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マッハプローブ周辺の粒子シミュレーションと較正係数
Calibration factor in a Mach probe measurement derived using a particle simulation

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1. Introduction

A Mach probe is one of the diagnostic tools for plasma flow with a simple structure and good spatial resolution. It consists of two collecting surfaces facing to different directions with respect to plasma flow. An ion Mach number M_i can be determined from the ratio R between the upstream and downstream ion saturation current densities J_{is} with the following equations.

$$M_i = M_c \cdot \ln R \quad (1)$$

$$R = \frac{J_{up}}{J_{down}} = \exp(K v_f), \quad (2)$$

where M_c and K are constants, and j_{up}, j_{down} are the ion saturation current densities measured by upstream and downstream tips of the Mach probe, respectively.

In order to evaluate an ion Mach number reliably, it is necessary to determine the constant values M_c and K in variety of conditions. In this study, we calculated these constants using a PIC code, which simulates dynamics of charged particles in the sheath region around the probe surface. The calculated results are compared with those obtained by experiments.

2. Experiment in the HITOP device

Fig. 1 shows a schematic of the HITOP device, which consists of a vacuum chamber with 3.4 m in length and 0.8 m in diameter, and magnetic coils to form a uniform magnetic field up to 1 kG. An MPD arcjet is attached on one end and high density plasma exhausts with Mach number of nearly unity.

A directional Langmuir probe (DLP) was installed in the chamber for modeling of a Mach probe. It can be rotated around its axis in order to measure the dependence of ion saturation current on an angle θ between the flow direction and the normal direction of the collecting surface of the probe [1]. A barrier wall was attached on the DLP in order to evaluate the effect of the shadow due to the wall.

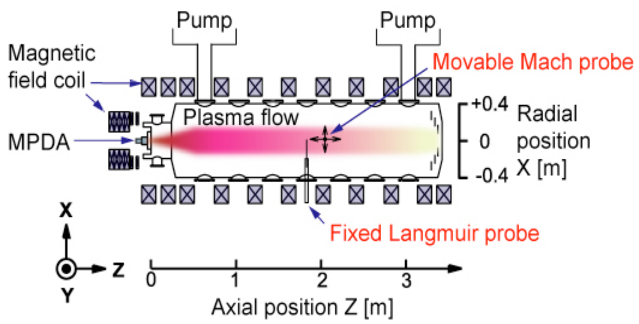

Fig. 1 Schematic diagram of the HITOP

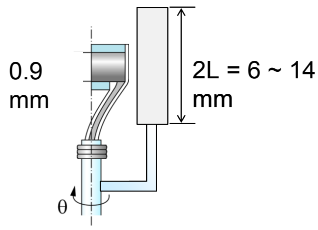

Fig. 2 Schematic of the DLP.

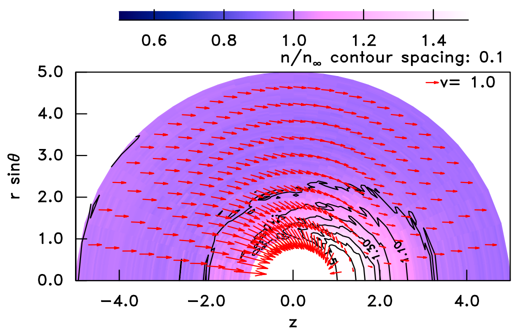

Fig. 3 Calculated density distribution around the probe

3. Numerical Calculation

In order to simulate probe currents, we used the specialized-coordinate electrostatic-coordinate electro-static particle and thermals in cell (SCEPTIP) code [2, 3]. In the simulation model, the spherical coordinate was used and a probe was placed at origin. Fig. 3 shows the calculated potential and density distribution. The arrows represent averaged ion velocities at each position. The constants, K and M_c, were derived from the calculation and compared with data obtained experimentally in various conditions.

References

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