§24. Comparison of Free Boundary Equilibrium Calculation with HINT and VMEC

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Calculation of finite beta equilibria is the most fundamental and important work in the configuration design of a new device. VMEC code has been widely used internationally because its fixed boundary calculation needs only boundary shape and profiles of current and pressure. However, since the boundary shape is not the direct condition determined by the device hardware (especially for helical devices), more realistic calculation is its free boundary calculation using coil vacuum field information. But for this mode of calculation, we have to determine the size of boundary (in terms of a total magnetic flux) which is uncertain input value within the framework of VMEC calculation.

HINT code basically calculates free boundary equilibria without assuming the existence of magnetic surfaces. Since the reliability of VMEC code is very high (within an appropriate range of conditions) due to a large number of experiences of its use in many experiments, it is very useful to compare HINT and VMEC code results for CHS-qa equilibrium calculation. We report here examples of free boundary calculations of CHS-qa without additional vertical field. Main purpose of this work is to understand the mechanism of the reduction of the size of the last closed magnetic surface (LCMS) for high beta equilibrium observed in the HINT calculation for CHS-qa.

Fig. 1 shows magnetic surface plots of HINT code calculation for the vacuum and 1.5% average beta equilibria of 2b32 configuration. Because we do not apply vertical field, the position of magnetic surfaces for 1.5% beta case is shifted outward and a considerable part of outer magnetic surfaces is lost.

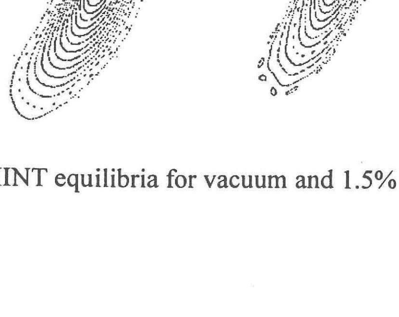

Fig. 1 HINT equilibria for vacuum and 1.5% beta

We made vacuum field line tracing calculations using MAGN code to create two types of magnetic surface plots shown in Fig. 2 similar to the plots in Fig. 1.

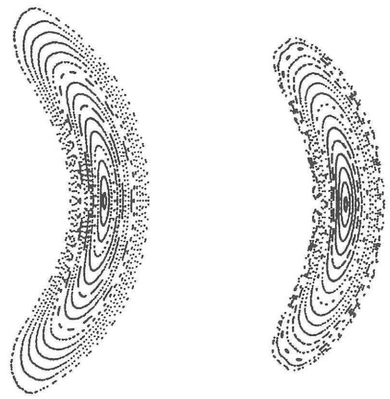

Fig. 2 Vacuum field line tracing calculations

Left plot is for no vertical field (very similar to the HINT result) and the second plot is an outward shifted case with 0.015 T vertical field for 1 T toroidal magnetic field. It is found that the magnetic surface is not closed when the outboard-side of the magnetic field lines moves out beyond the outer edge of the LCMS of no vertical field case. The loss of outer magnetic surfaces for 1.5% beta HINT equilibrium in Fig. 1 can be understood based on the same mechanism of magnetic surface breaking for the outward shifted vacuum configuration.

Finally Fig. 3 shows VMEC free boundary calculation for vacuum and 1.5% beta case with total flux values adjusted to locate the position of VMEC boundary at the position of LCMS of Fig. 2 (vacuum field line tracing results). The resulting shapes of boundary are very close to the HINT results. The iota profiles obtained from HINT and VMEC are also very similar. For this level of beta, we confirmed the equilibria given by two codes are in a good agreement. However we found the iota value in VMEC calculation for 2.4% beta is significantly lower than HINT result. A further study is necessary for the comparison of HINT and VMEC equilibrium calculation.

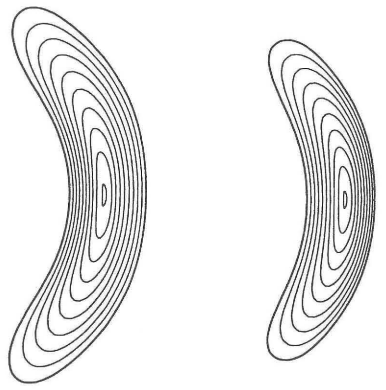

Fig. 3 VMEC equilibria for vacuum and 1.5% beta