INVESTIGATION OF PLASMA BEHAVIOR DURING THE ECRH INJECTION IN GAMMA 10

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Electron Cyclotron Resonance Heating (ECRH) is used for the formation of the axial confining potential by plug/barrier-ECRH (P/B-ECRH) and for the bulk electron heating in the central-cell by central-ECRH (C-ECRH) in GAMMA 10. The plasma performance was increased with ECRHs injection. However the degradation of the plasma parameter was occasionally observed during C-ECRH injection. Increase of the number of the loss particle was also observed at the same time. The mechanism of the degradation of the plasma parameter was investigated in terms of the particle balance.

I. Introduction

GAMMA 10 tandem mirror is an open magnetic plasma-confining device [1]. In GAMMA 10, analysis of particle balance in the plasma is one of the most important issues for optimizing the plasma performance. In GAMMA 10, a central limiter and two iris limiters have been installed, the former is fixed type of limiter and the latter are capable of changing each diameter [2]. The plasma boundary is controlled by these limiters. Therefore recycling phenomena on the limiters have a more significant influence on plasma performance and hydrogen recycling is also the major source of the plasma in GAMMA 10. In order to measure neutral particles, Hα emission detectors and medium-speed camera have been installed [2, 3]. Hα emission detectors are located near each limiter for observing the recycling source around the limiters.

In GAMMA 10, the initial plasma is produced by plasma guns, and the main plasma is produced and heated by ion cyclotron range of frequency (ICRF) waves. Therefore, the plasma with a significant difference between the ion temperature and the electron temperature is generated. To prevent the electron drug caused by this difference, electron cyclotron resonance heating (ECRH) is injected. However the stored energy is occasionally decreased in the C-ECRH period. It is speculated that the decrease of the stored energy is caused by the particle loss. Loss-particles were measured in order to investigate the cause of this stored energy decrease.

The purpose of this experiment is to comprehend the mechanism of the degradation of the plasma performance in the C-ECRH period. End-loss particles and radial-loss particles in the ECRH period are analyzed in terms of the particle balance. We examine the mechanism of the deterioration in the plasma performance from analytical results.

In section 2, an experimental setup is described. In section 3, experimental results are shown. Finally, experimental results are discussed in section 4.

II. Experimental setup

GAMMA 10 tandem mirror is open magnetic plasma-confining device with thermal barrier. It consists of central-cell, anchor-cells, plug/barrier-cells, and end-cells. Mid-plane of the central-cell is z = 0 cm and west and east sides correspond to plus and minus in z-axis, respectively. The central-cell is the main region to confine plasma and 6 m in length and the diameter of 1 m. In the anchor-cell with minimum-B magnetic configuration located at the both end of the central-cell, MHD stabilization of the plasma is controlled. In the standard hot-ion mode plasmas, initial plasma is build up by plasma guns located in both ends. The plasma is sustained by gas puffing coupling with ICRF. C-ECRH and neutral beam injection (NBI) are additionally supplied for the plasma production and heating, located in the central-cell. In order to plug the axial escaping plasma, the axial confining potential is produced by P/B-ECRH in the plug/barrier-cells. P-ECRH produces the positive potential which called plug potential in order to plug the axial escaping ion and B-ECRH produce produces the negative potential which called thermal-barrier potential in order to plug the axial escaping electron [4].

As shown in Fig. 1, the schematic view of GAMMA 10 and axial profile of magnetic field strength and electric

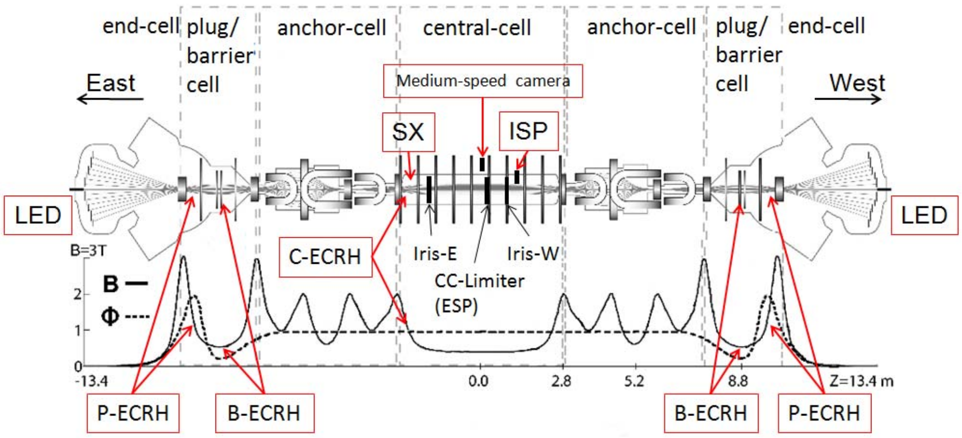

Fig.1 The overall of the GAMMA 10. The plasma and vacuum vessel structure and the limiters are illustrated.

static potential. The central limiter is located at z = +30 cm, the west and east limiters are located at z = 100 cm and z = -155 cm, respectively. The diameter of the central limiter is 360 mm, while the iris limiter is radially variable type of limiter. The diameter of the limiter can be changed within 340 mm to 400 mm. Ion Sensitive Probe (ISP) located at z = 120 cm, is used to measure the radial loss ion. Loss electron diagnostic (LED) are set up in the both end-cells. LED measures the axial escaping electron. Electro-statics probes (ESP) are set up on the central limiter. ESP measures the ion saturation current and its fluctuation. ESP is composed of the tungsten wire with a diameter of 0.5 mm and a length of 1 mm, covered the ceramic tube and the stainless steel pipe. Assignment of ESPs is shown in Fig. 2. The particle behavior was investigated by these diagnostics instruments. Soft X-ray system is installed in the central-cell. Soft X-rays (SX) are radiated by the bremsstrahlung of the electron heated by the C-ECRH.

III. Experimental results

In GAMMA 10, C-ECRH is usually supplied for the plasma electron heating to the potential confined plasma (P/B-ECRH). In the case of a certain suitable condition for the C-ECRH injection, the diamagnetism in the central-cell (DMcc) was increased during only C-ECRH.

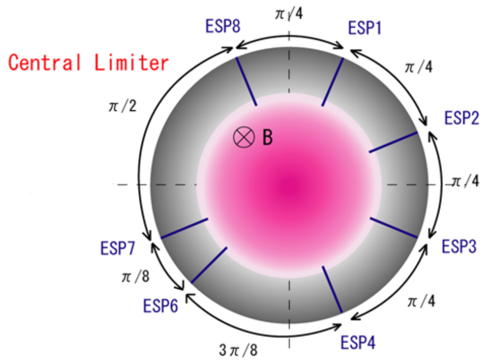

Fig.2 The assignment of ESPs is illustrated.

However the diamagnetism and the electron line density (NLcc) measured in the central-cell were occasionally decreased in the C-ECRH period.

In order to understand the physical mechanism of the degradation of the plasma during the C-ECRH, the experiment of the C-ECRH injection without the confining potential was performed in order to verify the effect of the C-ECRH. The two types of time behavior of the plasma parameters are compared in Fig. 3. One is "only C-ECRH" that the experiment is performed without the confining potential. The other is "with all ECRHs" that the experiment is performed with the confining potential. In this experiment, the signal of LED, ISP and ESP increases at the same time. These results mean that

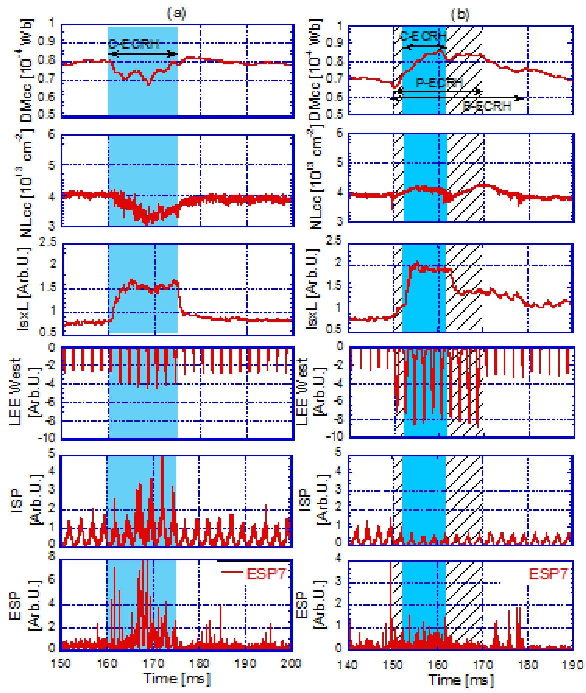

Fig.3 The temporal behavior of plasma parameters.
(a) Only C-ECRH, (b) With all ECRHs

the particle loss causes the degradation of the stored energy. Therefore, it is considered that the degradation of the plasma is induced by the enhancement of the particle loss with C-ECRH. However the intensity of the SX was increased in the C-ECRH period. On the other hands, it was already observed that the plasma sustained in the C-ECRH injection under the condition that a large amount of particle source from limiter recycling and gas puffer is generated.

On the basis of these results, the optimized condition of the experiment was investigated. As a result, the DMcc was increased during the C-ECRH injection with P/B-ECRH even though the NLcc was slightly decreased. Furthermore the signal of ISP and ESPs was decreased at the same time. This means that the bad influence induced by the C-ECRH is significantly suppressed by the confining potential.

IV. DISCUSSION

From the experimental results, the degradation of the plasma performance was thought to be induced by the plasma particles loss. In the case that the axial confining potential plugged the axial escaping particle, the plasma performance was improved.

We considered how the electron was expelled during the C-ECRH injection. When the ECRH is injected to the region with the magnetic gradient, the electron is expelled in weak direction of the magnetic field. This is a mechanism into which the electron is expelled. The axial confining potential improved the plasma performance because the axial escaping electron was plugged by the axial confining potential.

The end plates (EP) have been installed at both end cells for receiving the end loss plasma. End plates are separated in five segments in radial direction and 4 or 8 in azimuth direction. Each plate is isolated with 1 MΩ register [5]. We measured the floating potential of each EP by using the 50 Ω of pick up resister. In the C-ECRH injection, the potential of the EPs was about -200 V. This means that the electron was expelled along the magnetic field. On the other hand, the EP potential was -2 ~ -3 kV because a large amount of the electron was expelled in order to produce the axial confining potential [6]. That EP potential has a strong effect which bounces the expelled electron. It is consistent that the bad influence of the C-ECRH injection is improved during the P/B-ECRH.

V. SUMMARY

The plasma behavior during the C-ECRH injection and the mechanism of the degradation induced by the C-ECRH injection were investigated. From the experimental results, the following is clarified.

- The particle loss was induced by the C-ECRH injection.
- The particle loss caused the degradation of the stored energy.
- In the case that the loss particle was plugged by the axial confining potential, the plasma performance was improved with all ECRHs injection.

From above results, one of the mechanisms of the degradation of the plasma performance was confirmed. However we have not clarified the all mechanism of the degradation of the plasma performance.

We will investigate the radial transport in more detail in terms of the dependence of the power of the all ECRHs. It is already noticed that there is a significant relationship between the plasma performance and the fluctuation. Therefore, we investigate not only the behavior of the plasma but also the fluctuation of the plasma parameter.

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