

## §1. Development and Application of HINT2 to Helical System Plasmas

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The MHD equilibrium is the basis of both most theoretical considerations and physics interpretation of the experimental results. As a standard technique to calculate the 3D MHD equilibrium, inverse equilibrium solver VMEC [1], assuming the existence of perfect nested flux surfaces, is widely used. In such a technique, a magnetic coordinate system is directly constructed so as to satisfy the force balance, or, MHD equilibrium equation  $\vec{J} \times \vec{B} = \nabla p$ . For low  $\beta$  equilibria, since the magnetic field sustains clear flux surfaces, the standard technique is acceptable. However, by nature, 3D MHD equilibria have magnetic islands and stochastic regions in the plasma because of the absence of toroidal symmetry. For high  $\beta$  equilibria, the degradation of flux surfaces by the finite  $\beta$  effect is not avoidable, so that the standard technique based on the nested flux surfaces could not be directly applicable to them. On the other hand, in recent experiments, various types of 3D MHD equilibrium are obtained, namely, low-shear 3D MHD equilibria with magnetic islands, 3D MHD equilibria with multiple magnetic axes, 3D MHD equilibria with zero rotational transform, two dimensional MHD equilibria with current hole near the magnetic axis. The standard technique based on the nested flux surfaces is not suitable in such situations. In order to analyze such MHD equilibria with magnetic islands and stochastic magnetic field, other techniques are required such as the HINT [2] and PIES [3] codes.

The HINT code is one of such solvers, where a relaxation method based on the dynamic equations of the magnetic field and pressure is used. Details of the numerical scheme of the relaxation process are seen in references. The HINT code has been applied to the study of MHD equilibrium in many helical configurations, in order to clarify the properties inherent to 3D MHD equilibrium in various types of helical systems. However, it is fairly difficult to use it because of its code structure coming from the conventional coding style of Fortran77 and older ones. The HINT code also consumes large computational memory and a lot of computational time by the same reason. To use the HINT code more easily for analyzing MHD equilibria in many devices, those features become obstacles.

In order to remove those obstacles, the HINT2; a new version of HINT, has been created [4]. Some features and improvements are the followings.

1. HINT2 succeeds basic functions of older version HINT.
2. The coordinate system used in HINT2 is improved.
3. HINT2 is written in the modern coding style of Fortran90/95.
4. HINT2 is an efficient code by optimizing to vector supercomputer and parallel computer.
5. HINT2 is developed and administered on CVS (Concurrent Versions System), so that the users can easily access current source codes.

As mentioned above, the HINT2 code is a powerful and user-friendly code. By using HINT2, 3D MHD equilibria of the Large Helical Device (LHD) are studied as a first demonstration of HINT2. Figure 1 shows (a) Poincaré plots of a finite- $\beta$  equilibrium ( $\langle\beta\rangle\sim 3.5\%$ ) in LHD and (b) radial profiles of the rotational transform and the connection length for an inward shifted configuration ( $R_{\text{axis}}=3.6\text{m}$ ,  $\gamma=1.254$ ). All figures are plotted on the horizontally elongated cross section. Two vertical lines and arrows in figures indicate a well-defined last closed flux surface (LCFS) in the vacuum configuration. For the finite- $\beta$  equilibrium, field lines in the edge region are strongly ergodized by the finite- $\beta$  effect and the region with clear flux surfaces decreases. The ergodic region spreads over the vacuum LCFS. On the other hand, the connection length of the field line in the ergodic region is still long ( $> 10\sim 10^2\text{m}$ ). From the viewpoint of the parallel transport along the field line, since the connection length of the field line is longer than the mean-free path of the electron, the sustaining of the pressure is expected. In order to confirm the role of ergodic region on 3D MHD equilibrium, it is under the investigation.

### References

- [1] Hirshman S. P., et al. Phys. Fluids 26 (1983) 3553
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- [3] Reiman A., et al., Comput. Phys. Comm. 43 (1986) 169
- [4] Suzuki Y. "Development and Application of HINT2 to Helical System Plasmas" in Joint meeting of 2<sup>nd</sup> 21COE Plasma Theory Workshop and US-Japan JIFT Workshop (2004, Kyoto) submitted to Nucl. Fusion.

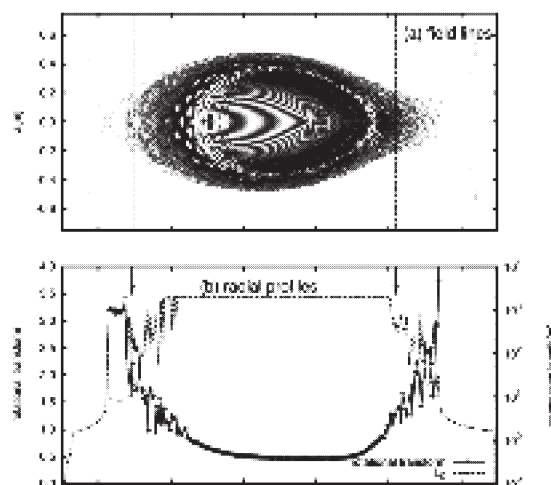


Fig. 1 (a) Poincaré plots of a finite- $\beta$  equilibrium ( $\langle\beta\rangle\sim 3.5\%$ ) in LHD and (b) radial profiles of the rotational transform and the connection length for an inward shifted configuration ( $R_{\text{axis}}=3.6\text{m}$ ,  $\gamma=1.254$ ).