*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-1.139 (2006)*

On the time scales and statistical properties of turbulence during ExB sheared flow development in the TJ-II stellarator

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1.- Introduction

Previous experiments in the TJ-II stellarator have shown that the generation of spontaneous perpendicular sheared flow (i.e. naturally occurring shear layer) requires a minimum plasma density. Plasma density and heating ECR power have been systematically modified in TJ-II to control the shear layer development. A biased electrode has been also used to externally change the edge radial electric field. Sheared flow development/damping occurs in time scales of the order of the turbulence time scale (typically 10-50 μs). The statistical properties of edge fluctuations have been also investigated during the shear layer development.

2.- Experimental Set-up

Experiments were carried out in TJ-II stellarator Electron Cyclotron Resonance Heated plasmas (P_{ECRH}= 200 - 400 kW, B_T = 1 T, R = 1.5 m, $\langle a \rangle \leq 0.22$ m, $\iota(a)/2\pi \approx 1.6 - 2.1$). Plasma density was in the range (0.35 – 1) x 10^{19} m^{-3}. The edge plasma parameters were characterized mainly by a multi-array of Langmuir probes, installed in a fast reciprocating probe drive. The reversal in the ExB rotation has been also recently 2-D visualized by means of Ultra Fast Speed cameras [1].

A 2-D Carbon composite mushroom head shaped electrode (12 mm height and a diameter of 25 mm) has been developed and installed in another fast reciprocating system. The electrode was inserted typically up to 2 cm inside the LCFS and biased with respect to one of the two TJ-II poloidal limiters [2].

3.- Edge sheared flows development

It has already been reported that the existence of sheared flow in TJ-II plasma edge requires a minimum plasma density or gradient. Below and close to this threshold density, the level of edge turbulent transport and the turbulent kinetic energy significantly increase in the plasma edge. Above this threshold value, once sheared flow is completely developed, fluctuations and turbulent transport slightly decrease although edge gradients become steeper [3, 4]. As a summary, figure 1 shows radial profiles of the ion saturation current and

4.- Time scales during spontaneous shear flow development

Slow density ramp experiments have revealed the presence of two different time scales in the time evolution of edge plasma parameters during edge shear flow development. A slow time scale, in the range of the particle confinement time (10 ms) (figure 2a), and a fast time scale in the range of few turbulence correlation times (10 – 50 μs). Within the experimental uncertainties, no evidence of hysteresis in the slow time scale has been found, however, the slow density ramp experiments has revealed the existence of fast transients in the floating potential and ion saturation current at times at which density is in the proximity of the threshold value (figure 3). These fast jumps take place in a time scale of the order of tens of μs (time scale of the fluctuations) that can be interpreted as the characteristic fast time scale for the development of the edge ExB sheared flows [8]. Similar time scales have been found in 2-D visualization techniques [1].

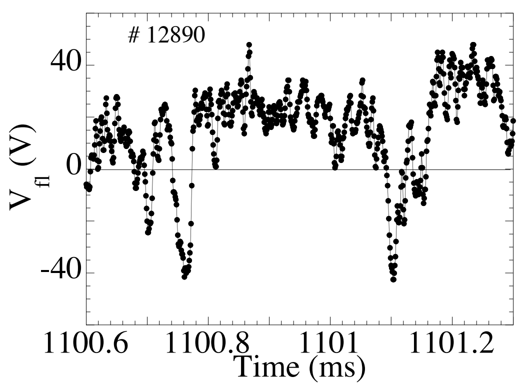

Fig. 3.- Detail of the transients observed when sheared flows are being developed at the critical density.

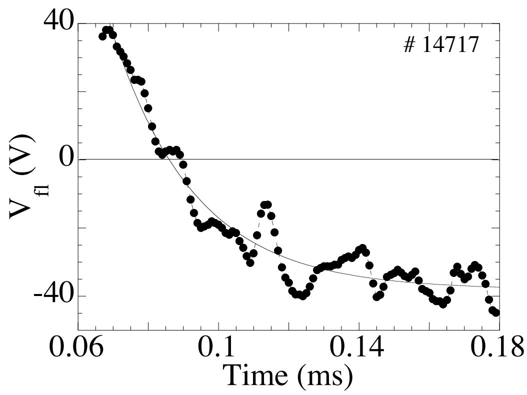

Fig. 4.- Detail of the fast time scale decay observed when electrode is switched-off (at time=0 ms).

5.- Time scales during electrode biasing and ECRH modulation experiments

As has been previously reported the relaxation of floating potential profiles when electrode biasing is turned off also shows two different characteristic decay time scales [9]. The time decay of the fast scale has been estimated when electrode is switched-off (figure 4) and results of the order of 10-40 μs whereas the long decay time is comparable to the particle confinement time (see figure 2c). ECRH power modulation, in the proximity of the critical density, shows time scales relaxation of plasma potential in the same range (see figure 2b).

Measured TJ-II relaxation times are comparable to the ones measured in other confinement devices [10, 11]. Plasma conditions effects on potential decay times is under investigation in TJ-II; preliminary results show no significant variations on fast decay time scales neither with plasma density or plasma volume (i.e. magnetic ripple). However, results show that decay times might be affected by the presence of sheared flows development near marginal stability, showing a tendency for longer decay times once edge sheared flows are fully developed. This result might be considered as the first experimental evidence of the influence of sheared flows on anomalous viscosity that can play a role in the bifurcation to the H-mode [12] and can shed some light on quantifying the importance of neoclassical mechanisms on the damping physics of the radial electric fields and flows in fusion plasmas.

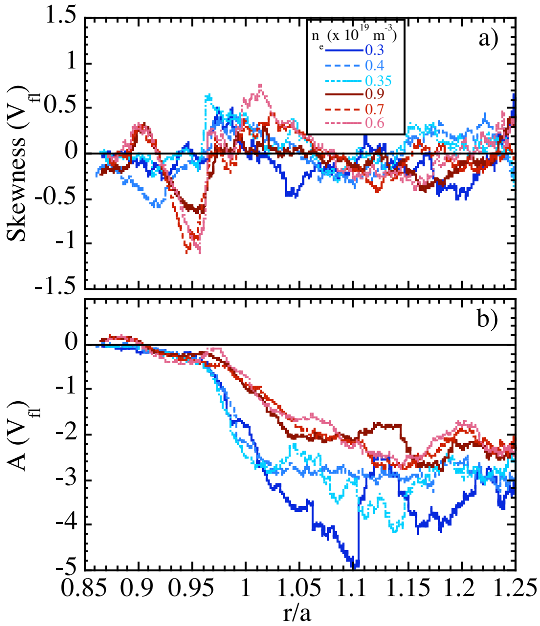

Fig. 5.- Skewness and Asymmetry of floating potential measured at different plasma densities (see figure 1).

5.- Statistical properties of turbulence during ExB sheared flow development

Experimental results (figure 5) show evidence of coupling between non-Gaussian behaviour of fluctuations, magnetic topology and edge shear flow generation. In particular asymmetries (A) in the time rise and in time decay of turbulent events have been observed both in floating potential and ion saturation current signals (A=0 corresponds to a signal whose time derivative has a symmetric PDF [13]). Pulses are rather symmetric near the LCFS both at plasma densities above and below the threshold density to trigger edge sheared flows. The A parameter increases in the SOL region, being the increase more significant at densities below the threshold value. This finding clearly shows the leading role of magnetic topology to explain the development of pulses that are asymmetric in time in the plasma boundary region.

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