§4. Mach Number Measurement using Facing-Double Probe

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Using the facing-double probe (FDP) and a conventional Mach probe, both of which have approximately a same geometric size, Mach number of plasma flow was measured. Obtained results were compared to establish a measurement method of the Mach number estimation using the FDP. Detailed description on the FDP is described in Refs. 1 and 2. Pictures of the FDP are shown in Fig. 1. The electrodes are connected through a power supply and an ammeter. When a current becomes 0, that is, the probe is regarded to be a floating potential, V_0, then a Mach number, M, is calculated by the following equation:

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

where e is the elementary charge, k_B is the Boltzmann constant, T_e is the electron temperature of a plasma between the electrodes, and α is the normalized viscosity. The value of α is assumed to be 0.5 following to the report by Amagishi *et al*[3]. It is probably possible for the FDP to measure the spatial distribution of the Mach number because the observed position is restricted between the electrodes. In addition, an extension of a presheath due to the electrodes is limited between themselves since the electrodes are placed face-to-face each other.

Experiments were performed using the HYPER-I device of NIFS. Helium gas was used at a pressure of (7.5～9.5)× 10^{-4} Torr. Plasma was produced using the electron-cyclotron resonance with a micro-wave of a frequency 2.45 GHz and a power 5 - 7 kW. Strength of a magnetic field was approximately 1 kG and weakly diverged. A generated plasma had the electron density of approximately 10^{10} cm^{-3}, and the electron temperature of approximately 6 eV, which were measured using FDP as a double-probe. A picture of the generated plasma, viewed from a small window equipped at the end wall, is shown in Fig. 2. Roughly speaking, it is found that the plasma has a uniform radiation of visible-light in its radial direction although the central region has a relatively strong one. A plasma flow was measured at 1175 mm from the micro-wave injecting point and at 253 mm from the chamber wall, which is the plasma center. Since our present purpose is to establish the Mach number measurement method, we concentrated only on the plasma flow along the chamber axis, which is approximately along the magnetic field line. A direct injection of charged particles to the electrodes due to an oblique flow such as the $\boldsymbol{E}\times\boldsymbol{B}$ drift is not eliminated, this time.

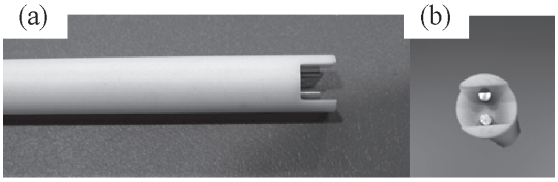

Fig. 1 Pictures of the FDP; (a) a side view and (b) a top view. A diameter of the ceramics insulator is 8 mm. Two tungsten electrodes, which are 0.8 mm in diameter and 4 mm in length, are placed 4 mm apart center to center.

The results of the Mach number measurements using the FDP and the conventional Mach probe were as follows: $M_{FDP} = 0.29 \pm 0.04$ with the FDP, and $M_{MP} = 0.22 \pm 0.09$ with the conventional Mach probe based on the magnetized kinetic model in which the normalized viscosity $\alpha = 0.5$ [4, 5]. It is found that both methods gave the similar results. This suggests that the determination of Mach number using FDP is probably easier than using the conventional one because its model and used electric circuit are simpler. Further detailed investigations are required to establish the Mach number measurement method using the FDP. In addition, its geometrical shape should be refined to avoid an injection of charged particles from aside due to the $\boldsymbol{E}\times\boldsymbol{B}$ drift *etc*. It is expected that the FDP method has wide range of application after being established.

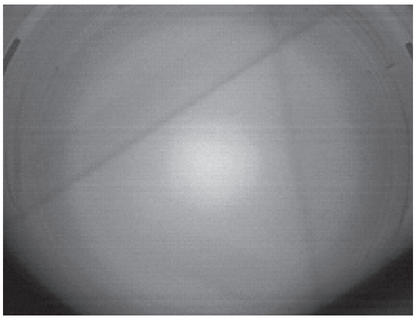

Fig. 2 Generated He plasma in the HYPER-I device, which is viewed using CCD camera located at outside of the end wall. Two dark lines are shadows of outer structures of the device.

References

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