Study of edge flows during emissive electrode biased discharges on ISTTOK

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1. Introduction

Electrode bias experiments have been studied previously on ISTTOK [1]. The modifications in plasma confinement and edge parameters have been investigated in detail and experiments have shown that biasing can lead to an improvement in gross particle confinement while suppressing edge turbulent flux. In this contribution the electrode biased discharges are further characterized using a Gundestrup probe, with focus on the relation between the radial electric field and edge flows.

2. Experimental setup

ISTTOK is a large aspect ratio circular cross-section tokamak (R = 46 cm, a = 7.8 cm, B_T = 0.5 T, $\Delta\Phi$ = 0.22 Vs), which has a fully poloidal graphite limiter at r = 7.8 cm. For the experiments reported in this paper, the typical values of the discharge parameters were: $I_P \approx$ 4-6 kA, $\tau_D \sim$ 30 ms, $n_e \approx 2.5\text{-}6 \times 10^{18}$ m^{-3}, $T_e \approx$ 150-200 eV, $\tau_P \sim$ 0.5 ms.

A movable emissive electrode [2], located in the same toroidal position of the rake probe, has been used for biasing the edge plasma. The emissive electrode consists of a lanthanum hexaboride (LaB_6) electron emitter heated by a tungsten filament. The large current it is able to produce allows an effective control of the local plasma potential at negative bias, while behaving as a regular electrode at positive bias.

A radial array of Langmuir probes (rake probe) has been used to measure the floating potential in the boundary plasma. The rake probe consists of a boron-nitride head carrying seven tungsten tips with spatial resolution down to 4 mm. Plasma SOL flow measurements were made using a Gundestrup Probe [3]. It consists on eight round electrodes mounted around an insulating cylindrical housing as shown in fig. 1a. The electrodes are negatively biased and a polar diagram of ion saturation current is obtained. A 1D fluid probe model [4] was used to deduce the parallel and perpendicular components of the unperturbed flow, taking

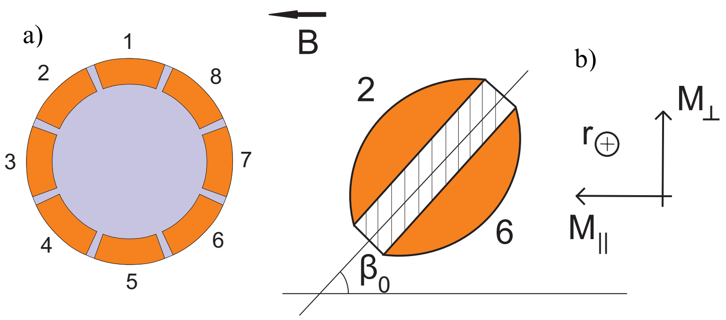

Fig. 1 - a) Schematic drawing of the Gundestrup probe
b) Vector convention used

into account the roundness of the collectors. Following the convention of fig. 1b, the parallel Mach number $M_{\|}$ was derived using $R_{\|} = e^{cM_{\|}}$, where $R_{\|}$ is the saturation current ratio of upstream and downstream collectors (7 and 3) and c is a fit parameter (the value 2.4 was used). The perpendicular Mach number $M_{\perp}$ was computed from $\frac{R_{\perp}}{R_{\|}} = \int_{\beta_0-\alpha/2}^{\beta_0+\alpha/2} \cos(\beta) e^{cM_{\perp} tg(\beta)} d\beta \Big/ \int_{\beta_0-\alpha/2}^{\beta_0+\alpha/2} \cos(\beta) e^{-cM_{\perp} tg(\beta)} d\beta$, where $R_{\perp}$ is the saturation current ratio of collectors 6 and 2 or 8 and 4, β_0 is the angle of the probe axis with respect to the magnetic field direction (45^0 was chosen) and α is the collectors angular extent (42^0 for our probe).

3. Experimental results

The measured parameters for two shots, with positive bias (#11898) and with negative bias (#11918) can be seen in figure 2. Bias was applied for a period of 2 ms starting at 14ms. The temporal traces of density and gross particle confinement time (blue for positive and red for negative bias) and the radial traces of plasma potential (derived from $V_P = V_f + 3\ T_e$) and radial electric field before (in grey) and during the biasing period are shown. The grey lines represent the average profile of the two shots and the Gundestrup probe location is shown by the dotted line. Also plotted is the polar diagram of the Gundestrup probe collected ion saturation current and the computed mean Mach numbers before and during the bias. We note that for both polarities there is a strong increase in density, but only the negatively biased plasma has a substantial increase in gross particle confinement n_e/H_α. This is a standard result in ISTTOK edge bias experiments, compatible with the measured electric field shear which is stronger for the negatively biased discharges in the region just inside the limiter. The Gundestrup probe measures a large variation of the poloidal flow in the same region, indicating that the plasma changes the direction of rotation after the bias was applied ($M_{\perp}$ varied form 0.22 to -0.26), while for the positively biased discharge there was just a small increase of the poloidal flow. Concerning toroidal rotation we note that it also varies in different directions. $M_{\|}$ has a large increase when negative bias is applied and a modest

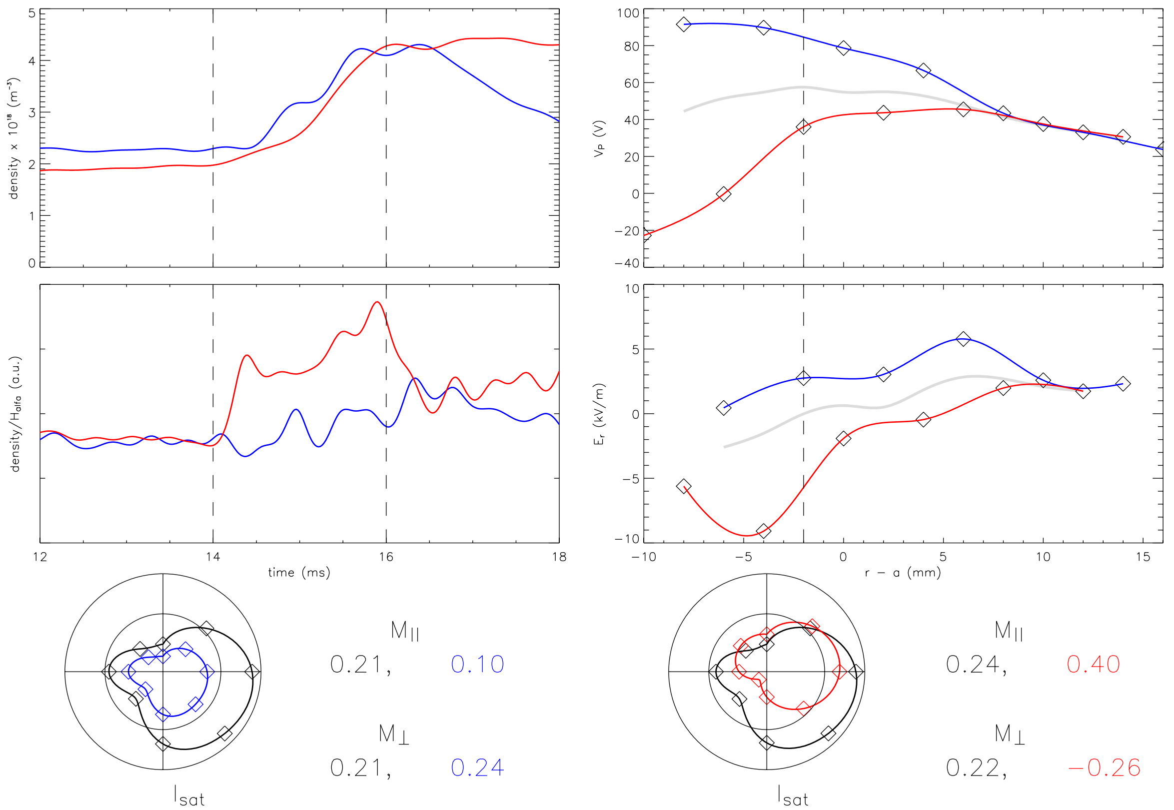

Fig. 2 - Plasma parameters for positive (blue) and negative (red) biased discharges.

decrease under positive bias, although the rotation direction remains unchanged for both polarities.

In figure 3, the radial profile of the Mach numbers is shown (same color scheme used in previous figure). Each plotted point represents the mean value of 5 to 10 reproducible discharges. We note that the positive bias is not able to drive large sheared flows, which for both type of bias are larger around the limiter radius. The perpendicular Mach number behaves in opposite ways inside the LCFS and in the SOL region when bias is applied. We further note that the unbiased plasma exhibits a toroidal flow of about 0.2 throughout

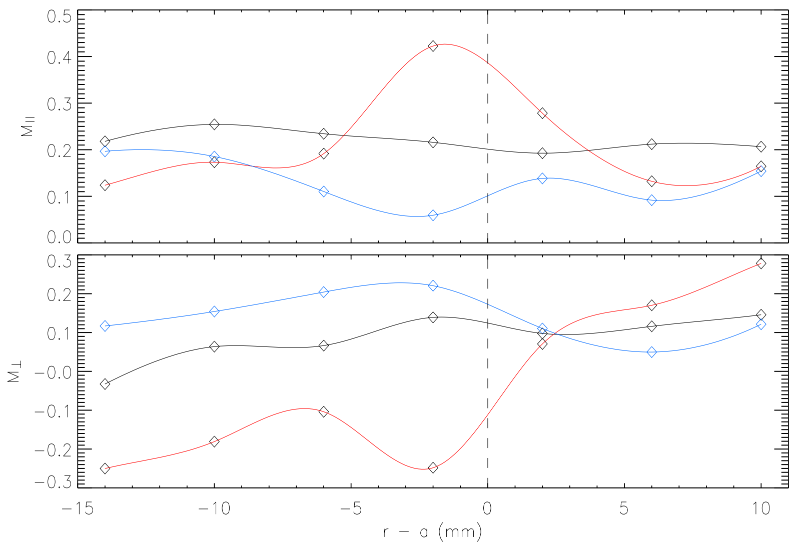

Fig. 3 - Radial traces of parallel and perpendicular Mach numbers.

the measured region, being the direction the same as that of the toroidal field and plasma current. Comparing the velocity profiles of the ExB drift and the poloidal flow, a good correlation is found in the edge plasma, but not in the SOL. Furthermore, we note that the modification induced by biasing in the flows is maximum for negative bias and occurs in the region just inside the limiter for both parallel and perpendicular flows.

Decay characteristic times of edge flows were studied also. In figure 5 we show a plot of the emissive electrode collected current, the floating potential 10 mm inside the limiter position and the perpendicular Mach number for a negatively biased discharge at the damping period (16 ms). As the bias voltage is switched off the decay time of both the electric field and poloidal flow is roughly ~15 μs, which is much smaller than the expected damping time based on magnetic pumping mechanism (~100 μs) and charge exchange (~500 μs) indicating that anomalous viscosity may play an important role in edge poloidal damping.

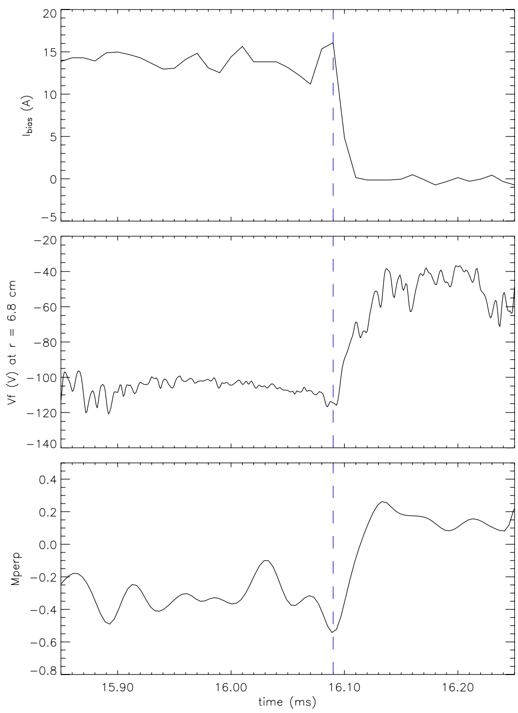

Fig. 4 - Plasma parameters during bias switch off.

Summary

The first measurements of edge flows during electrode bias have been performed using a Gundestrup probe. We have observed that the plasma rotates poloidaly in opposite directions for positive and negative bias in agreement with the modification in the radial electric field.

Acknowledgements: This work has been carried out in the frame of the Contract of Association between the European Atomic Energy Community and Instituto Superior Técnico (IST) and of the Contract of Associated Laboratory between Fundação para a Ciência e Tecnologia (FCT) and IST. The content of the publication is the sole responsibility of the authors and it does not necessarily represent the views of the Commission of the European Union or FCT or their services.

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