§26. 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. Brief summaries are shown as following.

1. If the tokamak and stellarator are compared, many people consider the tokamak has the good confinement but the stellarator is the bad confinement. However, the optimized stellarator to reduce the neoclassical transport is proposed based on the quasi-symmetric configuration. Tokamaks is very difficult for the steady state operation and density limit. Stellarator and Heliotron lines should concentrate the steady state operation with high density regime.

2. The LHD is an L/M=2/10 heliotron configuration. One important characteristic of the LHD is the classical winding law of continuous helical coils are used. Continuous helical coils have engineering advantages but the design window of the helical coil is too narrow. Modern optimized stellarators, like the Wendelstein 7-X, use poloidal modular coils. Using modular coils, the local pitch of magnetic field lines, in other word, strong shaping of flux surfaces can be controlled. If the continuous helical coil is used, such kind strong shaping is impossible because the curvature of the helical coil is too large. Thus, optimized Heliotron configurations are studied based on poloidal modular coils. Controlling shapes of flux surfaces, the effective helical ripple can be reduced. This is good news for the optimization of the neoclassical transport. On the other hand, the magnetic hill exists in the plasma. From the LHD experiments, the MHD instability will be appeared. However, the instability will not be disruptive. Special attention is the divertor configuration. The Heliotron configuration naturally have the separatrix structure. However, the modular coil is difficult to make the same configuration. Studies of that is a future subject.

3. 3. The Heliotron J device is an L/M=1/4 Helical-axis Heliotron. The basic concept is the compatibility of the transport and MHD stability. The Heliotron-E device was a classical Heliotron, which means the high magnetic shear configuration. Thus, the MHD instability in the edge region is stabilized by the magnetic shear but the core instability was problem. In addition, the ripple transport was always problem. To resolve those issues, the Heliotron J is designed by following ideas. First, superposed the helically moved axis, the magnetic well exists in the plasma. In principle, the interchange instability is stable. Secondly, the bumpy field is superposed. The bumpy field improves the confinement of trapped particles. Finally, the target beta value is not the vacuum. The magnetic configuration is optimized for the finite beta value. In the Heliotron J experiment, the experiment to confirm the conceptual ideas is done.

4. 4. In the design of the optimized stellarator, numerical framework, so-called the stellarator optimizer, was widely used. This frame work is a package of various numerical codes consisting of the 3D MHD equilibrium code, stability calculation code, neoclassical transport code and so on. As an example, the Wendelstein 7-X device was designed by this framework and it is constructing. However, this framework does not have the divertor module. Therefore, it is difficult this framework apply the reactor design. The divertor design is most important missing a part. We should take effort to develop the divertor design module.

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