§7. Helical Magnetic Field Configuration Optimization

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For the future prospect of LHD experiments, researches on the optimization of non-axisymmetric toroidal magnetic configurations are important. A new combined concept of spherical tokamak-stellarator hybrid called TOKASTAR (Fig.1) is proposed and its plasma behavior is simulated with respect to the plasma confinement, steady-state operation, simple coil configuration and inherent diverter configuration. The plasma energy measurement using the helical coil system is also carried out related to the above configuration optimization within the framework of the LHD Project Research Collaboration program.

In the configuration simulation analysis, the magnetic field tracing code HSD is used to define vacuum magnetic surfaces, and the DESCUR code is used for Fourier mode analysis of the vacuum last closed surface. The finite-beta three-dimensional equilibrium was solved by the VMEC code, and the effects of current-free or flux-conserving high-beta configuration were evaluated. The simplified coil configuration with one or two helical coils and a pair of poloidal field coils is adopted. The aspect ratio of the plasma is ~1.2, and its ellipticity is ~ 2. The rotational transform is large on the outboard side, but small on the inboard side.

By the helical modification of the central conductor, we can increase the inboard-side rotational transform. As another approach, by adding the plasma current, the average rotational transport increases and the finite-beta radial-shift of the equilibrium is found to be suppressed by introducing plasma current, which leads to the increase in the achievable beta value, and the decrease in the neoclassical ripple loss. Recent confinement analysis on this configuration is presented in Ref.1.

The relevant miniature experimental machine is now under construction (Figs.2 & 3) to demonstrate the confinement concept of this compact tokamak-stellarator hybrid configuration.

Related to the confinement configuration with helical coil system, we proposed a new method for measuring plasma energy using superconducting helical field coil (HFC) signals. The change in HFC flux in LHD is experimentally confirmed due to the increase in the plasma energy. The HFC signal change is found to be a combination of the diamagnetic toroidal flux change and the Pfirsh-Schlüter poloidal flux change. The comparison between the conventional diamagnetic measurement and the present proposed method using HFC has been done, and the demonstration of the effectiveness of the proposal technique has been performed[2].

The accuracy of the present method for measuring plasma energy using HFC is still limited by the eddy current effects on the structural materials and the integration method of the coil voltage. The accuracy also depends on the plasma equilibrium model, especially the plasma boundary shape, the plasma radial profile and the effect of high energy beam components. Recent results related to beam energy contribution is presented in Ref.3.

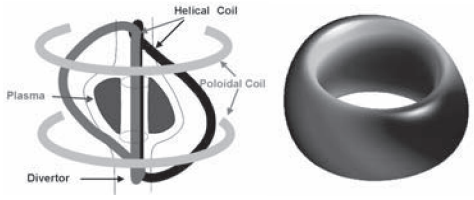

Fig.1. TOKASTAR concept and 3D finite-beta plasma

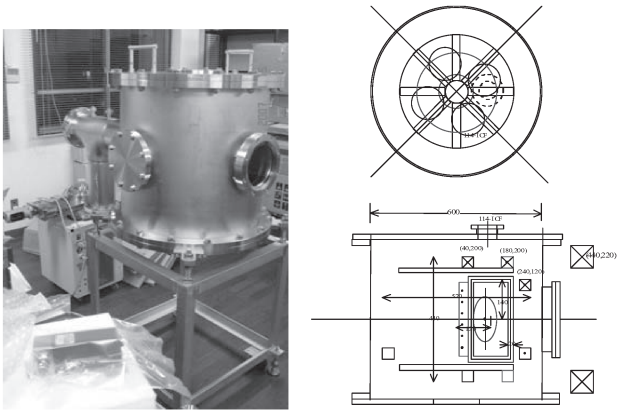

Fig. 2. A TOKASTAR machine is under construction.

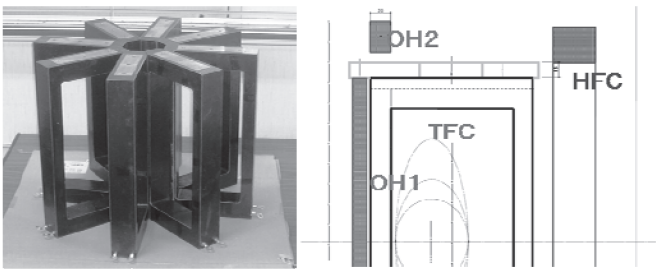

Fig. 3. A photo of eight toroidal field coils (TFC) which will be installed in the vacuum chamber. Outer helical field coil (HFC) is also under construction.

1) Sawafuji, T., Yamazaki, K., Mikhailov, M., Arimoto, H., Shoji, T., "Confinement Analysis of Compact Magnetic Fusion Configuration Combined with Tokamak and Stellarator Concepts", Proceedings of International Symposium on EcoTopia Science 2007, ISETS07 (23-25 November 2007, Nagoya Japan)
2) Hamamura, K., Yamazaki, K., et al., Fusion Engineering and Design 81 (2006) 2827–2830.
3) Ohnishi, T., Yamazaki, K., Funaba, H., Arimoto, H., Shoji, T., "Time-Dependent NBI-Heating Simulation of LHD Plasmas with TOTAL (Toroidal Transport Analysis Linkage) Code", Proceedings of ITC/ISHW2007 (15-19 October 2007, Toki, Japan)