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The Study of Fluctuations at the Edge of CT-6B Tokamak

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Abstract

Edge plasma fluctuations of CT-6B tokamak based on Mirnov oscillations, a moveable limiter and H_α line emission were investigated through the application of a positive limiter biasing, changes in gas pressure and plasma displacement. The results show that when the vessel gas pressure increases, the initiation of magneto-hydrodynamic (MHD) activity occurs in high plasma current and the main frequency of magnetic oscillations which corresponds to the maximum amplitude of the magnetic perturbation increases in direct correlation with increases in gas pressure. Positive biasing reduces MHD oscillations frequencies, initially, but after a short delay time, the main frequency of oscillations increases. Effects of positive biasing on the magnetic, electrostatic and H_α fluctuations are also presented.

Keywords:

magnetic fluctuation, electrostatic fluctuation, limiter biasing, Mirnov oscillations, tokamak

1. Introduction

Plasma turbulence is considered one of the main causes of anomalous transport in toroidal magnetic confinement devices. Edge biasing experiments have been found to be important in modifying edge turbulence and transport, but the mechanism of biasing penetration in edge fluctuations and its levels are different with respect to devices operation. The magnetic and floating potential fluctuations and their levels have been shown as addresses of the edge turbulence and particle transport. [1-10]

In the present research, an experimental study for edge fluctuation in the regimes with and without limiter biasing is carried out. Without biasing, the effect of changing chamber gas pressure, P_{gas}, and plasma horizontal displacement, Δx, on magneto-hydrodynamic (MHD) activities using Mirnov coils are investigated. During biasing regime, the effects of a positive limiter biasing on the plasma floating potential, poloidal magnetic field and H_α emission fluctuations are also examined.

In the sections to follow a description of the experiment, its findings and conclusion are presented.

2. Description of the experiment

The experiments were conducted on the ohmically heated iron core CT-6B tokamak, with a major radius R=0.45 m and a minor radius a=0.125 m defined by a fixed four-block poloidal limiter. The vacuum chamber was a stainless steel welding structure with two toroidal breaks and a minor radius b=0.15 m. An array of twelve Mirnov coils is used for measuring the poloidal magnetic field oscillations and a segment poloidal limiter made of thin molybdenum plate, with 8cm height and 2 cm width, electrically isolated with the chamber positioned at r=0.125 m on the outer side of the equatorial midplane of the plasma, was employed as the biasing limiter, where r is the minor radius. The biasing voltages was continuous. It was applied on the plasma at some moment (starting time) during the plasma current plateau and ended after the discharge termination. The biased voltage was restricted to $-125\ \mathrm{V} \leq V_{bias} \leq 220\ \mathrm{V}$. The array of Mirnov coils and H_α spectrometer detectors were mounted at toroidally 75° and 90°, respectively, from the limiter-biasing device. The horizontal displacement of the plasma column, Δx, was measured with a set of cosine coils and saddle coils. The value of Δx can be controlled with a feedback system of vertical magnetic field in each discharge.

The conditions of the experiment were as follows: The toroidal magnetic field B_t=6.5–7.5 kG, plasma current I_p=17–25 kA, chord-averaged electron density $\bar{n}_e$=0.5–1.5×10^{19} m^{-3} in hydrogen and the plasma discharge duration ~30 ms. The data were digitized at 6.4 μsec resolution using a multi-channel data acquisition system.

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3. Results and discussion

At the beginning of the experiment, a typical discharge condition for observing the typical behavior of sinusoidal Mirnov coils oscillations with clear and large MHD activity was selected. In Fig. 1, the points show the conditions for gas pressure, plasma displacement and plasma current when a clear sinusoidal oscillation is seen in the Mirnov coils. The points are from shot by shot experiments. By changing Δx via a feedback control vertical system to maintain the plasma column at a given horizontal position, and P_{gas}, the threshold of I_p about MHD activity changed, too. These experiments are conducted under two different pressures, 7.0×10^{-5} torr and 8.5×10^{-5} torr. As the vessel pressure increases, a clear MHD behavior is initiated in high plasma current, 20 kA, and through a lowering of pressure the beginning of MHD activities occurs in low plasma current, 17 kA.

In addition, the poloidal magnetic field fluctuations were detected through shot-to-shot experimentation by varying chamber's gas pressure, $P_{gas}=1.0\times10^{-4}$ torr to $P_{gas}=1.6\times10^{-4}$ torr, on a fixed plasma displacement at a value of 1.4 cm. Subsequent to the taking of Fast Fourier Transform (FFT) from Mirnov signals, it was observed that the frequency of oscillations increased in direct relationship to increases in gas pressure. Yet, in another set of experiments, the chamber gas pressure was kept constant at value of 1.2×10^{-4} torr and the plasma displacement changed from Δx=0.5 cm to Δx=2.5 cm outer-side of the chamber. The main frequency spectrum of the Mirnov signals under this set of conditions shows that by moving plasma displacement to outer-side, the main frequency of oscillations decreases. The results of these experiments are shown in Fig. 2. During limiter biasing experiment we chose an optimum condition of gas pressure and plasma displacement, because it is seen that after biasing, the plasma moves 0.1–0.2 cm outward and it effects less than 0.5 kHz on reduction of main frequency of Mirnov oscillations after positive biasing. In this set of experiments we didn't measured variation of plasma density for the pressure effects.

In the biasing experiments, subsequent to the application of a positive bias, a decrease followed by an increase in the main frequency of magnetic field fluctuations was observed. To cite an example, after applying +180 V bias voltage in the plasma current plateau at 16.8 ms, the main frequency of oscillations decreased by about 10–15 %. Then, after a short delay time of about t_d=2–2.5 ms from 16.8–18.5 ms, it increased by about 20–25 % with respect to their values without biasing. Temporal evolution of the magnetic fluctuations spectrum is shown in Fig. 3. The result of this experiment for positive bias is different from other tokamaks. For example, the MHD behavior of *negative* bias in the ISTTOK [11] tokamak is similar to *positive* bias in the CT-6B tokamak. The plasma current in CT-6B experiments is about four times higher than in the ISTTOK one, and in the Fig. 1, it has been shown that plasma current plays an effective role in MHD activity. Also, in the CT-6B, the amplitude of high-frequency fluctuations (>25 kHz) decreased following a positive bias application, as in the KT-5C [12], Thorello [13] and DIII-D [14] tokomaks. Figure 4 illustrates the spectrum of magnetic fluctuations before biasing at t=15 msec, after biasing at t=18 msec and ramp down of discharge at t=23 msec for a 0.48 msec partial time interval.

A possible mechanism for the suppression of turbulence is the strong shear of the $\boldsymbol{E}\times\boldsymbol{B}$ velocity flow, so that the results of [15] suggests the existence of a close link between the electrostatic and magnetic behavior of plasma turbulence [15]. In the CT-6B Tokamak the FFT analysis of oscillations detected by the Mirnov coil as magnetic behavior positioned at equatorial outer-side midplane, the floating potential fluctuation, V_f as electrostatic behavior, at r/a=1 and line emission H_α intensity at r/a=0.8 investigated before and 3msec after biasing (V_{bias}= +150 V) shows a clear coherency between signals at the frequency of about 25 kHz. At many shots the H_α intensity fluctuations in the area of q=2–3

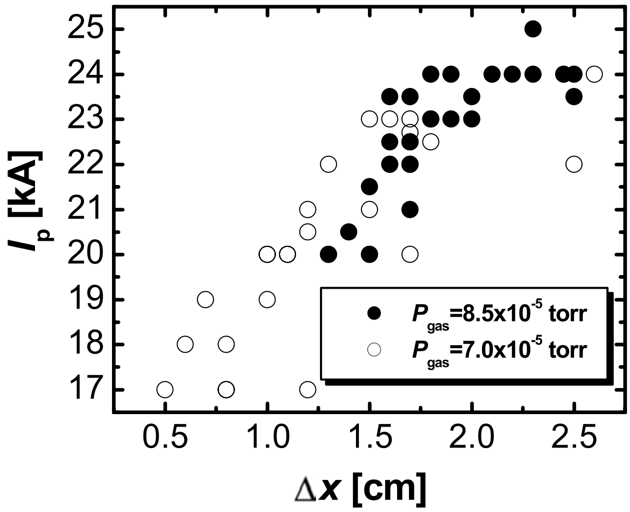

Fig. 1 Relationship between plasma current and plasma displacement, when the MHD activity began. Points are from shot by shot.

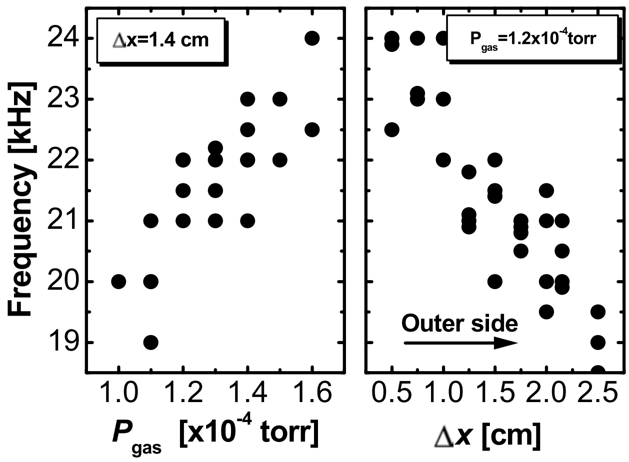

Fig. 2 The frequency dependence of MHD oscillations with changing chamber gas pressure (left) and plasma displacement (right). Points are from shot by shot.

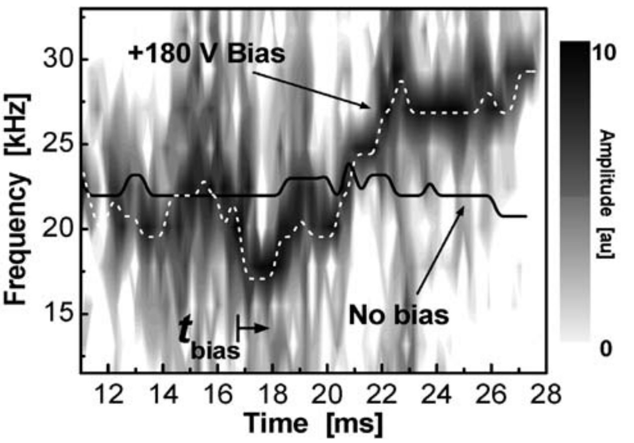

Fig. 3 Temporal evolution of the magnetic fluctuations spectrum. The time of biasing is t_{bias}=16.8 msec and the P_{gas}=1.4×10^{-4} torr. The solid line indicates the reference data without biasing and dash-line indicates the peak of main frequency in the biasing experiment.

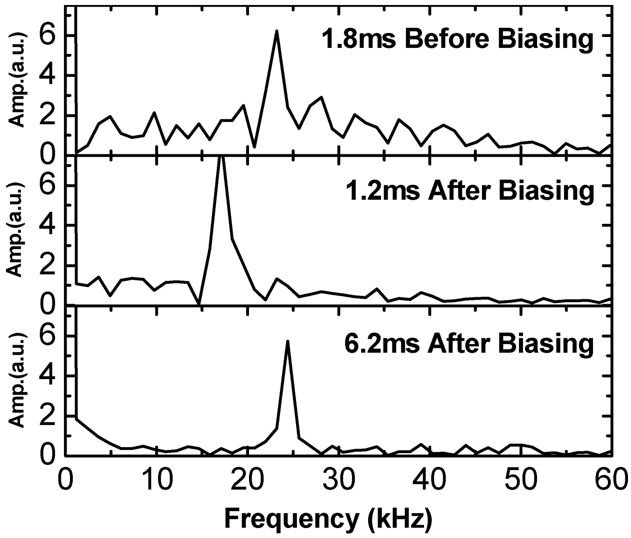

Fig. 4 The spectrum of magnetic fluctuations, before biasing at t=15 msec, after biasing at t=18 msec and ramp down of discharge at t=23 msec for a 0.48 msec partial time interval. Time of bias application is 16.8 msec from shot in Fig. 5.

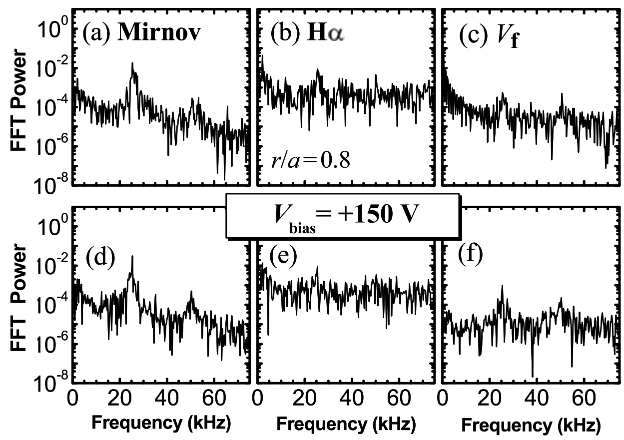

Fig. 5 The FFT analysis of oscillations detected by the Mirnov coil positioned at equatorial outer-side midplane, the floating potential fluctuation, V_f, at r/a=1 and line emission H_α intensity at r/a=0.8; (a,b,c) before biasing and (d,e,f) at 3 msec after biasing (+150 V).

correlates more with Mirnov signal fluctuations, which are not shown here.

When the limiter is biased, the plasma potential floats to a value close to the bias potential. Following the comparison of the potential fluctuations detected by the segment poloidal limiter and the oscillations detected by Langmuir probe at the same position, correlation is found in their behavior. In Figs. 5(c) and 5(f), it can be seen that the low frequency floating potential fluctuations level < 20 kHz decreases after a positive bias near the limiter. This reduction is similar to results of the ADITYA [16], KT-5C, ATF Torsatron [17] and Thorello. Thus, our results may show that after the biasing, the outward-flowing current based upon the existence of the turbulence is quenched and an inward radial current is recovered. On the other hand, the floating potential fluctuation in TEXTOR [18] and STOR-M [19], through positive biasing, increases near the limiter when outward flow decreases. The difference between results can be due to the conditions of device operation. Therefore, determining the penetration value of magnetic fluctuations and floating potential fluctuations levels on the transport and turbulence requires further measurements of plasma parameters.

4. Conclusion

Behavior of plasma fluctuations with changing gas pressure, horizontal displacement experiments, and a positive limiter biasing experiment were studied on the CT-6B Tokamak using an array of external Mirnov coils and an isolated limiter, to get magnetic and potential fluctuations, and using an optical system to measure the line emission of H_α intensity. The results prove that by changing plasma conditions MHD activities varied. When vessel gas pressure increases, the start of MHD activity occurs in high plasma current and by decreasing pressure, the beginning of MHD activity occurs in low plasma current. The frequency of oscillations increases along with the increases in gas pressure and the frequency spectrum of the Mirnov signals show that by increasing plasma displacement to outer side, the frequency of oscillations decreases. Positive biasing reduces MHD oscillations frequency, at first, but after a short delay time the frequency of oscillations increases. During the biasing regime, it was found that the magnetic and electrostatic fluctuations in the CT-6B tokamak have a close coherency with H_α line emission fluctuations. The results for magnetic oscillation frequency and floating potential fluctuations during positive biasing are different from other devices, which may be due to the conditions of device operation. Therefore, the determination of the penetration value of magnetic fluctuations and floating potential fluctuations levels on the transport and turbulence require further measurements of plasma parameters.

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