23P122-P

Diffusive Transport Analysis in Low Aspect Ratio Reversed Field Pinch
低アスペクト比逆磁場ピンチプラズマにおける輸送解析

Yasuo Nagamine[1], Atsushi Fukuyama[2], Shoichi Shiina[3] and Masamitsu Aizawa[1]
長峰康雄[1], 福山　淳[2], 椎名庄一[3], 相澤正満[1]

[1]*Institute of Quantum Science, Nihon University*
1-8-14 Kanda-Surugadai,Chiyoda-ku,Tokyo 101-8308, Japan
日本大学量子科学研究所 〒101-8308　東京都千代田区神田駿河台1-8-14
[2]*Department of Nuclear Engineering, Kyoto University*
Yoshida-Honcho, Sakyo-ku, Kyoto 606-8501, Japan
京都大学大学院工学研究科 〒606-8501　京都市左京区吉田本町
[3]*National Institute of Advanced Industrial Science and Technology*
Umezono, Tsukuba, Ibaraki 305-8568, Japan
産業技術総合研究所 〒305-8568　つくば市梅園

For the evaluation of confinement property of the low aspect ratio reversed field pinch (RFP) plasma, diffusive transport analysis including the neoclassical and turbulent transport models is studied. To analyze such transport phenomena, the applicability of TASK (Transport Analysing System for TokamaK) simulation code is considered. Several turbulent transport models are implemented, but this code has been developed for the tokamak and (recently) helical magnetic configurations. For the analysis of RFP, because of the different nature of the magnetic configuration, some modifications and validation analysis of the physical models in TASK code are required.

1. Introduction

In order to evaluate the confinement properties of a low aspect ratio (A) reversed field pinch (RFP) plasma, diffusive transport analysis is studied theoretically. For the conventional RFP plasma with laeger aspect ratio, transport analyses by using the theoretical model or three-dimensional numerical simulations based on the cylindrical approximation have been shown to be nearly consistent with experimental results such as the confinement scaling in the standard ohmically driven RFP [1,2]. On the other hand, confinement performance in a low aspect ratio RFP is not well understood, but it is considerd to be important to introduce the transport model including the effect of toroidal geometry. Numerical analysis based on the neoclassical transport model in a low aspect ratio RFP shows that a considerable bootstrap current contibution can be expected in the RFP configuration, when incorporating the effects of non-circular cross-section and low aspect ratio [3]. However, of transport phenomena in an RFP, the energy confinement time τ_E might be determined by anomalous transport due to micro-instabilities. Therefore, it must be considered to introduce an appropriate model for the turbulent transport in the RFP configuration.

2. TASK code

TASK (Transport Analysing System for TokamaK) code is an open source code which has been developed at Kyoto University [4,5]. This code consists of some modules calculating each physical process such as equilibrium, transport, wave propagation, etc. and analyzes the transport process of the whole nuclear burning plasma by integrating them. A part of the modules are listed in Table I.

Table I. A part of modules of TASK code [5]

EQ	2D Equilibrium	Fixed boundary, Toroidal rotation
TR	1D Transport	Diffusive Transport, Transport models
WR	3D Geometr. Optics	EC, LH: Ray tracing, Beam tracing
WM	3D Full Wave	IC, AW: Antenna excitation, Eigen mode
FP	3D Fokker-Planck	Relativistic, Bounce-averaged
DP	Wave Dispersion	Local dielectric tensor, Arbitrary $f(\boldsymbol{v})$
PL	Data Interface	Data conversion, Profile database
LIB	Libraries	

In this study, we use EQ and TR modules mainly for the diffusive transport analysis. In the TR module, some diffusive transport models based on the neoclassical transport theory and turbulent transport theory are implemented. Applied for the first time to the RFP configuration, the code is exploited for steady state calculations with the neoclassical and basic turbulent transport models.

In order to include the description of the RFP geometry, some parts of the code need to be improved. The most fundamental improvement is related to the existence of 0 points of the toroidal magnetic field at the reversal surface [6].

3. Preliminary Results of TASK/EQ calculation

As preliminary calculations of TASK code, equilibrium analysis of low A RFP is performed by the modified EQ module. Figure 1 shows the result of calculations: (a) toroidal and poloidal current density profiles on the midplane, (b) safety factor profile, in the case of parameters A=2.0, ellipticity κ=1.4, triangularity δ=0.4, plasma current I_ϕ=0.15MA and parabolic pressure profile.

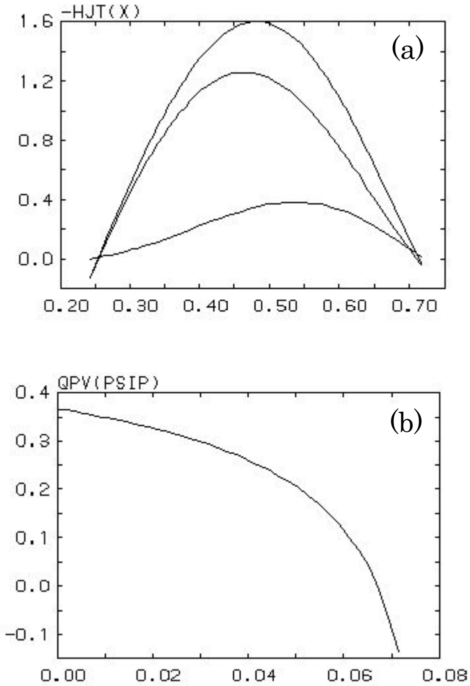

Fig. 1. Basic equilibrium profiles calculated by the modified EQ module: (a) toroidal and poloidal current density profiles on the midplane, (b) safety factor profile.

4. Considerations for turbulent transport analysis

In tokamaks, so many transport analyses have been performed, and developed some turbulent transport models, such as gyro-kinetic or gyro-fluid simulations of ITG (Ion Temperature Gradient) instability and turbulence. Comparisons and physics basis of tokamak transport models and turbulence simulations are summarized in Ref. [7].

As major turbulent transport models, CDBM (Current Diffusive Ballooning Mode), GLF23, IFS/PPPL and Weiland models are employed in TASK code. In these models, it is considered that the CDBM model has difficulty in application to the RFP configuration. Three of the remainder are all models based on the gyro-fluid description. More basic models such as Bohm or Gyro-Bohm model are also implemented in this code. For the first application to RFP, it is expected that these models are passable as a model of the anomalous transport.

Recently, linear gyro-kinetic calculations are applied to the RFP configuration to investigate the occurrence of ITG instabilities [8]. In Ref. [8], linear electrostatic calculations of ITG instability are performed by exploiting the GS2 numerical code, which is a widely known gyro-kinetic code based on the electromagnetic nonlinear gyro-kinetic equation and the flux tube geometry. This analysis shows ITG modes are in general stable in RFP plasmas in the area of experimental parameters, and this type of instability to be only marginally responsible for particle and energy transport. The required gradients could be reached only in correspondence to the temperature slopes arising at the boundary of the helical structure in QSH states.

Numerical calculations in Ref. [8], however, are based on geometry and parameters of the RFX experimental device. Also some geometric simplifications such as circular surfaces with no shift and so on are imposed, for the code is based on the flux tube domain.

As for a low aspect ratio RFP with shaped magnetic surface and neoclassocal effects, understanding the mechanism of transport is considered to be an interesting subject, for its configuratin has some different characters from the standard high aspect ratio RFP plasma.

5. Summary

In analysis of a low A RFP using TASK code, because of the different nature of the magnetic configuration from tokamaks, some modifications and validation analysis of the applicability of the physical models in this code are required.

References

[1] Bruno A, *et al.*, *Physics of Plasmas* **10**, 2330 (2003).
[2] Scheffel J and Schnack D D, *Nuclear Fusion* **40**, 1885 (2000).
[3] Shiina S, *et al.*, *Physics of Plasmas* **12**, 080702 (2005).
[4] Fukuyama A, *et al.*, *J. Plasma Fusion Res.* **81**, 747 (2005).
[5] http://bpsi.nucleng.kyoto-u.ac.jp/bpsi/en/
[6] Nagamine Y, *et al.*, *Journal of Physics Conference Series (to be published).*
[7] Dimits A, *et al.*, *Physics of Plasmas* **7**, 969 (2000).
[8] Predebon I, *et al.*, *Physics of Plasmas* **17**, 012304 (2010).