## §24. Engineering Study for Physics Experiments in Quasi-Axisymmetric Stellarator with Low Aspect Ratio

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One of main experimental subjects of quasi-axisymmetric stellarator with low aspect ratio (CHS-qa) is to study mechanisms of confinement improvement in toroidal plasmas. CHS-qa can cover a variety of toroidal magnetic configurations from tokamak to conventional helical systems by controlling the Fourier component of magnetic field strength in the Boozer coordinate, $B_{mn}$ (m: poloidal mode number, n: toroidal mode number per period), especially the bumpiness with m=0 and n=1. In CHS-qa 20 modular coils are employed for the toroidal field period of 2. Standard connection of 20 coils [1] under 2 power supplies (PS1 and PS2) is described showing the good quasi-axisymmetry with small residual Fourier components. To vary the bumpiness another connection is proposed; PS1 for M19, M20, M1, M2, M9, M10, M11, M12 coils in series of 8 coils that are close to the vertically elongated plasma with a bean shape, and PS2 for M3, M4, M5, M6, M7, M8, M13, M14, M15, M16, M17, M18 coils in series of 12 coils. When the coil current of PS1 that energizes 8 coils is 80 % of the current of PS2 the $B_{01}$ component can be increased up to 0.1 Tesla that results in the neoclassical transport almost comparable to that of conventional stellarators. The magnetic surface kept almost unchanged in comparison with the standard operation [2].

The stress analysis has been done when PS does not work because of its failure. The result under the failure of PS1 shows that the maximum stress in the coil frame is 124 MPa in M4 and M14 coils, which is within the allowable level of SUS. On the other hand, when PS2 does not work the maximum stress is –90 MPa in M3 and M13 coil frames. However, the stress in the leg that supports the whole modular coil assembly from the ground exceeds 140 MPa, being 184 and 172 MPa for above two cases of the power supply failure, respectively. The remedy can be easily found by inserting additional supporting bars between 4 quadrants (M20-M1, M5-M6, M10-M11, M15-M16 coils).

The robustness of the magnetic surface for the standard operation is examined against the following deformation and misalignments of modular coils: 1) electromagnetic deformation of which maximum deviation (pessimistic value without additional bars) is about 3mm at the full field of 1.5 Tesla, 2) random errors of which maximum displacement is 3mm given by random numbers at every point (total 49 points) of all modular coils approximated by filamentary ones that are supposed to be originated from winding processes, 3) displacement of 5mm of M1 coil in the X-direction (along the longer semi-axis direction of the toroidal plasma) which is supposed to be from assembly process, 4) displacement of 5 mm of quadrant of M1 to M5 coils which is also supposed to be from assembly. Comparison between designed magnetic surfaces of the 2b32 version and those for case 4) is shown in Figure 1, being almost the same for other three cases. It is shown that the magnetic surface is robust enough against deformations and misalignments that are much larger than envisaged errors. This is because the helical machine is usually manufactured by paying attention to keep the mechanical accuracy of 0.5mm/1m. Boozer spectra of the magnetic field strength under the above deformations of modular coils show that the largest change in the component $B_{mn}$ from the designed one is in $B_{01}$ being about 10%, that is, reduction from 0.00535 Tesla to 0.00479 Tesla in the core region (at 1/3 of plasma radius), and the changes in other components are out of question giving almost no effect on magnetic surface quantities as is shown in Figure 1. This amount of change is negligibly small in comparison with that of the change in the bumpiness-scanning experiment [3].

References

1) Matsuoka, K., et al., Annual Review (Apr.2003 - March 2004), p.319.
2) Shimizu, A., et al., Annual Review (Apr.2000 - March 2001), p.326.
3) Matsuoka, K., et al., Fusion Science and Technology, to be published.

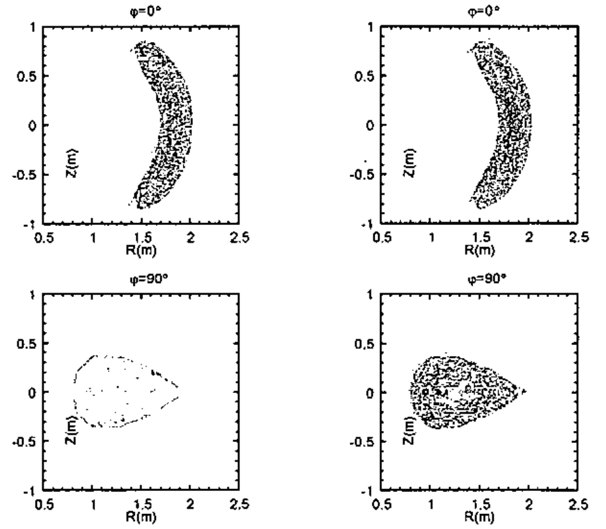


Fig. 1. Comparison between designed magnetic surfaces (left) and those under misalignment of the quadrant by 5mm in the X-direction (right).