§14. New Helical Magnetic Configuration and Novel Plasma Energy Measurement

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Among fusion confinement configurations, the tokamak concept seems to be superior to helical system from the view-point of the good plasma confinement and the simple axi-symmetric system. However, in tokamak systems pulsed operation and current disruption events are problems to be solved. Here, we proposed a new magnetic configuration combined with tokamak and helical systems, and evaluating its compact concept property with respect to the plasma confinement, steady-state operation, simple coil configuration and inherent diverter configuration

In the analysis, 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.

A spherical tokamak-stellarator hybrid called TOKASTAR (Fig.1) is proposed and its magnetic field and diverter field tracing properties are clarified. The simple 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 the ellipticity is ~2.0. 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 suppressed, which leads to the increase in the achievable beta value, and the decrease in the neoclassical ripple loss.

The relevant miniature experimental device is being constructed 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 [1] 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 VMEC- DIAGNO equilibrium analysis code clarified the relation between the HFC flux change and the plasma energy increase, and the scaling law for the plasma energy measurement is obtained. The HFC signal change is found to be a combination of the diamagnetic toroidal flux change and the Pfirsh-Schlüter poloidal flux change (Fig.2). 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 is performed (Fig.3). With the help of the scaling law obtained by the VMEC- DIAGNO code, the measurement accuracy can be improved.

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. For improving this accuracy the application of an empirical equilibrium reconstruction method [2] is under investigation, because the poloidal flux signal on HFC from the plasma strongly depends on the plasma position, the plasma boundary shape and the radial pressure profile. In addition, the effects of various eddy currents in the device structures should be included in the plasma energy evaluation model in the future.

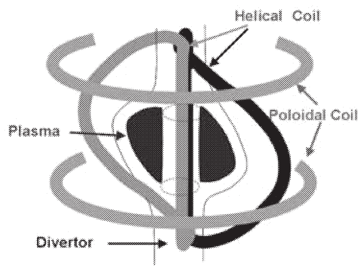

Fig. 1. A new compact coil configuration TOKASTAR

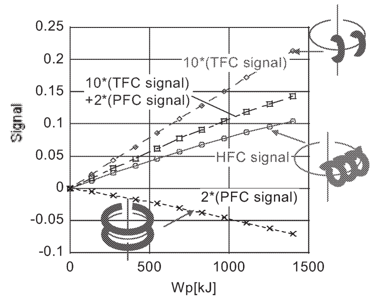

Fig.2. Interaction between the plasma and the coil systems in LHD.

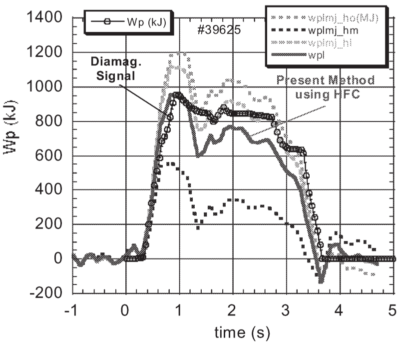

Fig.3. Evaluation of plasma energy using HFC comparing with conventional diamagnetic coil measurement.

Reference

1) Hamamura, K., Yamazaki, K., et al., Fusion Engineering and Design 81 (2006) 2827–2830.
2) Yamazaki, K., and the LHD Experimental Group, J. Plasma Fusion Res. 79 (2003) 739-741.