Measurements of Plasma Diffusion Coefficient in Pilot-PSI Device Using Katsumata Probe

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Abstract:

Cross-field transport of particles and energy is a major issue in magnetized fusion-relevant plasmas, due to its relevance for plasma confinement. In this paper Katsumata probe measurements performed in Pilot-PSI linear magnetized plasma device are presented. The plasma diffusion coefficient in perpendicular direction to the magnetic field was estimated from the measurements.

Keywords: *Katsumata probe, magnetized plasma, diffusion coefficient.*

1. Introduction

For studying plasma diffusion of magnetized plasmas, different experimental methods can be applied. One of these is to use the Katsumata probe [1]. Katsumata probe measurements performed in a linear magnetized plasma device called Pilot-PSI are presented in this contribution. This device was designed for investigations of plasma-surface interaction at ITER relevant parameters [2]. The device is fully operational at FOM-Institute for Plasma Physics Rijnhuizen, the Netherlands. Plasma diffusion coefficient in normal direction to the magnetic field was determined by Katsumata probe measurements using the model recently proposed by Brotankova *et al.* [3].

2. Experimental set-up

The scheme of Pilot-PSI device [2] is shown in Figure 1. The cylindrical vacuum vessel made of stainless steel is 1 m long and 40 cm in diameter. The plasma source of the discharge is a cascaded arc, installed in the center of the frontal flange of the vacuum chamber.

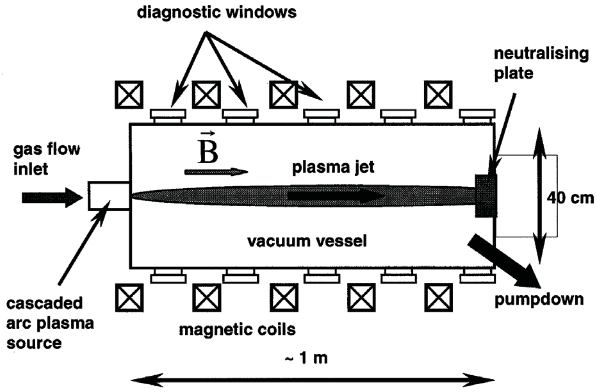

Fig. 1. General scheme of Pilot PSI set-up.

Five magnetic coils distributed along the vessel are used to create rather uniform magnetic field inside the vacuum chamber. The maximum value of the axial magnetic field can be 1.6 T. At the end of the vacuum vessel, face to face with the plasma source there is installed a water-cooled solid target. Copper, carbon or tungsten is used as target materials. The main goal of this set-up is to study the interaction of high density magnetized plasmas with solid targets made from the same materials which will be used to realize the divertor in ITER tokamak. Pilot-PSI is also the prototype for the new plasma fusion experimental set-up Magnum-PSI. The plant shall obtain particle fluxes at target surface similar with particle fluxes at the divertor surface in ITER, using confining magnetic fields up to 3 T.

A Katsumata probe was used to determine the diffusion coefficient perpendicular to the magnetic filed direction, in Pilot-PSI. The Katsumata probe consists of a tungsten collector having the diameter of 1.6 mm that can be moved inside of a ceramic tube, which is bigger in diameter. A schematic drawing of a Katsumata probe is shown in Figure 2.

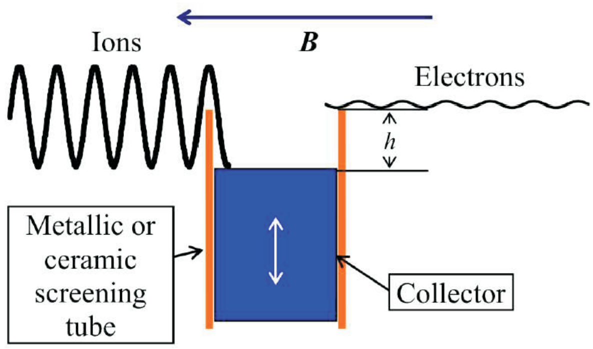

Fig. 2. Schematic drawing of a Katsumata probe.

The depth position of the tungsten collector inside the ceramic tube was marked down with h having origin (h = 0) at the level of the ceramic tube. The probe had radial mobility and was inserted inside the vacuum chamber at 3.4 cm in front of the target. The fluctuations of the floating potential were measured at different radial positions of the probe and also for different depth of the collector inside the ceramic tube. The radial position had a range from 0 to 2 cm, referenced to the axis of the vacuum vessel. Like collector position inside the ceramic tube, the depth h had a range from 0 to 5 mm. The fluctuations spectrum show that, as the collector is retracted inside the ceramic tube, the signal amplitude corresponding to certain frequencies (in the range of hundreds of KHz) has an exponential decay.

3. Results and discussions

Spectra of the floating potential fluctuations of the collector is shown in Figure 3 for a radial position of the Katsumata probe R = 0.4 cm and depths of the collector inside the ceramic tube as parameter (h between 0÷5 mm). The method used to process the data for a Katsumata probe is the one described by J. Brotankova *et al.* in the paper [3]. Fluctuations spectra obtained for each depth (h = 0÷5 mm) were smoothed using twenty adjacent points on each graph. After graphs smoothing for all h values, the amplitude A dependence versus h for certain frequencies was extracted.

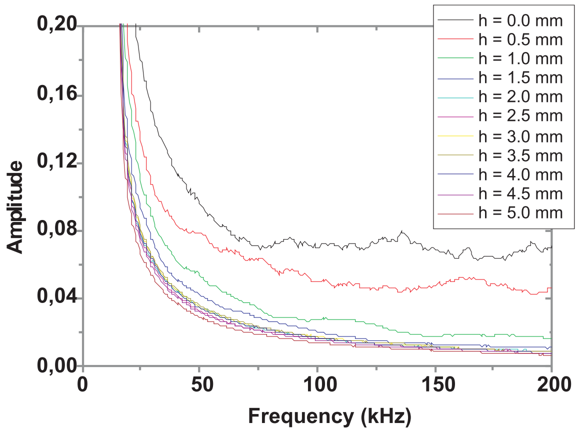

Fig. 3. Amplitude spectrum of the fluctuations on the collector for different h position.

Then, the graph of ln(A) versus h values is represented, for each different constant frequency in the range from 30 KHz to 120 KHz (Figure 4). From this drawing one can notice that for values of h smaller than 1.5 mm the amplitude logarithm decreases linearly and this means that the real signal registered by the Katsumata probe collector diminishes exponential. The relation between diffusion length L inside the ceramic tube [3] and the corresponding frequency is:

$$1/L^2 = \pi f/D$$

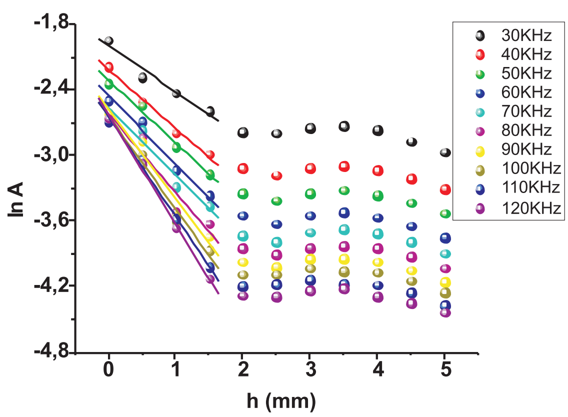

Fig. 4. Decay of ln A inside the ceramic tube for constant frequency of the fluctuations.

Here D is the diffusion coefficient of the plasma inside the ceramic tube, in perpendicular direction to the magnetic field lines.

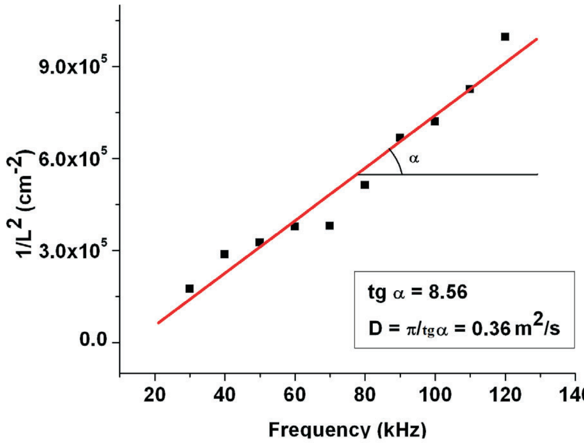

Fig. 5. Dependence of $1/L^2$ on the frequency.

In Figure 5 it can be observed that the dependence of $1/L^2$ on the frequency f is almost linear and, according to the above mentioned relation, the graph's slope is equal witch π/D. Thus, the transversal diffusion coefficient can be determined.

For the measurements achieved in the experimental conditions of pressure p = 7.4 Pa, magnetic field B = 0.4 T, current through the plasma source I_S = 90 A, gas flow Q_{H2} = 3 slm (standard liters per minutes), the obtained transversal diffusion coefficient varied between 0.23 m²/s in the center of the plasma column (at the radial position R = 0 cm) and 0.74 m²/s at the edge of the plasma column (at the radial position R = 1 cm). This coefficient slowly increases from the center of the plasma column towards the edge. These values are in good agreement with the Bohm diffusion [4]. These values are in the same range as Bohm diffusion coefficient. For example, for an electron temperature of 1.7 eV measured on the axis of Pilot-PSI in a magnetic field of 0.4 T [2], the transversal Bohm diffusion coefficient is 0.27 m²/s

4. Conclusions

Katsumata probe measurements can be used to estimate plasma diffusion coefficient in Pilot-PSI linear magnetized plasma device. The obtained values for transversal diffusion coefficient were in the range 0.23 to 0.74 m²/s. These values are in good agreement with the Bohm diffusion and also there are similar with the one obtained nowadays in tokamak devices [5].

ACKNOWLEDGMENTS

This work, supported by the European Communities under the contract 1EU-3/11.08.2008 of Association EURATOM-MEdC, was carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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