§29. Optimization of Heliotron Conguration based on LHD Experiments

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Recntly, the construction of ITER is advanced and the conceptual design of the DEMO based on the tokamak is discussing in the world fusion community. However, the DEMO based on the tokamak has many difficulties, for examples, current drive, steady state operation, melting divertor components and so on. On the other hand, comparing with the tokamak DEMO design, stellarator and Heliotron concepts hava many advantages from the viewpoint of the steady state operation. Up to now some conceptual designs were proposed but those were not optimized by the experimental evidence. Therefore, studies of stellarator and Heliotron DEMO designs based on the experiment are important and urgent issues.

The Large Helical Device (LHD) is only one heliotron device to study the fusion-relevant plasma. The FFHR, which is a Heliotron based fusion reactor, has been designed but it does not optimized because the FFHR is a large scale Heliotron device based on the LHD. Since the LHD is a classical Heliotron, studies of the window on operations and hardware designs are necessary for high performance and economical fusion reactor. To do that, experimental and theoretical studies of the LHD should be integrated.

In this study, arranging the meeting, agendas to design the optimized fusion reactor are picked up from various experiments and theoretical studies. Note that agendas from other stellarator and Heliotron, of course, tokamaks, should be included. In this year, the meeting was continued. Brief summaries are shown as following.

1. The design window of Heliotron-type reactor, so-called FFHR, is discussed. The system code to design the reactor is developing. Recently, the self-consistent model to simulate the ignition of the reactor is implemented to the system code. In the analysis of the system code, the enough space of the blanket is very important to get the fusion power to the ignition. However, in the present design, the space of the blanket is very tight. Therefore, the optimization of the helical coil windings should be studied. In addition, the present design is focusing to the reduction of the neoclassical transport and fast ion confinement by shifting the magnetic axis to the inward direction. However, the strong inward shifted configuration leads to the MHD instability because of the magnetic hill. The compatibility of the transport and MHD properties is very important but the solution was not obtained yet. That is a future subject.

2. The new helical coil winding law, so-called NITA coil is reviewed. The configuration based on the NITA coil is, in principle, an L/M=2/10 heliotron configuration. In the new configuration, additional L=2 helical coils will be installed in the outside of the original L=2 helical coils. In the NITA coil, the current flow is set to an opposite direction of the original coil. Thus, the space of the blanket can be made. For the vacuum magnetic field model, the new configuration based on the NITA coil can be worked. However, the MHD equilibrium and stability, the transport are not studied yet. That is very important task.

3. One direction of the optimization process for the stellarator and heliotron is the reduction of the neoclassical transport. The neoclassical transport code has two directions. A first direction is the momentum method base on the mono energy particle such as the DKES code. The DKES code is very efficient code coupling with the 3D MHD equilibrium calculation code but the convergence property in the low collisionality is too bad. On the other hand, the montecarlo code has no bad convergence property in the low collisional regime. However, enough number of the sampling particle is necessary to get the converged solution. The speed up of the montecarlo based code is one urgent task for the optimization.

4. The design of the poloidal modular coil is reviewed. Many people believe the poloidal modular coil of the optimized stellarator can be designed by the computer code. However, the basic idea of the poloidal modular coil is an interchangeable poloidal coil based on the toroidal helical winding law. As a traditional design of the poloidal modular coil, the Rehker-Wobig coil design is reviewed. This design was used to the Wendelstein 7-AS stellarator. This is very surprising because the coil was designed without the supercomputer. As an extension of the Rehker-Wobig coil, the NESCOIL algorithm was proposed by the numerical code. By solving the Neumann boundary problem numerically, the current line along the poloidal direction can be solved numerically. In the original NESTOR algorithm, the current filament is approximated by only the Fourier representation. Recently, the cubic spline method is implemented in addition to the Fourier representation. Thus, polodialy unclosed coil like the saddle coil can be used to the coil design.

From these summaries, seeds and needs to design the future reactor must be selected. Those discussion will be next object in this study.