8P03 早期発電実証炉設計を目指したヘリオトロン方式核融合炉コイル形状最適化

Optimization of coil geometry of heliotron type fusion reactor for early power generation demonstration reactor design

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A helical fusion reactor based on the heliotron configuration with continuous helical coils has several advantages in its engineering design: helical divertor field structure that enables flexible divert design, coil shape with a small variance in its curvature that enables flexible winding, large apertures between coils for the maintenance of in-vessel components. On the other hand, there are two major issues to realizing a fusion power plant with a compact size and high plant efficiency. One is an insufficient plasma confinement performance. The plasma performance of various magnetic configurations has been examined in the LHD experiment and it was found that there is a trade-off between MHD stability and energy confinement property. This trade-off limits the achievable fusion gain of a fusion power plant. The other is a limit on the distance between the helical coil and plasma at the inboard side of the torus. This limit leads to the insufficient performance of neutron shielding and tritium breeding of the blanket module.

Configuration optimization is expected to be a solution for these issues. In a previous study, it was found that a slight change in the pitch modulation, which is one parameter in the definition of the helical coil winding law, simultaneously improves MHD stability and energy confinement property [1]. However, this change reduces the distance between the helical coil and the plasma. It is not practical to scan all parameters of the winding law. Recently, the helical coil optimization code OPTHECS has been developed. OPTHECS can optimize the shape and the current of the helical and vertical field coils by considering overall plasma performance, such as plasma volume, MHD equilibrium, rotational transform, neoclassical diffusion, alpha particle orbit, and so on with a flexible change in the shape of the helical coil beyond the conventional winding law. Currently, optimization calculations are being conducted to include the distance between the plasma and the coil in the optimization target. The comparison of the Mercier parameter (index of MHD stability) and the neoclassical energy loss of the initial candidate configuration with 4 cases of the vacuum magnetic axis positions and the two reference configurations is shown in Fig. 1. The comparable performance is obtained with ~10% increase in the distance between the helical coil and the plasma. In the presentation, the latest calculation results and future prospects in the optimization study.

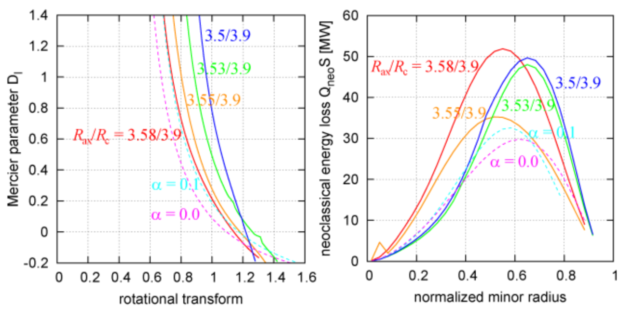

Figure 1. Comparison of Mercier parameter (left) and neoclassical energy loss (right) of the initial candidate configuration obtained by OPTHECS with 4 cases of the vacuum magnetic axis position R_{ax} (solid curves, R_c is the major radius of the helical coil) and the reference configurations (broken curves with $R_{ax}/R_c = 3.5/3.9$).

[1] T. Goto et al., Plasma Fusion Res. **16** (2021) 1405085.