§27. Magnetic Configuration Optimization with Auxiliary Coils

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An optimization of magnetic field configuration is one of important research topics in Heliotron J experiment. A program of the magnetic configuration optimization with auxiliary coils is planned to contribute to the topic by introducing an additional knob of magnetic current control to the existing magnets of Heliotron J.

In general, the control of the magnetic field configuration is a basic plasma control knob for any type of magnetic confinement device because the stabilities and transport of plasmas strongly depend on the magnetic field structure. In tokamaks, since the plasma current is one of major components of electric currents which create confining magnetic field, the control of plasma current in its magnitude and spatial profile is a powerful knob of plasma control. Although such a control is not usually referred as a magnetic configuration control, ranges of variations of key parameters of magnetic surface quantities such as a rotational transform, magnetic shear and magnetic curvature are sufficiently wide for the effective plasma performance control in tokamaks. In terms of control parameters of currents in magnets, tokamak has three different groups: currents in toroidal coils (all in the same value), currents in poloidal coils (different values are possible for different types of coils) and plasma current. In addition, the profile control of plasma current is equivalent to many number of freedom of current control in different channels of plasma current. Because the current control in a current channel which is located very close to the plasma is very effective (the helical coil wound on the circular core in the heliac is a good example), the plasma current profile control in tokamaks is a powerful knob for the plasma control.

In stellarators, a number of free parameters defining the magnetic field configuration is expected to be much larger than tokamaks because the configuration is three dimensional. It is true in the configuration design process. However once the device is constructed, most of magnets (actually all magnets) are fixed in their shapes and positions. Control parameters which remains to be free variables in the experiment are only the amplitudes of their currents. The flexibility of the axisymmetric poloidal magnetic field configuration is similar to tokamaks (actually larger flexibility for tokamaks which have a larger number of poloidal coils). The flexibility of the amplitude of the rotational transform is given by the separate control of helical and toroidal coil currents (it is not possible in LHD except the small level of control with helical coil minor radius variations: γ control). An advantage of Heliotron J is the magnetic field bumpiness control with a two sets of toroidal coil system. Nevertheless we do not have an effective knob for the control of the rotational transform profile (q profile control) which is given by the plasma current profile control in tokamaks. The q profile control has shown powerful plasma performance controls in tokamaks which was essentially important in the study of the advanced tokamak scenarios.

The motivation of this collaboration program is to find an additional knob of magnetic field configuration control which gives the variation of the rotational transform profile. In order to achieve such a configuration control, we have to add auxiliary coils which are completely different type from the existing helical coils. Because the existing magnetic field configurations of Heliotron J have flat profiles of the rotational transform for all possible variations of current control of magnets, the first step of the auxiliary coil design work should be searching for the coil shape which gives the stellarator type of magnetic shear (increasing the rotational transform toward the plasma edge). Such process can be done by the fragmentation of the standard helical windings into a number of saddle coils (multiples of toroidal period number). Additional work for another type of auxiliary coils which create tokamak type of magnetic shear (decreasing toward the edge) is also necessary but it would be very difficult for the external coils without using the plasma current. Although the saddle coil design is a simple straight-forward process for the stellarator type magnetic shear, it might be necessary to use a special computer code in the real geometric design because the Heliotron J is non-planar axis type stellarator and the simple helical winding may not so simple in three dimensional geometry.