§5. Plasma Flow Measurement using Facing-Double Probe

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A plasma flow is concerned in various phenomena observed in plasmas. Consequently, to measure the plow velocity is required in wide range of fields of plasma science, from basic investigation to applications. In this research, it is our purpose to establish a method how to determine a precise Mach number of a plasma flow using the Facing-Double probe (FDP). The observation method using the FDP is our new proposal for estimating the Mach number of the plasma flow[1, 2]. It is shown that the method is capable of determining the wide range of Mach number up to 2 by particle-in-cell (PIC) simulation and numerical calculations based on the fluid model. In addition, preliminary performed experiments have tended to support these numerical results. It is required for establishing the evaluating method of Mach number using FDP to compare Mach numbers obtained by other method such as the conventional Mach probe and/or Laser-Induced-Fluorescent method. The HIPER-I device in National Institute of Fusion Science (NIFS) has various methods for this propose.

Schematic drawing of the FDP for the present experiments is shown in Fig. 1. The gray parts are tungsten electrodes. In a conventional Mach probe, the electrodes are placed back-to-back putting an insulator between them. In case of FDP, it is a peculiarity that the electrodes are placed face-to-face. Because of such a shape of FDP, disturbance of plasmas due to a pre-sheath formed in front of the electrode is considered to be less than the disturbance in the case of the conventional Mach probe. At the same time, the shape of FDP has a new advantageous point in measuring the spatial profile of Mach number because the spatially limited pre-sheath expansion brings a relatively high spatial resolution and makes it possible to obtain a spatial Mach number distribution. Sizes of the electrodes and a distance between the electrodes are determined from a point of view that a plasma exists between the electrodes are regarded to be 1-dimensional. The electrodes are connected through a direct-current (dc) variable power supply and an ammeter.

When FDP is inserted into a flowing plasma, the dc voltage V_0, at which the ammeter shows no current, is related to Mach number M. That is, there is a following relation between V_0 and M:

$$\frac{eV_0}{k_B T_e} \cong \left\{ 1 + \frac{\alpha}{\sqrt{1+\alpha}} \tan^{-1}\left(\sqrt{1+\alpha}\right) \right\} M \qquad (1)$$

where e is the elementary electric charge, k_B the Boltzmann constant, T_e the electron temperature between the electrodes, and α the normalized viscosity. When M is small, the value of M is proportional to the value of V_0. This suggests that the determination of Mach number using FDP is probably easier than using the conventional one.

The observed data from HIPER-I suggest that FDP seems possible to estimate Mach number though the results require us to refine the method at the same time. For example, the present electrodes of FDP have wide lateral areas and easily detect the charged particles plunged into them irrelevantly to the plasma flow. From this point of view, the shape of the electrode should be a plate with small lateral area. It is expected that FDP method is capable of measuring the spatial distribution of Mach number because of its shape. The measurement circuit is quite simple and easier to evaluate Mach number. It is expected that the method has wide range of application after the method is established.

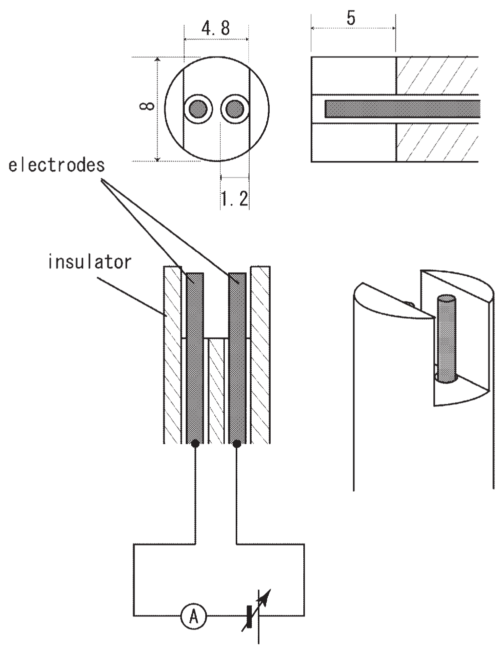

Fig. 1 Schematic drawing of the Facing-Double probe.

References
1) Y. Saitou and A. Tsushima: Jpn. J. Appl. Phys., **40** (2001) L1387 - L1389.
2) Y. Saitou and A. Tsushima: J. Phys. Soc. Jpn., **70** (2001) 3201 - 3204.