18PB-055

Influence of boundary condition in three-dimensional MHD calculation code HINT2
三次元MHD平衡計算コードHINT2における境界条件の影響

Hiromitsu Kamiuttanai, Yasuhiro Suzuki and Yuji Nakamura
上打田内啓允[1), 鈴木康浩[2), 中村祐司[1)

1)*Graduate School of Energy Science, Kyoto University, Gokasho, Uji-shi, Kyoto-fu 611-0011, Japan*
1)京都大学大学院エネルギー科学研究科 〒611-0011　京都府宇治市五ヶ庄
2)*National Institute for Fusion Science, 322-6 Oroshi-cho, Toki-shi, Gifu-ken 509-5292, Japan*
2)自然科学研究機構 核融合科学研究所 〒509-5292　岐阜県土岐市下石町322-6

Recently three-dimensional effects are attracted in tokamak researches. The superimposing method is used for the estimation of these effects in present studies, but this method does not include plasma response effects. In non-axisymmetric plasmas, three-dimensional MHD equilibrium calculation code HINT2 is widely used for the analyses considering the response effect. However, HINT2 is inappropriate for calculation in plasmas with large currents because the normal component of the magnetic field is kept fixed at the computational boundary in the HINT2. In this study, we propose the new boundary condition of HINT2 and apply it to the calculation in non-axisymmetric tokamak plasmas.

1. Introduction

Tokamaks are usually assumed as an axisymmetric system. However, some external factor such as Resonant Magnetic Perturbation (RMP) field, Toroidal Field (TF) ripple create the non-axisymmetric magnetic fields.[1] In most analyses of Tokamak including them, a vacuum helical perturbed field due to RMP coils[2] is superimposed on a 2D MHD equilibrium. It is a so-called the vacuum approximation. The vacuum approximation does not include the plasma response that might influence the equilibrium. Previous studies[3] show that the vacuum approximation is good approximation. But 3D effect could not be ignored completely, particularly in high-β plasma. Therefore, studying three-dimensional Tokamak equilibria is important.

HINT2[4], three-dimensional MHD equilibrium calculation code, has widely used to analyze helical system plasmas. Since HINT2 does not assume the existence of nested flux surfaces, the equilibrium including magnetic islands and stochastic region can be treated. However, HINT2 assumes fixed normal component of the magnetic field at the computational boundary. In the previous study[5], in Large Helical Device (LHD), few influences of the boundary condition has been shown. In addition, the boundary condition may not be suitable in plasmas with large currents. Because field near the boundary is changed by plasma current, fixing normal component of the field would be incorrect.

For those reasons, we calculate the field using Biot-Savart law on the boundary in Tokamak. Final aim of this study is calculating three-dimensional equilibria by HINT2, which could not be treated by conventional methods.

The investigation method for this study is described in Sec.2 and these results are shown in Sec.3. Finally, summaries, conclusions and future issues are described in Sec.4.

2. Investigation method

In this study, rectHINT2 code, which uses real coordinates system (cylindrical coordinates (R, Z, φ)), is applied. The field on boundary was calculated by using full-torus plasma current. As an initial guess in HINT2, calculated equilibrium by VMEC was used. This VMEC input was calculated by using Biot-Savart law at vacuum region. Specifically, equilibrium field obtained by the new HINT2 which uses new boundary condition is compared to that by the conventional HINT2 and that by the VMEC. In this study, magnetic field configurations, plasma current, plasma pressure, position of magnetic axis, rotational transform and beta value on axis are also compared. When calculating Biot-Savart law, plasma currents are set to same values at all toroidal angles for the axisymmetric calculation.

3. Results

In this research, equilibrium conditions are set as follows:

- Computational Domain : $4.0[\mathrm{m}] \le R \le 9.7[\mathrm{m}]$ and $-5.7[\mathrm{m}] \le Z \le 5.7[\mathrm{m}]$

For the benchmark test, we calculate the some equilibrium by A) VMEC code, B) original HINT2, and C) HINT2 with new boundary condition. Z components of the magnetic field produced by the plasma current are described in Fig.1., and plasma pressures on $Z = 0$ are also described in Fig.2., where the red, green points and blue line show dependence on position (R) for A, B and C.

These figures show that results of A, B and C are almost identical magnetic field configurations and plasma pressure profiles. Comparison of beta values and position of magnetic axis is described in Table I. This table shows that little differences at beta value and magnetic axis are observed.

It is shown that the HINT2 code with new boundary condition works well.

4. Summary

In this study, HINT2 is applied for the equilibrium calculation in the tokamak plasma. Biot-Savart law is applied for new boundary contiditon in HINT2. To verify correct implement into the code, we compare the results between input equilibrium, conventional HINT2 code and HINT2 which using new boundary condition.

In order to compare the results, VMEC result is used. However, VMEC cannot calculate some situation. Therefore, calculation of three-dimensional MHD equilibrium using HINT2 in tokamak is urgent.

We will report the detailed analysis of three-dimensional equilibrium by HINT2 using new boundary such as plasma pressure, plasma current, rotational transform and so on.

5. Acknowledgments

This study was performed with the support and under the auspices of the National Institute for Fusion Science (NIFS) Collaborative Research Program.

Table I. Beta values and Magnetic axis

	A	B	C
On Axis β_0[%]	7.198	7.158	7.155
Magnetic Axis[R]	6.7062	6.7040	6.7033
Magnetic Axis[Z]	0.5091	0.5091	0.5089

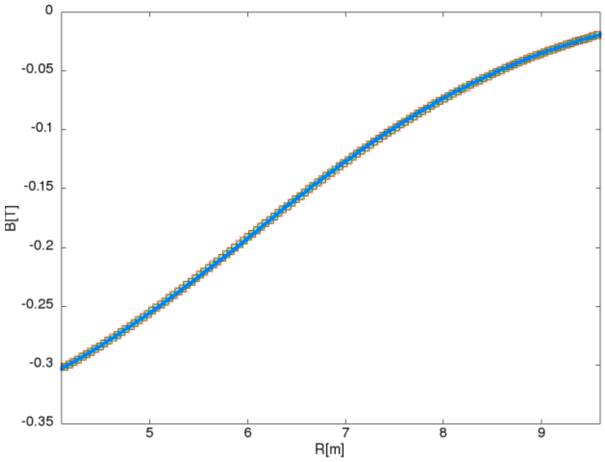

Fig.1 Plasma magnetic field on third grid from Z bottom for A(the red points), B(green) and C(blue line).

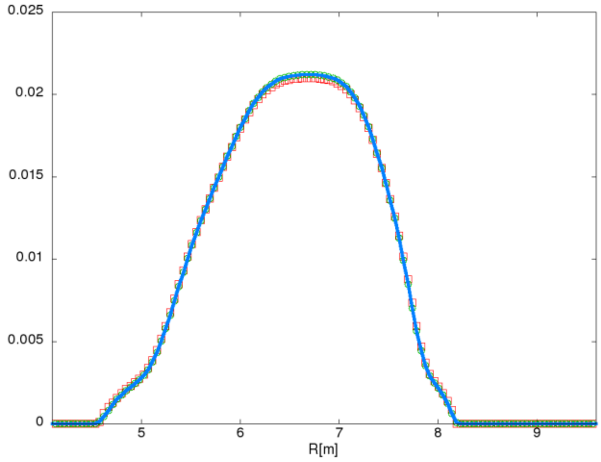

Fig.2 Plasma pressure on $Z = 0$ from for A(the red points), B(green) and C(blue line).

References

[1] K. Yamazaki: J. Plasma. Fusion. Res. **88** (2012) 151.

[2] C. Wiegmann and Y. Suzuki et.al: *Proceedings of ITC18, 2008* (Toki, Japan, 2008) ed., P1-13

[3] Y. Nakamura: J. Plasma Fusion Res. **88** (2012) 168-172

[4] Y. Suzuki et al.: Nucl. Fusion **46** (2006) L19–L24

[5] Y. Hanazono: "Boundary condition of three-dimensional MHD calculation code HINT2" Master's thesis, Graduated School of Energy Science, Kyoto University. (2013) Unpublished.