23P057-P

Profile Control of Bootstrap Current in Tokamak Fusion Reactor
トカマク核融合炉におけるブートストラップ電流の分布制御

Junji Mano, Kozo Yamazaki, Tetsutarou Oishi, Hideki Arimoto, Tatsuo Shoji
真野純次、山﨑耕造、有本英樹、大石鉄太郎、庄司多津男

Nagoya University
Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan
名古屋大学 〒464-8603 名古屋市千種区不老町

For the commercialization of steady-state tokamak reactor, it is necessary to keep the burning plasma with a high bootstrap current ratio. In order to control burning plasma having high autonomy with low external current, we consider the current density profile affecting particle and heat transports. In this study, we suspected that peak of bootstrap current density profile moves to the center of plasma, because of sinking and diffusion of current. It is concluded that external current-drive is required at both the center and periphery of the plasma in order to maintain steady-state profile of temperature and density in the high bootstrap current ratio.

1. Introduction

In Tokamak Fusion Reactor, burning plasma should be maintained by only non-inductive current-drive for the achievement of steady-state reactor. Total non-inductive current is a summation of a bootstrap current proportional to the pressure gradient of plasma and an externally driven current, such as neutral beam current-drive. But in order to establish a commercial reactor postulating steady-state operation, it is necessary to reduce the amount of external current drive and to cover the majority of the plasma current with bootstrap current. Burning plasma has high autonomy, so we need to consider the current density profile with little disturbance including changes in particle and heat transports.

In this study we conducted an analysis of time evolution of the current density profile for burning plasmas by using 2.0-dimensional equilibrium, 1.5-dimensional-transport code (TOTAL code [1]).

We assume that the reactor size is that of ITER. In order to get much bootstrap current, the internal transport barrier (ITB) is required, and here we used current-diffusive ballooning mode model [2,3] as a heat transport model.

2. Analysis Method

First we performed iteration computation considering the difference between trial value and target value of the total plasma current, such that the current profile becomes consistent with the given profile of the safety factor. After this plasma equilibrium iteration analysis, we evaluate the bootstrap current ratio and the total current density profile during steady state which is obtained from profiles of both the external driving current and the bootstrap current given in the end.

When we assume high safety factor area in the center of plasma, which is weak poloidal magnetic field,

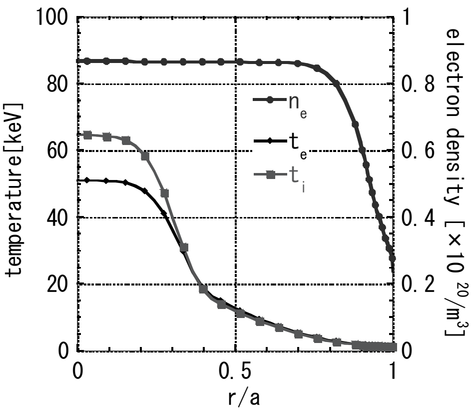

Fig.1. Profiles of electron temperature Te, ion temperature Ti and electron density ne.

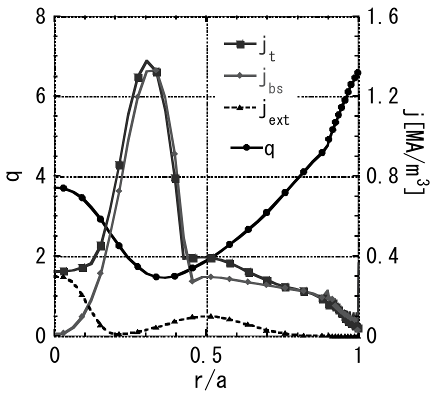

Fig.2. Profiles of safety factor q, total current density j_t, bootstrap current density j_{bs} and external current density j_{ext}.

there is a problem that confinement of fast particle become worse [4]. We performed two simulation cases; driving a current only in the center of plasma and both in the center and at the normalized minor radius r/a=0.5 of plasma.

3. Results

The radial profiles of steady-state temperature and electron density are shown in Fig. 1. The profiles of safety factor, total plasma current density, bootstrap current density and external current density are shown in Fig. 2 in the case of driving a current at both the center and the half normalized minor radius. Time evolution of alpha heating power in both cases is shown in Fig. 3.

In the case of driving a current only at the plasma center, the ratio of the bootstrap current I_{bs} and the total plasma current I_p, I_{bs}/I_p is 0.981. However, electron density cannot be maintained and the nuclear fusion reaction rate becomes lower. In this case, the peak of bootstrap current and the minimum of safety factor approaches into the center of plasma. It is reported form existing simulation study that because of sinking and diffusion of current, external current-drive is required in order to maintain steady-state current profile [5]. The simulation code used here does not include sinking and diffusion dynamics of current, though same phenomenon comes about.

In the case of driving a current at both the center and the half normalized minor radius, the ratio I_{bs}/I_p is 0.901 and the profiles of temperature and electron density can be maintained throughout more than 200 second. In this case, the peak of bootstrap current and the minimum of safety factor keep the same position.

From this we suspected that since plasma pressure is modified by the change in q profile due to bootstrap current change, peak of bootstrap current density profile moves to the plasma center. And we concluded that to maintain the steady-state temperature and electron density profile of ITER in high bootstrap current ratio in the present model, external current-drive is required at both the center and the periphery of the plasma.

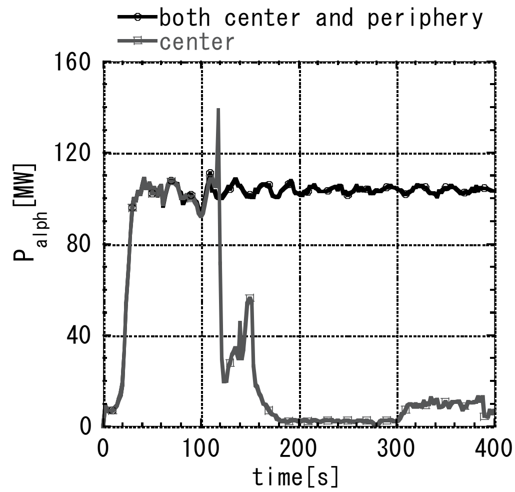

Fig.3. Time evolution of alpha heating power in both cases.

References

[1] K.Yamazaki and T. Amano, Nucl. Fusion **32** (1992) 633.
[2] K.Itoh et al., Plasma Phys. Control. Fusion **36** (1994) 279 .
[3] A.Fukuyama et al.,Plasma Phys. Control.Fusion **37** (1995) 611 .
[4] T.Suzuki, J. Plasma Fusion Res. **83** (2007) 434 (in Japanese)
[5] A. Fukuyama, J. Plasma Fusion Res. **79** (2003) 1117 (in Japanese)