VALIDATION OF PLASMA VELOCITY MEASUREMENTS WITH MACH PROBES USING LASER INDUCED FLUORESCENCE

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1. Introduction

Mach probes have been used in several tokamaks to measure the plasma speed along magnetic field lines [1]. Other techniques exist and are used to measure plasma flow. For example, spectroscopy presents the advantage of not perturbing the plasma but is a non-local measurement. Although relatively simple from the experimental standpoint and providing a local measurement of the velocity, Mach probes require that a model be used to deduce the Mach number and the absolute value of the velocity from the measured saturation currents of the electrostatic collectors. Several models have been proposed and it is the purpose of the present work to enlighten the choice of the model by comparing the probe results with those obtained with a different diagnostic, in this case Laser Induced Fluorescence (LIF).

2. Experimental set-up

2.1. The plasma

Axial discharges in argon are used as test plasmas. Electron cyclotron resonance is used to generate the plasma. A 1.5 kW magnetron at 2.45 GHz is used in conjunction with an appropriate axial magnetic field of 875 Gauss. The magnetic field along the column is generated by 11 coils which are energized by two power supplies, the field at the magnetron and the rest of the column being adjustable independently. The working gas pressure was varied to scan the plasma density, temperature and axial velocity.

2.2. LIF

LIF consists in the excitation of atoms or ions by the laser photons at a wavelength and observing the ensuing emission at another, the resonant transition being specific to the atom or ion [2]. A tunable dye laser pumped by an excimer laser scanned from 616.359 to

621.728 nm in steps of 0,001 nm was used to excite a resonant transition (λ_0 = 617.229 nm) of the singly ionized argon ion leading to the emission of fluorescence (λ_f = 458,993 nm) observed through a filter (1,0 nm wide at 459,0 nm). The beam was aimed axially through the discharge but was aimed perpendicularly to the axis of the column for a calibration at λ_0 . The intensity of the observed emission plotted against the incident wavelength will have a maximum at a wavelength which is Doppler shifted from λ_0 due to the axial velocity of the argon ion.

2.3. Probe

A single circular (8 mm radius) rotatable collector was used and its ion saturation current was measured when facing both directions parallel and anti-parallel to the magnetic field. With an estimated collection length of 4 cm approximately, the collector was not connected in either direction. According to Mach probe models [3,4,5], the ratio of these currents is a direct measurement of the Mach number, the numerical result depending on the model used.

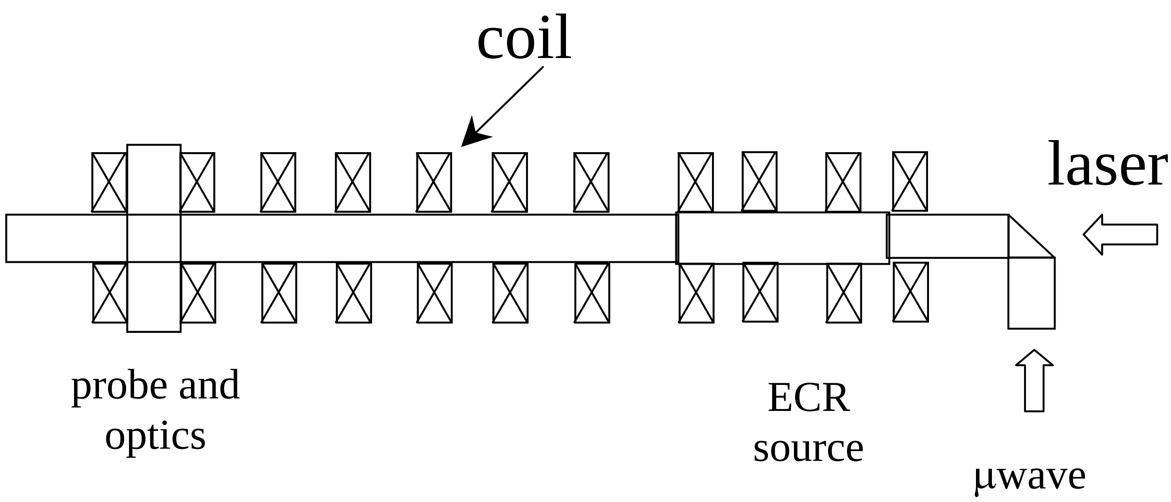

Figure 1. Experimental set-up

3. Results

Figure 2 summarizes the results. The ratio of the ion saturation currents collected parallel and anti-parallel to the axial magnetic field is plotted against the Mach number obtained by dividing the velocity measured by LIF by the ion sound speed calculated using the temperature measured by the probe. The different lines represent the predictions of different models[3,4,5]. The different symbols represent the current ratios measured experimentally. It should be noted that the Hutchinson model with $\alpha = 1$ was used, α being the ratio of the viscosity to the diffusivity:

$$\alpha = \eta / m_i n D_\perp$$

where η is the viscosity, m_i is the ion mass, n the density and $D_\perp$ the perpendicular diffusion coefficient. This assumption is unverified, although an α between 0,8 and 1,2 was obtained in the scrape off layer of TEXT [6] for comparable electron densities and temperatures in a deuterium plasma. Other experimenters [7], on the other hand, have obtained α ~ 0,5 but this result was open to interpretation [8].

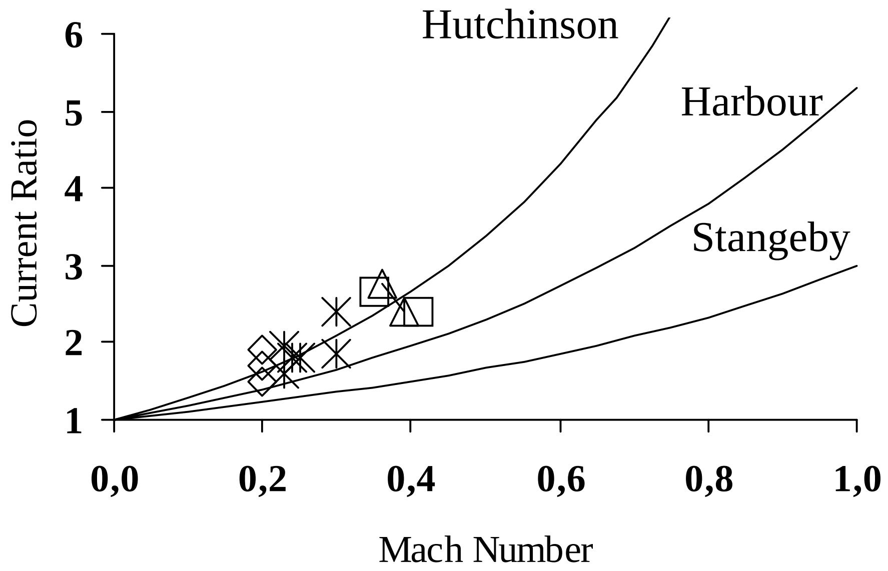

Figure 2. Comparison between models ans experiment. The squares (□) are at 1,5 x 10^{-4} Torr, the triangles (Δ) at 2,6 x 10^{-4} Torr, the stars (*) at 3,0 x10^{-4} Torr and the diamonds (◊) at 3,5 x 10^{-4} Torr.

4. Conclusion

Even though the experimental results stop at a Mach number of 0,4 approximately, this comparison between the probe and LIF measurements suggests that the relation between the current ratio and the Mach number is best modeled by the theory proposed by Hutchinson [3] as long as the viscosity factor is around 1.

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