Biasing Experiments on the Tokamak ISTTOK

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Introduction

A velocity shear stabilization mechanism has been proposed to be responsible for an improvement in plasma confinement. A clear correlation between the modification of radial electric fields induced by bias and the reduction of turbulence has been also observed in several experiments [1]. The control of the shear layer is therefore an important tool to modify transport in tokamaks. Both limiter and electrode bias have been used on ISTTOK to investigate the possibility of shaping the plasma potential profile.

Electrode and limiter biasing experiments on ISTTOK have been already described in detail [2,3]. It has been shown that both positive limiter and electrode bias can modify the plasma behaviour. Electrode bias is more efficient than limiter bias in modifying the radial electric field and confinement, introducing stronger modification in the plasma potential, probably because it was inserted 1.5 cm inside the Last Closed Flux Surface (LCFS). However, it has been also shown that for negative electrode and limiter bias ($-250<V_{bias}<0$ V) no significant modification of either the global or the edge plasma parameters was observed since the electrode (limiter) drawn current was too low, 1 A (4 A), to modify the plasma parameters.

In order to obtain the larger current necessary to modify confinement at negative applied voltages, biasing experiments have been performed using the top limiter inserted well inside the fully poloidal limiter position (r=7.8 cm). In this contribution, biasing experiments using the top limiter are presented, emphasizing the influence of the limiter position and bias voltage.

Experimental set-up

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 two small stainless steel localized limiters, one at the horizontal outside and the other at the vertical top positions relative to the tokamak axis. The localized limiters consist of a section of a poloidal limiter, covering a poloidal extension of ~90º. The projection of the localized limiter area along the magnetic field is a factor of 5 larger than that of the electrode. Recently, an additional fully poloidal graphite limiter has been installed at r=7.8 cm. In the experiments described the top limiter position has been varied between r_{lim} =8.0 and r_{lim} =6.0 cm and the bias applied between the limiter and the vessel. Both the fully poloidal limiter and the horizontal limiter were grounded and at a fixed position (r=7.8 cm).

The main diagnostic used in this work is a radial array of Langmuir probes (rake probe). The rake probe consists of a boron-nitride head carrying nine tungsten tips and covering an extension of 27 mm (spatial resolution down to 4 mm). Two of the deepest tips are at the same radial position and used to measure the parallel Mach number.

Limiter bias results

A large variety of limiter biasing experiments have been performed on ISTTOK. In this work we report mainly on the effect of the limiter position and the bias voltage. Alternating bias voltages (50 Hz, 120 peak voltage) provided by a transformer have been used to determine the limiter voltage-current characteristic in a single shot. This is illustrated in figure 1, which shows the variation of the limiter current and the floating potential modification with the applied voltage for different limiter positions. Data points obtained with DC bias (full symbols) are also shown to extend the applied voltage range. From the analysis of the figure we may conclude that: (i) at negative bias, the limiter current and the modification in the floating potential increase as the limiter is inserted deeper into the plasma; (ii) contrary to the observed with electrode bias [3], a clear modification in the floating potential[1] (ΔV_f) is observed for $r_{lim}<7.0$ cm due to the larger collected current; (iii) for positive bias the effect of the limiter position on ΔV_f is small for $r_{lim}\geq 7.2$ cm; (iv) for each limiter position there is a roughly linear relation between the collected current

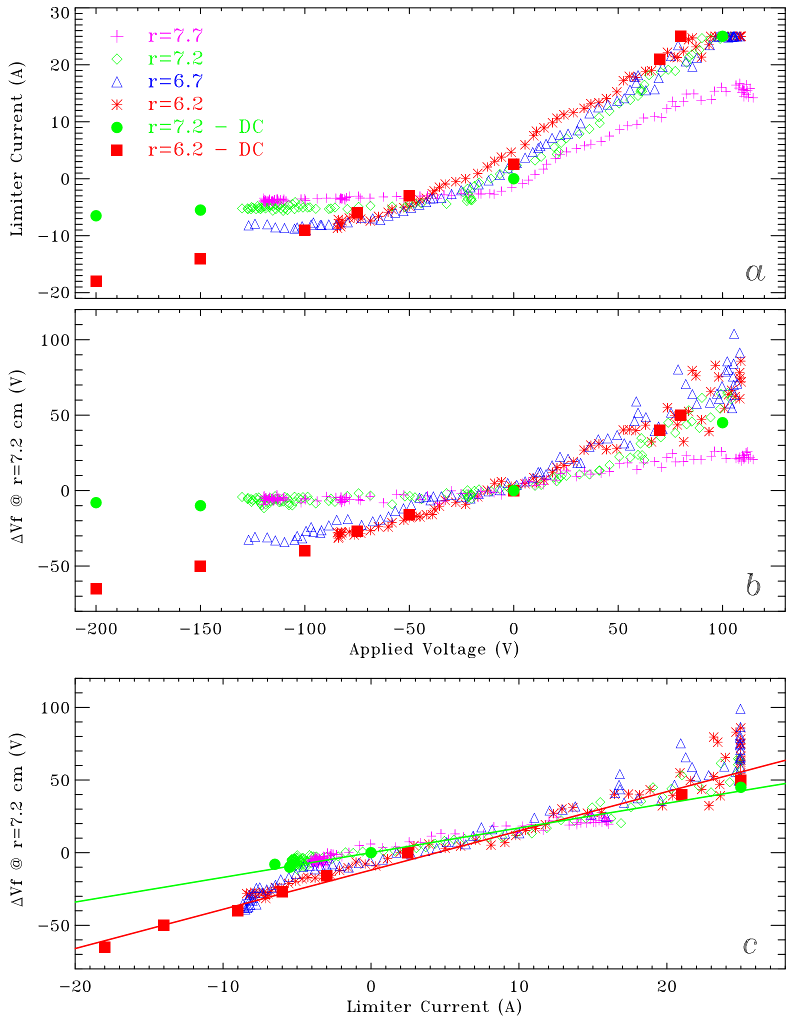

Figure 1: Variation of the limiter current (a) and ΔV_f (b) with the applied voltage for different limiter positions and dependence of ΔV_f on the limiter current (c). Data represented by full symbols have been obtained in DC biased discharges while the open symbols correspond to data from AC biased discharges.

[1] Variation of the plasma potential in relation to its value at V_{bias}=0.

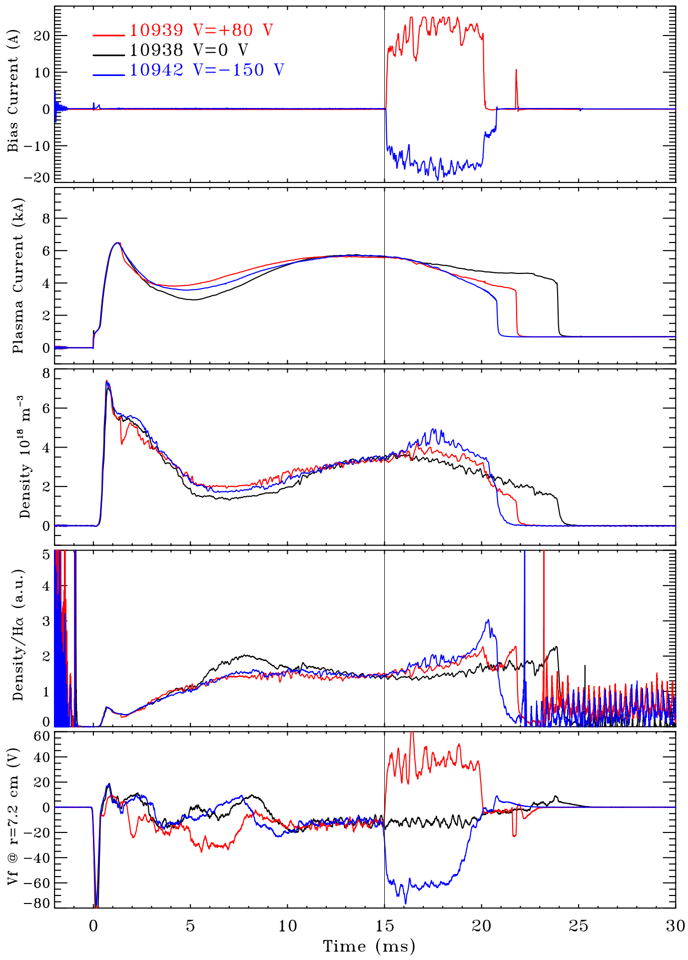

Figure 2: Time evolution the main plasma parameters for positive (V_{bias}=80 V), negative (V_{bias}=-150 V) and no limiter bias for r_{lim}=6.2 cm. Bias has been applied to the top limiter at t=15 ms during 5 ms.

and the modification in the floating potential, suggesting that the electric field created at the edge plasma is a result of an increase in the plasma rotation due to the collected radial current; (v) the modification in the floating potential is not only a function of the limiter current but also of the limiter position. This is clear at negative applied voltage, where, for the same current the variation on the floating potential profile increases as the limiter is inserted into the plasma (for I_{lim}=7A, ΔV_f=-9 V at r=7.2 cm (V_{bias}=-200 V) while at r=6.2 cm ΔV_f=-27 V (V_{bias} =-75 V)).

The effect of the limiter bias at different position on the overall plasma conditions has also been investigated. We have observed an improvement in confinement for both positive and negative limiter bias for r_{lim}<6.7. In figure 2, the time evolution of the main plasma parameters for positive (V_{bias}=80 V), negative (V_{bias}=-150 V) and no limiter bias are compared for r_{lim}=6.2 cm. Bias has been applied to the top limiter at t=15 ms during 5 ms. For both polarities an increase in density is observed which leads to a clear improvement on the gross particle confinement, as indicated by the rise in the ratio n_e/H_α. Due to the increase in density, the radiation losses also increase, leading to the plasma cooling and to the earlier termination of the discharge.

The floating potential in the plasma edge is modified in a short time scale (<100 μs) for both polarities. For the discharges shown in figure 2, the floating potential at r=7.2 cm increases by about 50 V for V_{bias}=80 V and decreases by ~45 V for V_{bias}=-150 V. Close to the fixed limiters the floating potential does not change significantly, leading to an increase in the edge radial electric field for both positive and negative limiter bias. Figure 3 shows the floating potential radial profile measured with the rake probe for the discharges shown in figure 2. The radial electric field inside the limiter decreases by ~7 kV/m for negative bias and increases by ~4kV/m for positive bias. We note that the radial electric field is relatively small for discharges with no applied voltage (1-2 kV/m) [3]. Therefore, both negative and positive bias increases significantly the magnitude of the electric field (up to +/- 6kV/m) in the region just inside the fixed limiters. This modification in the edge E_r profile may explain the observed improvement in particle confinement.

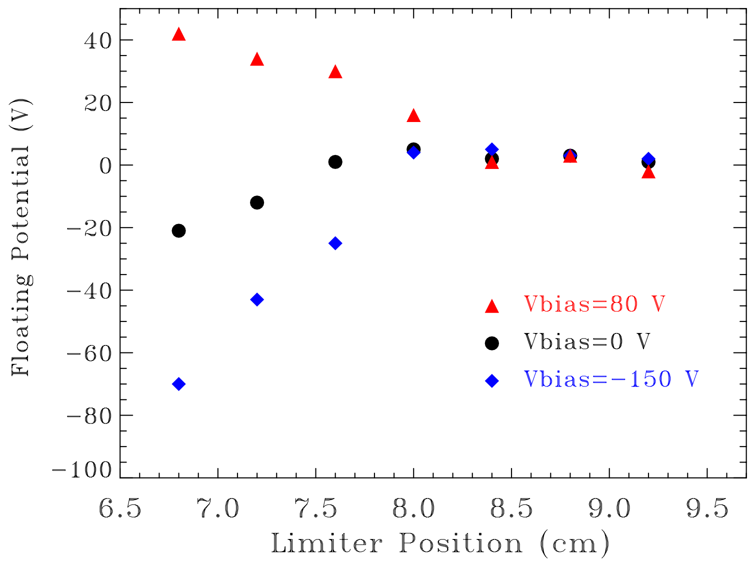

Figure 3: Floating potential radial profile for positive (V_{bias}=80 V), negative (V_{bias}=-150 V) and no limiter bias for r_{lim}=6.2 cm.

Summary and conclusions

Using a movable limiter we have shown that improvement in confinement can be obtained for both positive and negative limiter bias. A larger collected current was obtained by using the top limiter, which has an area 5 times larger than the that of the electrode and by inserting this localized limiter up to r_{lim}=6.0 cm. It has been observed that the current collected by the limiter increases as the limiter is inserted into the plasma and that the modification in the floating potential is proportional to the collected current, suggesting that the electric field created at the edge plasma is a result of an increase in the plasma rotation due to the collected radial current. Larger electric fields are induced in the region just inside the limiter for both polarities explaining the observed improvement in confinement.

Acknowledgements: *This work, supported by the European Communities and "Instituto Superior Técnico", has been carried out within the Contract of Association between EURATOM and IST. Financial support was also received from "Fundação para a Ciência e Tecnologia" in the frame of the Contract of Associated Laboratory. The views and opinions expressed herein do not necessarily reflect those of the European Commission, IST and FCT.*

References

[1] – G. Van Oost, et al., Plasma Phys. Control. Fusion, **45** (2003) 621
[2] - J.A.C. Cabral et al., Plasma Phys. Control. Fusion, **40** (1998) 1001-1009
[3] – C. Silva et al., 17th IAEA Fusion Energy Conference, EX/P1-10, Lyon, October 2002