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2-D effect of ion dynamics on radial profile of ion temperature in the edge of magnetized plasma

磁化プラズマ周辺領域のイオン温度分布における イオンダイナミクスの2次元的効果

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Ion dynamics in the edge region of magnetized plasmas have been studied by comparing experimentally obtained radial profiles of ion temperature with analytical ion mean energy profiles based on the ion Larmor motion. Both radial profiles show the tendency that ion temperature increase at the outside of the plasma column with increasing the radial distance from the plasma center. Two-dimensional model considering the radial profile of magnetized plasma indicates the importance of high-energy ions which have large Larmor radius.

1. Introduction

It is important to understand the edge and the divertor plasmas in order to operate high performance plasmas in magnetic confinement fusion devices. The spatial profiles of ion temperature T_i, electron temperature T_e and electron density n_e are the key parameters for characterizing the transport in these boundary plasmas.

So far, T_i measurements using an Ion Sensitive Probe (ISP) [1] have been done using a linear plasma device, Compact Test Plasma device with Hot Cathode (CTP-HC), in Nagano National College of Technology. The observed results showed the tendency that T_i becomes high with increasing radial position at the outside of the plasma column [2,3]. A simple analysis about the radial profile of T_i also has been done using one-dimensional (1-D) T_i evaluation model based on ion Larmor motion [4]. According to the model, a probe put at far from the plasma column measures high-energy ions selectively. The analysis model showed the results consistent with experimental one.

In this study, in order to check the influence of two-dimensional (2-D) effect for T_i profile we have measured T_i using an ISP in the linear divertor plasma simulator NAGDIS-II in Nagoya University of which plasma diameter is larger than CTP-HC. The experimental results have compared T_i profiles with 1-D and 2-D models.

2. Experimental setup

Figure 1 shows a schematic of the ISP measurement system in NAGDIS-II. Radial position of the probe can be changed with 2mm in space resolution. In this study, Helium is used for plasma discharge.

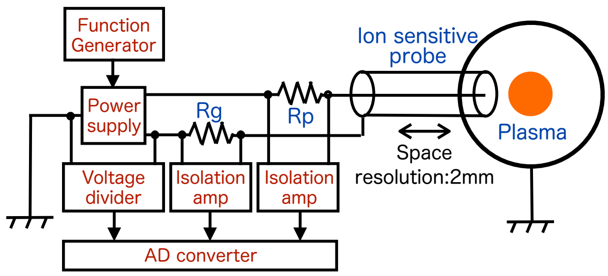

Fig.1 Schematics of ISP measurement system

3. Analysis model

We consider the behavior of ion which is located at $P(r,\theta)$ in a cross section of a cylindrical plasma, where r is the distance from the plasma center and θ is an azimuthal angle as shown in Fig. 2. Assuming no diffusion process, the ion at $P(r,\theta)$ can reach a probe position r_c moving a Larmor orbit when it has ion energy $E_i(r,\theta)$. The distance between P and r_c is represented by l. At the probe position r_c, ions with Larmor radius of $l/2$ are collected. $E_i(r,\theta)$ is ion energy to reach probe head calculated by l and is proportional to squared Larmor radius.

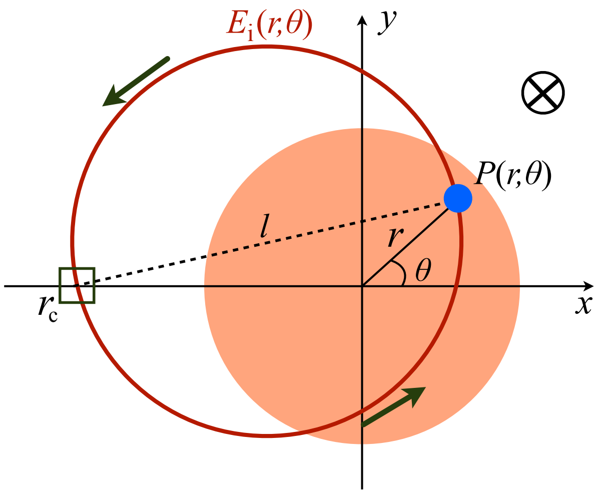

Fig.2 ion Larmor dynamics

This 2-D model indicates ions with large Larmor radius (higher energy) can reach more outside of plasma column. Therefore, T_i is expected to show high temperature with increasing radial position.

Considering the all position for the origin of ion, mean energy at the probe position T_i (r_c) is expressed as follows:

$$T_i(r_c) = \frac{\iint n(r,\theta)E_i(r,\theta)F(E_i)drd\theta}{\iint n(r,\theta)F(E_i)drd\theta} \qquad (1)$$

Where, $n(r,\theta)$ is plasma density. $F(E_i)$ is Maxwell distribution assuming a T_i in the plasma column at $P(r,\theta)$.

4. Results and discussion

Figure 3 shows the comparison of the experimentally obtained T_i profile with analytical results using Eq. (1). Both analyses assume the experimental condition of NAGDIS-II for n_e profile, gas pressure. T_i in the plasma column is assumed an exponent profile predicted by the experimental result.

As shown in Fig.3, the experimental result shows the tendency that T_i becomes high with increasing radial position like CTP-HC. Both analytical results of 1-D and 2-D model also show the same tendency. Hence, the analytical results are qualitatively consistent with the experimental result. However, analytical results show higher T_i profiles than the experimental result. Furthermore, 2-D analytical result shows higher T_i profiles than 1-D analytical one.

The reason why the difference caused might be due to lack of some assumptions. One possible reason is diffusing low temperature plasma around plasma column. Another one is the charge exchange reaction of ions during Larmor motion. Moreover parallel transport might be taken into account.

The cause of that 2-D analysis show higher T_i profile than 1-D could be due to considering more ions on the 2-D analysis than the 1-D analysis.

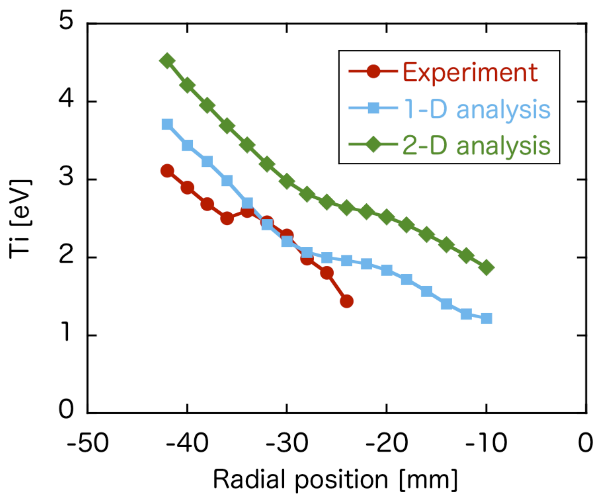

Fig.3 Comparison of Ti profile obtained by ISP measurement at the outside of the plasma column with results of analytical models of 1-D and 2-D

5. Conclusions

In this study, radial profiles of T_i have been measured using an ISP in NAGDIS-II. The experimental results show the tendency that T_i becomes high with increasing radial position. The results of 1-D and 2-D analyses based on the ion Larmor motion were compared with the experimental result. Both analytical results were qualitatively consistent with the experimental result, although the both analytical results showed higher profiles than the experimental result. Moreover, the 2-D analytical result showed higher profile than the 1-D analytical result.

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