

§9. Measurements of Plasma Flow Mach Numbers Using the Face-to-Face Probe with Multi-Electrodes

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Two of authors (Tsushima and Saitou) have proposed a new diagnostic method of a Mach number of a plasma flow, which is named “Face-to-Face Double Probe (FDP)”^{1, 2)} The FDP consists of a pair of face-to-face electrodes and the extension of the presheath is restricted between the electrodes. The FDP has a good spatial resolution due to its shape and restricted presheath expansion. The Mach number relates to the floating potential of the probe as follows:

$$\frac{eV_f}{k_B T_e} \approx \left\{ 1 + \frac{\alpha}{\sqrt{1+\alpha}} \tan^{-1} \sqrt{1+\alpha} \right\} M, \quad (1)$$

where e is the elementary electric charge, V_f the floating voltage, k_B Boltzmann constant, α the normalized viscosity, and M the Mach number.

In this research work, it is tried to measure the Mach number of the plasma flow using a newly developed “reversed Gundestrup-type probe (RGP)”, which is tentatively named, as one of variations of the FDP. A Gundestrup-type probe is known as one of Mach probes and consists of back-to-back multi-electrodes.³⁾ The RGP is a probe whose face-to-face multi-electrodes are arranged along a circumference. A pair of electrodes located symmetrical position with respect to the origin of the circle is used in the same way as the FDP.

The experiments were performed in the HYPER-I device at NIFS. The device was exhausted at a pressure of 10^{-6} Torr order and argon gas was fed at a pressure of $1.7 \times$

10^{-4} Torr. Plasma was generated by ECR with 3 kW microwave. The RGP was placed at $z = 155.5$ [cm] from the microwave injection window along the chamber axis and $r = 0$ [cm] in the radial direction. The strength of the magnetic field is approximately 800 [G] and the magnetic field was weakly diverged at the measuring position. The plasma parameters under this experimental condition have been estimated to be as follows: $n_e \approx 10^{11}$ [cm⁻³], $T_e \approx 8$ [eV], $T_i \approx 1.2$ [eV] from the measurements using the Langmuir probe or laser diagnostic methods. In addition, it is known that the plasma flows with $M < 1$ as well.

The RGP used in the present work has 6 electrodes as shown in Fig. 1 (a). Figure 1 (b) is its draft. The size of each electrode was 0.7 mm in diameter and 4 mm in length. The electrode was supported by a ceramic tube. The 6 electrodes consist of 3 pairs: that is Nos. 1-4, 2-5, and 3-6 in Fig. 1 (a). Each pair was used as one FDP and measured the V - I characteristics to obtain the floating voltage, V_f , for estimating the Mach number from Eq. (1). Furthermore, the probe tip was rotated every 15 degrees around its center and the measurement was repeated to calibrate the finite but inevitable difference in the surface area of the electrode.

Typical example of the obtained floating voltage is shown in Fig. 2. Plasma flows from 0 to 180 degrees. Black closed circles distribute elliptically as expected. It is considered that the distribution is a circle around the center if there is not the flow. The circle is deformed by the flow and becomes the ellipse. On the other hand, red closed circles show deep negative voltages. These are unexpected cases. A cause of such a negative voltage is under consideration.

- 1) Y. Saitou *et al.* J. Phys. Soc. Jpn. **70** (2001) 3201.
- 2) Y. Saitou *et al.* Jpn. J. Appl. Phys. **40** (2001) L1387.
- 3) *for examples:* C. S. MacLachy *et al.* Rev. Sci. Instrum. **63** (1992) 3923., and A. Litnovsky *et al.* Czech. J. Phys. **53** (2003) 903. *etc.*

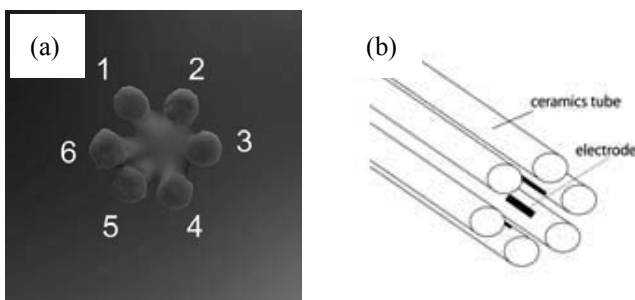


Fig. 1 The “reversed Gundestrup-type probe (RGP)” developed for the present work: a top view of RGP (a) and a draft of RGP (b). The electrodes are numbered from 1 to 6 in (a). The black parts in (b) denote the electrodes face inward.

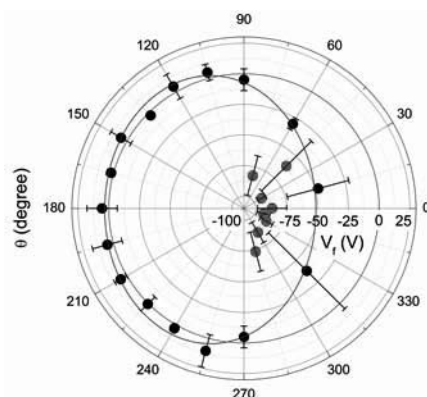


Fig. 2 Angle dependences of the floating potential. Plasma is flowing from 0 degree to 180 degrees. The reason the large negative voltage, which is denoted by red circles, are detected has not been clear yet and to clarify it is our future work.