§29. Engineering Design of CHS-qa

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Here described is the engineering design of the quasi-axisymmetric stellarator CHS-qa, as a reference design, on the basis of 2w39 magnetic configuration, which means the toroidal field period of 2, being characterized by a magnetic well over the plasma cross-section, and the plasma aspect ratio of 3.9. Since modular coils with substantially large scale are the first technological challenge in Japan, it is important to see, as soon as possible, whether the machine construction is within our engineering ability or not. This was the reason why the 2w39 configuration was chosen as a reference design, though the configuration is still under being improved from physics optimization. Schematic drawing of CHS-qa is shown in Fig.1.

The major radius and magnetic field strength envisaged are 1.5 m and 1.5 Tesla, respectively. The distance between the plasma and the vacuum vessel is about 8cm to be able to install some apparatus for particle and heat controls. The plasma volume is about 4.5 m^3. The size is determined so that the full torus can be transported from a manufacturing company, because it is not realistic to construct the machine in the torus hall in NIFS. The magnetic field strength is determined by the capacity of the motor generator (250MVA) by taking account of simultaneous operations of CHS-qa and heating devices of LHD. The simultaneous MG operation is now successfully being done between CHS experiment and LHD-NBI conditioning.

Major components of CHS-qa and their specifications are as follows: modular coils (number : 20, ampere turn / coil : 562.5kAT, coil casing : SUS), modular toroidal field coils (number : 8, ampere turn / coil : 70.4kAT), 3 pairs of poloidal field coils (OV : 170kAT, MV : 120kAT, IV : 160kAT), vacuum vessel (one-turn resistance : 1mΩ with bellows, material : SUS). The toroidal coils are designed to generate the toroidal magnetic field of +/- 0.075 Tesla. Power supplies for all of the coils were already completed as mentioned in the chapter of CHS and those are now used in CHS experiments. One modular coil consists of 160 hollow conductors of which size is 7.4 mm x 7.4 mm, which is almost the same size as that of CHS. Four conductors are connected in parallel so as to make the coil current 14.1kA applicable to the present power supply. Thicknesses of insulators between conductors, and between conductors and the coil case are 0.8 mm and 10 mm, respectively. The thickness of SUS coil case is 30 mm, which is determined by the stress calculation of the modular coil. The flat-top time is 1 second, and the temperature rise per shot is about 40℃, which results in the maximum coil temperature of 75℃ on the saturated phase when operated at every 9 min. The required water flow rate for modular coils is about 10 ton / hour, which is well within the present capacity.

The minimum curvature radius and the maximum torsion of modular coil conductors are 127 mm and about 5 rad. / m, respectively. These values are within the allowable level for the conductor. The most troublesome problem is how to support modular coils when energized. Because there exist concave-shaped parts in the coil on the inboard side of the torus and the wedge structure as in tokamak cannot be employed, we adopted three racetrack-like shaped horizontal SUS plates, fixed to the center pole, with the thickness of 90 mm to support the entripetal force. Besides this method, a lot of SUS rods between modular coils are used for their support. These supports are compatible with accessibility of ports. The stress calculation with NASTRAN code has been done and it is shown that the maximum stress and deformation of modular coils are 138 MPa and 2.95mm, respectively.

Four quadrants of the vacuum vessel will be welded into the full torus. Five modular coils are to be inserted into the vacuum vessel quadrant prior to the welding. This process was examined to have no problem.

Because of 2 field period there are 4 horizontal ports on the outboard side where the plasma shape has an up-down symmetry. These ports are to be used for basic diagnostics, for example, Thomson scattering and μ-wave interferometry. The tangential injection of two NBI's is possible.

Final design is to be done after further physics optimizations which might lead to more sophisticated shape of magnetic surfaces and accordingly the modular coil design will get more difficult, however, the machine construction will be still within our engineering levels.

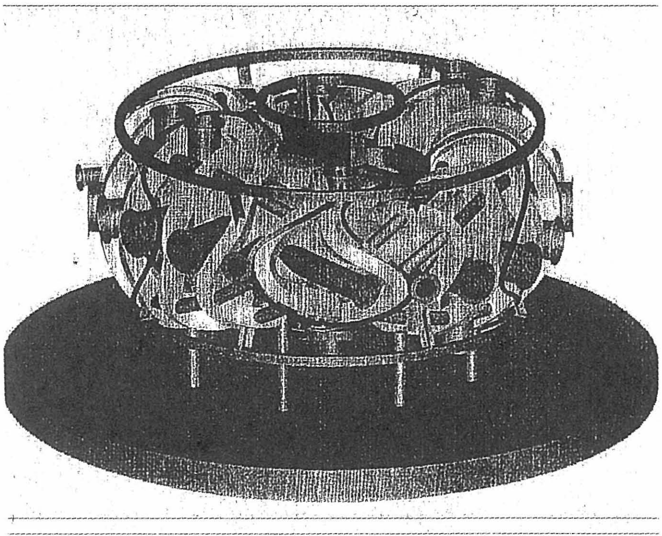

Fig.1. Schematic Drawing of CHS-qa