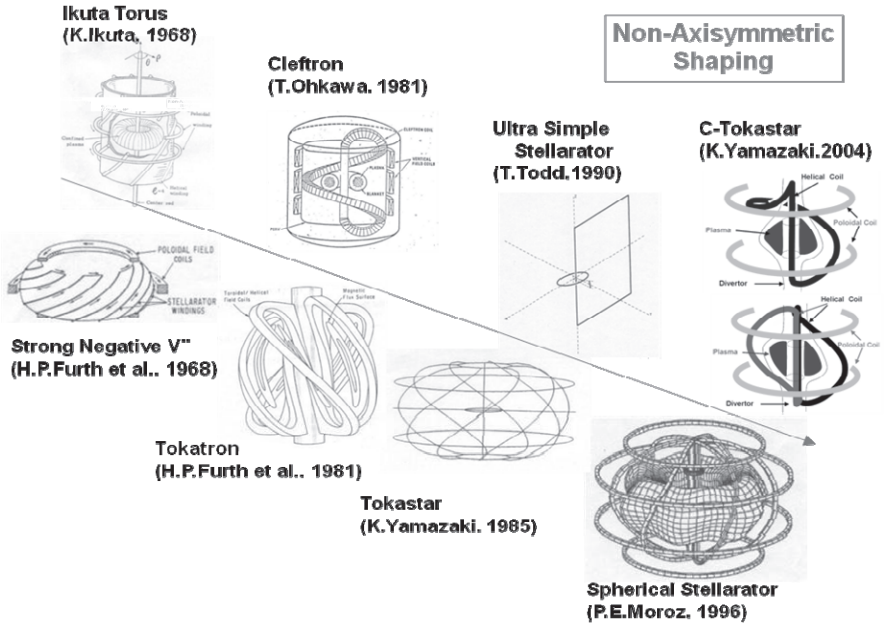

Fig.1. Historical outline of compact non-axisymmetric toroidal system proposals