Analysis of plasma behavior near the target plate in divertor simulation experiment

1 Introduction

In the International Thermonuclear Experiment Reactor and Demo reactor for future nuclear fusion power generation, heat-load of plasma particles led to divertor plate approaches tens of MW/m² on steady-state operation. In addition it reaches several GW/m² when ELM occurs. Therefore, it is important to develop materials which withstand the level of high heat-load from the divertor plasma. For solving this problem, it is needed to find out the physical mechanism to keep detaching divertor plate from the plasma influx steady. The divertor simulation experiments are widely performed by using linear devices because magnetic fields in liner devices are similar to magnetic field in actual fusion devices.

In GAMMA 10 tandem mirror, divertor simulation experiments were planed and started [1-3]. In the present experiments, characteristics of end-loss plasma in GAMMA 10 were measured.

2 Experimental device

GAMMA 10 consists of central-cell, two anchor-cells two plug/barrier-cells and two end-cells. Plasma heating systems which are ion cyclotron resonance heating (ICRF), neutral beam injection (NBI) and electron cyclotron heating (ECH) are installed for plasma production/heating and confinement. By applying ICRF in the central-cell and anchor-cells, end-loss can be generated with much higher ion temperature than electron temperature. In this plasma state, contribution of ion dominates the heat-flux density. In the case of superimposing ECH in plug/barrier-cell on ICRF-produced plasmas, on the other hand, the effects of electron become significant.

![Fig.1. Schematic view of the west end-cell in GAMMA 10](image-url)
In this divertor simulation experiments, directional probes and calorimeters are inserted near the exit of the end-mirror coil in the west End-Cell (z = 30, 70 cm). By using these diagnostic tolls, axial and radial profiles of particle-flux and heat-flux of end-loss plasma are measured.

3. Experimental results

In GAMMA 10, main plasma is produced at the central-cell and then leaks toward both end-cells through coulomb collision. Therefore, it is important that investigate the relationship between main plasma parameter of the central-cell and heat and particle flux at the end-cell. In the case of heat-flux, the result is shown in Fig.2. Heat flux depends on the time integral diamagnetism in central cell. On the other hand, results of particle flux are shown in Fig.3. Particle-flux is proportional to electron line-density in the central cell.

4. Numerical Code

Numerical simulation study is also important to understanding the behavior of background plasma in actual divertor environment. In an collaboration between Tsukuba and Keio universities, the numerical code is remodeled in simplification of B2 code [4]. A new code is modified to apply the GAMMA 10 end-mirror region. This numerical code is two-dimensional fluid code and utilizes finite volume method. Equations in this code are continuity equation, momentum balance equation, diffusion equation, electron energy balance equation and ion energy equation as follows,

\[
\frac{\partial n}{\partial t} + \nabla \cdot (n\vec{u}) = S_n \tag{1}
\]

\[
\frac{\partial}{\partial t} (n\vec{u}) + \nabla \cdot (n\vec{u}\vec{u}) - \eta \cdot \nabla p = -\nabla \vec{v} + S_n \tag{2}
\]

\[
v = -D_e \frac{\partial}{\partial y} (\ln n) \tag{3}
\]

\[
\frac{\partial}{\partial t} \left( \frac{3}{2} nT_e \right) + \nabla \cdot \left[ \left( \frac{5}{2} n \vec{u} T_e - k \nabla T_e \right) \right]
\]

\[
= \vec{u} \cdot \nabla p_i - k(T_e - T_i) + S_{ie} \tag{4}
\]

\[
\frac{\partial}{\partial t} \left( \frac{3}{2} nT_i \right) + \nabla \cdot \left[ \left( \frac{5}{2} n \vec{u} T_i + \frac{1}{2} n \mu_i c^2 \right) - \kappa \left( \frac{1}{2} n \mu_i c^2 \right) \right]
\]

\[
= -\vec{u} \cdot \nabla p_i + k(T_e - T_i) + S_{ie} \tag{5}
\]

The mesh structure of the magnetic field of GAMMA 10 end-cell is shown in Fig. 4.

5. Summary

Heat and particle flux of end-loss plasma are influenced strongly by the central-cell plasma parameter. Especially, it is founds that the increase with the central-cell diamagnetism and that the particle-flux is proportional to the central-cell electron line density. Numerical simulation which evaluates the background plasma parameter has been started.

References